

Shapeshifting attachment: Exploring multi-dimensional people-place bonds in place-based citizen science

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Abstract

1. Research on citizen science programmes has highlighted that they can foster science content and knowledge gain, enhance pro-environmental behaviour and cultivate civic action among participants. Especially in the case of place-based citizen science, which requires hands-on repeated activity in an out-of-door setting through a scientific lens, evidence suggests that some of these outcomes may be linked to the unique people-place relationships and interactions afforded by such programmes.
2. Even still, studies that empirically examine the influence of place on citizen science participant and programme outcomes are scant. This is due, in part, to the methodological challenges involved in interrogating complex aspects of a person's sense of place—aspects like place attachment—the emotional bonds between people and place.
3. Here, an adapted three-dimensional model of place attachment is proposed as a theoretical framework from which place-based citizen science experiences and outcomes might be empirically examined in depth. The model, which posits personal, social and natural environment dimensions of place attachment is contextualized with research findings from the US-based Coastal Observation and Seabird Survey Team (COASST) citizen science programme.
4. Data from COASST suggest that participants do exhibit place attachment in all three dimensions of attachment, categorized within seven unique constructs, although questions remain regarding the unique intensity, make-up (shape) and scale (spatial, social and nature-science) of individual-level attachment along the three central dimensions. Critically, more research is needed to investigate whether the unique place attachment 'profile' of participants is a function of personal, social or programmatic variables pre- and post-programme participation.
5. To encourage further scholarship on potential links between the experiences, exposures and programme components of place-based citizen science and the place attachment profiles of participants, this paper includes a brief review of the research opportunities presented by the adapted three-dimensional place attachment model discussed.

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6. Advancing this line of inquiry is an important component of broader efforts to understand how sense of place is altered via place-based citizen science and whether or not that is linked to specific programme outputs or participant outcomes in science knowledge, ecological understanding and civic engagement.

KEY WORDS

citizen science, place attachment, place scale, programme outcomes, sense of place

1 | INTRODUCTION

Citizen science is a large and growing tent within the informal science learning community (Bonney et al., 2014). At present, millions of people in the United States alone participate in projects aimed at advancing science knowledge while creating a stimulating and meaningful experience for the participant (Sauermann & Franzoni, 2015; Theobald et al., 2015). Because definitions vary, Parrish, Burgess, et al. (2018) have proposed a typology of citizen science focused on key aspects of project outcomes and participant experience. In this schema, projects categorized as 'active citizen science' are those requiring the production of data or information through the actions and thinking of participants (as opposed to more passive forms of engagement where a participant might host an automatic sensor to detect seismic activity in their backyard, for example). While all of active citizen science affords the opportunities for learning, studies indicate that the majority of participants in online projects fail to persist past their first encounter (Sauermann & Franzoni, 2015; Segal et al., 2015), thus limiting learning possibilities. By contrast, hands-on, out-of-doors projects have significantly longer retention times, with most participants continuing past their first encounter and many persisting for years (Parrish, Jones, et al., 2018). In this sense, hands-on, out-of-doors citizen science offering participants the chance to learn about the practice of science and the natural history and ecological connectedness of their local environment through continued involvement is akin to the practice of natural history (Fleischner, 2005; Greene, 2005), and further still has roots in traditional ways of being with and knowing place practiced by Indigenous peoples.

A large body of research has catalogued the benefits of hands-on, place-based citizen science (for a thorough review, see Haywood, 2014a). Such outcomes have included enhancements to science literacy, knowledge and understanding (Brewer, 2002; Danielsen et al., 2005; Jordan et al., 2011; Sullivan et al., 2009); increases in 'scientific thinking' and the ability to interpret science information (Braschler et al., 2010; Kountoupes & Oberhauser, 2008); and growth in science skills like observing, measuring and recording data (Bonney et al., 2009). We hypothesize that the impressive gains seen in many of these programmes may be because this type of citizen science engages participants in an out-of-doors place or geographically situated environmental phenomenon (e.g. the timing of plant budding, bird migration or first snow) that is personally attractive to them. The consistency of data collection over time in a place can help unlock the intricacies of place that hold meaning

for the individual, deepening understanding via personalized experience that leads to the formation of a place-based bond. As such, we believe the concept of place is an especially relevant lens through which to interrogate and explain if, how and why engagement through citizen science might yield larger goals. One such 'holy grail' of place-based citizen science and ecological learning initiatives is conservation action and the related concept of ecological literacy, or moving participants from learning to 'application' in the real world (Ballard et al., 2017; Bela et al., 2016; Cooper et al., 2007).

1.1 | Place attachment as a dimensional concept

At the most basic level, place attachment (PAT) can be defined as an emotional bond between a person and a place. Place attachment research has provided insight and guidance for land management projects, community development and planning, research on tourism, and environmental stewardship initiatives by exploring attachment to residential spaces and areas (Jorgensen & Stedman, 2001), birth-places (Nanistova, 1998), 'special places' (Eisenhauer et al., 2000), and tourist or recreational destinations (Vaske & Kobrin, 2001; Warzecha & Lime, 2001). Scholarship on place attachment thus provides a robust lens from which to consider the influence of place on citizen science outcomes. We contend, however, that the relationships between people and place that form or evolve through citizen science are distinct from these other types of interactions.

Although there are well-established examples of citizen science in the 'backyard', many citizen science projects take participants to places they do not own; and yet they are not 'visitors' exploring these places through seldom, singular or one-off interactions either. Instead, their relationship with place is defined by loose, unofficial and more collective notions of place 'ownership'. While the activities through which citizen scientists engage with the places they study are somewhat self-directed (e.g. participation is voluntary; participants can select a study site), the scientific lens through which participants engage foregrounds both an opportunity to realize a place through patient measurement and observation, as well as put that particular place within an ecological or environmental context simultaneously provided by project data collected by others. In particular, many citizen science projects involve interacting with other individuals to gather, collect or discuss information. Thus, the motivations that drive and maintain repeated, purposeful interactions with a place through citizen science may differ from those driven by

residential affiliation or pleasure-seeking. Given these differences and the distinct bonds that form between people and place through citizen science, we propose an adaptation of one theoretical framework within PAT scholarship—the three-dimensional model first presented by Raymond and colleagues (Raymond et al., 2010)—to explore the role of people-place relationships in understanding the personal, societal and scientific benefits of citizen science.

Synthesized and developed into a model and assessment tool of the degree to which rural landholders are attached to their natural resource management region, the integrative three-dimensional PAT model of Raymond et al. (2010) defines attachment as occurring along three primary dimensions or 'poles': personal context, community context and the context of the natural environment; with five central constructs within those three categories (Figure 1; Table 1). We use the word dimension instead of pole in this paper because we believe it captures more holistically the nature of place attachment and the intersections among various aspects of the phenomenon. Individuals may connect to place via one, two or all three dimensions, with the implicit assumption that increasing the number of expressed dimensions and/or the intensity of any/all of them connotes stronger PAT as a whole.

In this paper, we adopt the three-dimensional model as a foundation to guide exploration of place attachment among citizen scientists engaged in place-based interaction where place is not owned, and is divorced from concepts of home (Anton & Lawrence, 2014) or neighbourhood (Corcoran, 2002). Specifically, we posit that maintaining a multi-dimensional approach has the potential to enhance research on how the degree or intensity of attachment distributed among the three dimensions may facilitate exploration of PAT shape

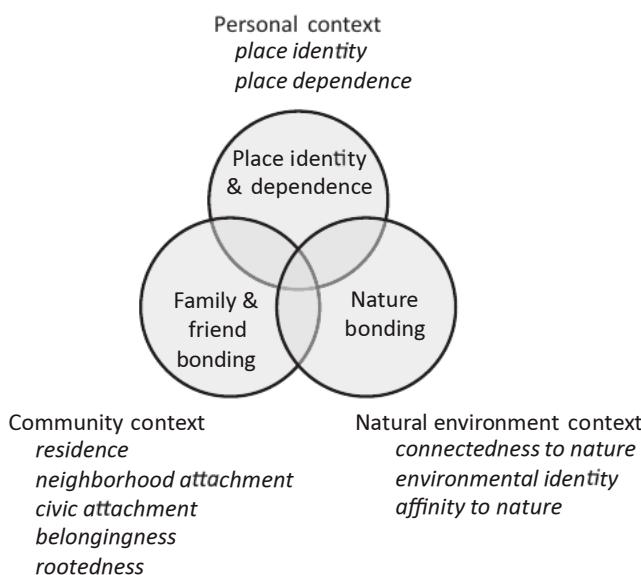


FIGURE 1 The three pole model of place attachment as originally presented in Raymond et al. (2010; Figure 1, p. 425), modified to incorporate the five constructs (place identity, place dependence, family bonding, friend bonding and nature bonding) also presented in Raymond et al. (2011; Figure 2, p. 326). Note that 'rootedness' has been transferred to the sphere of community, as described in the text of Raymond et al. (2010)

TABLE 1 A summary of the three-dimension categories and five major constructs as defined by Raymond et al. (2010, pp. 426)

Dimension category	Major constructs
Personal context	<i>Place identity</i> : 'Those dimensions of self, such as the mixture of feelings about specific physical settings and symbolic connections to place, that define who we are' <i>Place dependence</i> : 'Functional connection based specifically on the individual physical connection to a setting; for example, it reflects the degree to which the physical setting provides conditions to support an intended use'
Community context	<i>Family bonding</i> : Attachment based on a sense of belongingness or membership in a valued family group based on shared history or experience <i>Friend bonding</i> : Attachment based on a sense of belongingness or membership in a valued friend group based on shared history or experience
Natural environment context	<i>Nature bonding</i> : 'Implicit or explicit connection to some part of the non-human natural environment, based on history, emotional response or cognitive representation (e.g. knowledge generation)'

and intensity over time, including but not limited to: the existence of multiple, persistent shapes within a cadre of citizen scientists; and the degree to which shape intensifies through equal (or unequal) expansion along each dimension, that is, whether shape shifts.

1.2 | Questions of place attachment 'shape' and scale

While scholars can confidently determine if PAT exists, many questions about why, in what ways and to what effect still remain unanswered (Beckley, 2003). Attachment to place often involves common features like the existence of personally relevant meaning (Haywood, 2015), emotionally intense bonds (Manzo, 2003, 2005) and place-protective behaviours (Ramkissoon et al., 2012). However, the multiple and interrelated reasons for such attachment, the unique character of those bonds and the disparate ways through which that may shape behaviour is less understood. Over the past decade, PAT scholarship has increasingly demonstrated the complex and idiosyncratic nature of the emotional bonds that form between people and place (Altman & Low, 2012). This leads us to explore two issues central to the intersection of PAT and citizen science:

- **Shape:** While research has demonstrated the ability to determine the presence or absence of PAT, whether or not there are certain types or 'shapes' of PAT with uniquely distinguishing characteristics and impacts on behaviour and people-place interactions is an under-developed area of research. Further still, to what extent these hypothesized shapes are malleable over time is not known.
- **Scale:** As a phenomena where social, psychological and material realities collide, people-place relationships have inherent scalar

components. But whether PAT exists—equally or at all—at various geographical scales is relatively unexplored, and is unknown when considering scaling within non-geographical constructs seminal to PAT and citizen science, including social and scientific dimensions.

Because we believe these two issues are particularly significant in the attempt to understand the role of PAT in citizen science, we provide a brief review of both, highlighting existing theoretical frameworks and scholarship that provides a foundation to advance understanding within these areas. We then introduce a citizen science project called COASST (Coastal Observation and Seabird Survey Team) which we use as a case study to explore PAT. Finally, we discuss four emergent research themes that we believe will advance scholarship on PAT in hands-on, out-of-doors citizen science by utilizing critical perspectives revealed through our adapted three-dimensional model framework.

1.2.1 | THE 'shape' of place attachment

Over time, PAT theory has diversified beyond frameworks that understand the phenomena largely as a personal need for connection and fulfilment to those that recognize the many intersecting components of people–place relationships. Williams and Vaske (2003) first developed and validated a two-dimensional PAT model focused exclusively on the personal experience of place that has been utilized widely in the field. Recognizing the complexity and multi-dimensionality of place attachment that extends beyond this 'personal' or individual dimension, several measurement tools now consider both the social and natural components of the phenomenon (Brehm et al., 2006; Scannell & Gifford, 2010a). Scholars more recently have advocated for models that integrate three major dimensions of PAT—personal, social and natural environment (Davenport et al., 2010; Gustafson, 2001). That is, scholars are now recognizing that PAT emerges not just from a personal need to identify with place but also because of the social and ecological connections formed in and with those places. In fact, Scannell and Gifford (2010b) have demonstrated that the strength of disparate dimensions of place attachment can influence the outcomes of that attachment, including associated pro-environmental behaviours.

This work clearly conceptualizes PAT as a multi-dimensional concept, which begs the question of how individuals may differ in their relative attachment strength (intensity) across various dimensions—what we are calling *attachment shape*. Approaches to measuring and understanding PAT are often accomplished with a quantitative Likert scale allowing self-reporting of agreement, belief or association attached to a series of statements directed at place attachment, and assembled with a posteriori multivariate techniques facilitating the creation of a single integrated numeric measurement (Kudryavtsev et al., 2012; Lewicka, 2011). While this approach allows examination of the degree to which PAT intensity (i.e. the index value) correlates with other variables, such as the presence of protective behaviour, a willingness to invest resources or effort in the place,

or attitudes about the governance of that place; it does not provide a ready mechanism to measure the degree to which the relative strength among PAT dimensions might influence these relationships, nor whether intensity across dimensions varies in concert or independently. Because citizen science projects vary widely in structure (independent to large group data collection), focus (micro-organisms to macro system) and level of participant engagement (passive observation to active analysis of data), it cannot be assumed that the simple presence or absence of place attachment influences motivation to engage in citizen science or participant outcomes in a uniform way. Understanding the nuanced varieties of PAT shape is necessary to interrogate the potential relationship between those shapes and the diverse set of citizen science practices.

1.2.2 | The scale of place attachment

Geographical scale is inherent in the concept of place. However, with few exceptions (e.g. Cuba & Hummon, 1993; Hidalgo & Hernandez, 2001; Lewicka, 2010), PAT scholarship has largely avoided an explicit examination of the role of scale. Ardooin and colleagues (Ardooin, 2014; Ardooin et al., 2012, 2019) have pioneered an examination of spatial scaling related to sense of place, building on the earlier work of Hidalgo and Hernandez (2001). Ardooin (2014) examined the role of scale in place attachment versus environmental action, assessing place attachment at three different geographical scales: the immediate 'local' area, a 'medium' regional scale and a larger 'ecoregion' scale (a contiguous area defined by similarity of landscape and biodiversity). Across three disparate case studies, she found that up to a quarter of participants identified with place at an ecoregional scale, and that participants typically reported taking action at the same spatial scale at which they indicated the strongest attachment. Ardooin et al. (2019) found that the strength which individuals espoused a biophysical attachment (akin to nature bonding within the three-dimensional construct) to place varied as a positive function of their personal definition of place scale, and secondarily as a positive function of participant income.

Eanes et al. (2018) is among the first to attach the concept of scale to dimensions other than space, identifying both biophysical and social scaling as important elements of place attachment (e.g. Table 2, pg. 85, Eanes et al., 2018). While social scaling tended towards an attachment intensity peak at the 'narrow' scale (e.g. immediate family), biophysical scaling centred on the 'broad' scale (called 'bioregion' by Eanes et al. (2018)). These studies of PAT scaling suggest that an individual's attachment expressed through geographical, social and natural or biophysical lenses is both variable and flexible, and may include or exclude places, people and processes from the immediate to the immense. Because citizen science can occur at the local (e.g. the Lost Ladybug Project) to the global (e.g. eBird) spatial scales, within singular person to population scales of social interaction and identity, and investigate micro- to macro-ecological systems and processes, understanding how PAT may differ 'at scale' may help understand the role of people–place relationships in citizen science.

TABLE 2 A summary of the major constructs and their definitions in the adapted three-dimensional model of place attachment proposed in this paper

Dimension category	Major constructs
Personal context	<i>Place identity</i> : Attachment based on some aspect of the identity of the person (those things that define who we are) which is then connected, bonded symbolically to, or a part of the place <i>Place dependence</i> : Attachment based on a literal functional dependence on a unique service/function performed by the place, or the things found in that place. The service/function can relate to physical needs (e.g. health), psychological needs (e.g. mental health and well-being), emotional needs (e.g. positive affect) or for another reason (i.e. economic)
Community context	<i>Family/friend bonding</i> : Attachment based on a sense of belongingness or membership in a valued family or friend group based on shared history or experience. Must contain direct reference to a social relationship known or felt by the person and experienced at the place <i>Social rootedness</i> : Attachment based on a socio-cultural relationship that connects the past (including dead or unknown connections from the distant past) to the present through the experience and feelings of the person, and experienced at a place
Natural environment context	<i>Nature bonding</i> : Attachment based connections to the living world (other than people) experienced at the place <i>Environment bonding</i> : Attachment based on non-living or physical aspects of the environment experienced at the place <i>Science affinity</i> : Attachment based on how a person uses science (observation, investigation, monitoring, learning) through the practice of science or citizen science to experience the place

1.3 | The COASST citizen science programme

Housed at the University of Washington, the Coastal Observation and Seabird Survey Team (COASST) is a 20-year-old citizen science programme featuring hands-on, monthly data collection on beaches throughout the Pacific Northwest and Alaska. Data collection modules include beach-cast marine birds and marine debris, respectively. At present, ~1,000 individuals are actively collecting data. Most participants are non-experts and are local residents. New participants are recruited and trained locally in a single 3–5 hr, expert-led session, after which attendees are invited to sign up for the programme, select a beach of their choice and begin data collection. All participants are encouraged to survey with one or more partners.

Participant training encompasses learning how to demarcate and search the beach (referred to as surveying in COASST), and also how to collect basic data (referred to as evidence in COASST) from any beach-cast marine bird carcasses/debris pieces found. In the case of birds, this evidence is then used to make a deduction about the taxonomic

identity of the bird. Scientific skills used by COASST participants are aided by the use of specialized tools, including a dichotomous key to beached birds (a step-by-step identification process involving discrete choices about the features of the bird). Discovered carcasses are tagged (to prevent double counting), photographed and left in place. Debris is bagged, bags are tagged and removed from the beach for post-survey examination. All data are recorded on paper datasheets, which are then digitized and sent to COASST along with photographic evidence. STEM content and skills are reinforced through the continued practice of monthly surveys on the same beach, programme feedback and subsequent learning opportunities, including a range of online and in-person follow-up (Parrish et al., 2007).

In contrast to some hands-on, outdoor programmes in which participants engage for only limited periods, the so-called 'dabblers' (infrequent or inconsistent participants) of Boakes et al. (2016), the majority of COASST participants maintain their involvement in the programme for years. Over 91% of training event attendees choose to sign up to be monthly data collectors; 78% of those go on to conduct at least one survey. Fifty-four percent are still in the programme after 1 year and just over 20% are still active 5 years later (Parrish et al., 2007). Reasons for participant tenacity are varied but appear to include belief that programme-scale data are significant to science and useful in a management or conservation context (Haywood et al., 2016). In fact, COASST data are widely used in scholarly publications and in natural resource management decision-making, relative to issues as diverse as historic use of seabird die-offs as a Native American resource (Bovy et al., 2016), climate impacts on coastal ecosystems (Jones et al., 2018, 2019; Parrish et al., 2007), impacts of harmful algal blooms on coastal seabirds (Jones et al., 2017; Van Hemert et al., 2020) and fishery bycatch (Hamel et al., 2009; Moore et al., 2009). Our work with COASST (Haywood, 2015, 2019; Haywood et al., 2016; He et al., 2019) suggests that place plays a fundamental role in facilitating learning and motivating continued engagement in citizen science. This project extends that work to examine in greater depth the nature and influence of PAT among participants, with particular attention to PAT shape and scale.

2 | METHODS

We employed a mixed-methods strategy involving three datasets collected from COASST participants. In 2013, Haywood (Haywood, 2014; Haywood, 2019; Haywood, 2015; Haywood et al., 2016) conducted guided tour interviews of the data collection sites of COASST beached bird programme participants, allowing individuals to share their narrative of self and site. This qualitative research method involved participants guiding the interviewer through a specific space (in this case COASST beach survey sites) while responding to semi-structured interview questions. Individual interviews were performed with 71 COASSTers, and focus groups with another 14. All participants provided informed consent to participate. This research project was approved and governed by the Institutional Review Board (IRB) at the University of South Carolina, USA under permit

no. 25391. Interviewees included programme participants living in coastal communities in Washington, Oregon and northern California who had been active in the COASST programme for at least 1 year (hereafter, 'seasoned participants') with an average participation length of just over 5 years. In-depth qualitative interviews were structured around a set of open-ended questions along five major themes, including the 'dynamics and characteristics of the relationship between a participant and his/her survey site' (Haywood, 2019, pp. 131). In 2020, interview transcripts from this dataset were re-analysed with QSR Nvivo software using a deductive approach guided by the three-dimensional PAT model highlighted above. Text was analysed for alignment with the three dimensions and five articulated constructs, and instances were flagged that could not easily be categorized within the existing framework. For this uncategorized text, an inductive coding approach was utilized to segment into new meaningful categories. Key blocks of text were assigned specific descriptive codes to identify major themes, similarities and differences among respondents. These codes were developed iteratively, based on constant comparison of other text within the category. Coding was conducted by all three authors, with weekly meetings to refine a codebook and negotiate any differences in coding. A refined three-dimensional PAT framework containing seven constructs emerged from this process (Table 2) and is discussed below.

In 2012 and again in 2016, Parrish and colleagues conducted surveys of COASST beached bird participants as part of a larger programme evaluation (Char et al., 2014). All participants provided informed consent to participate. These interconnected research projects were both approved and governed by the IRB at the University of Washington, USA under permit numbers 37,516 and 47,963. Here participants were divided into those who had only attended a training session and had yet to conduct their first place-based survey (hereafter, 'new participants') and seasoned participants with more than a year of data collection experience. The surveys were originally designed to assess the efficacy of the training (i.e. a pre-post pairing of questions) and the impacts of regular, monthly practice on concept retention and scientific understanding of the system (i.e. a comparison of answers made by those attending a training versus programme participants of a year or more) and contained a range of question types, including free-write questions designed to assess the reason(s) individuals joined/remained in the programme. Answers to these latter questions were inductively coded accordingly to a framework constructed based on the 'person-object theory of interest' (Krapp, 2005), which divides interest or motivation into the object(s) of interest, the action(s) individuals wish to engage objects in, and the aspects of self or identity of the individuals (He et al., 2019). Quantitative data from He et al. (2019) were re-examined for this study as a means to triangulate the validity of our modified three-dimensional framework. Data were assessed first for alignment with the emergent seven constructs across the three dimensions, and, where possible, instances that did not fit the model were identified for further inductive coding. Data were analysed and discussed by all three authors. Because the He et al.'s (2019)

data were divided into new and seasoned participants, we also used these distinctions to investigate whether these populations displayed differences, suggesting that the practice of COASST on site may shift the intensity of PAT.

3 | A REVISED PAT FRAMEWORK FOR CITIZEN SCIENCE

Our existing survey and interview data indicate that COASST participants feel connected and attached to the places they survey (Haywood et al., 2016), that individuals attach to place for a number of disparate reasons (Haywood, 2019), and that, at the population level, the intensity of a given dimension of attachment is different between new participants and those who have had a year or more of experience in the programme (He et al., 2019). Haywood et al. (2016) reported that 89% (70/78) of interviewed participants who had participated in the COASST programme for a year or more indicated some sense of place attachment to their data collection site. Attachment emerged for these seasoned participants from five specific pathways or 'catalysts' including (a) aesthetics or the physical appeal of the place; (b) encounters with wildlife and in particular with birds; (c) a sense of personal investment in the place developed through the time and effort spent collecting data there; (d) site-specific knowledge defined as a sense of confidence or competency in knowing the place through the data collected and (e) a sense of

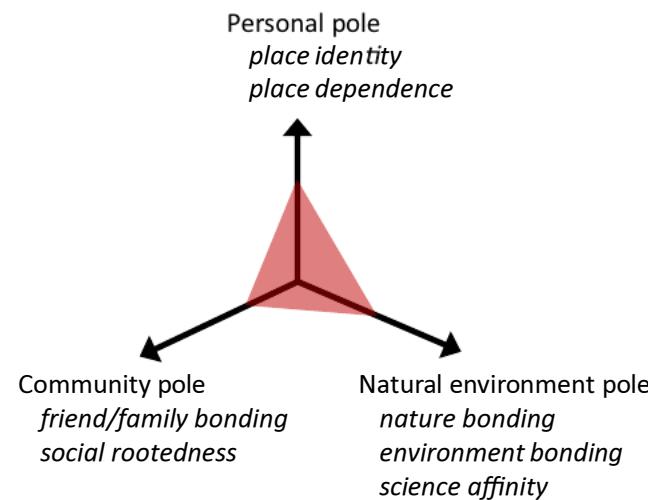


FIGURE 2 The Raymond three pole model re-imagined as relevant to hands-on, out-of-doors citizen science where the individual has the opportunity to engage repeatedly at a particular location of their choice. The five constructs of Raymond and colleagues have been expanded to seven constructs (here in italics; see also Table 2). Aspects of residence and ownership are dropped, and a connection through science is added. Each pole is imagined as an axis along which the intensity of attachment could be measured, resulting in a PAT 'shape' indicated here by the red triangle. Shapes could thus apply to a person (e.g. an individual participant in a citizen science programme) or to a group (e.g. a cadre of citizen science participants)

familiarity or comfort with the place arising out of repeated visitation and/or multiple ways of knowing (Haywood, 2019; Haywood et al., 2016). He et al. (2019) found that both seasoned COASST participants and those new to the programme were motivated to join/remain based on strong connections to the beach environment and to birds, and through their social connections to friends and family.

Taken together, these findings suggest that evidence exists for all three place attachment dimensions as articulated by Raymond et al. (2010). However, we also found that the five primary constructs included in the original model (Table 1) were not appropriate or sufficient to capture the range of COASST participant responses as they related to PAT within the context of their citizen science activity. Therefore, and as detailed below, we propose a revised attachment framework for conceptualizing the most prominent constructs of place attachment within the context of out-of-doors, place-based citizen science (Figure 2; Table 2).

3.1 | Personal dimension

Survey and interview responses that demonstrated a direct connection/bond/relationship between the COASST participant and survey site that reflected the identity of the person, and/or a service or function the place performed for the person, were all categorized as attachment within the personal dimension.

Seasoned COASST participants espoused a strong sense of personal connection to the place(s) that they survey for the programme: almost all (96%) referred to that place as belonging to them (i.e. 'my beach'; Haywood et al., 2016) even though actual ownership did not exist. Place attachment along the personal dimension in COASST participants is demonstrated via both place identity and place dependence, the two primary constructs in the original three-dimensional model. Haywood (2019) reported that nearly a third (27%) of seasoned COASST participants interviewed shared that their survey site was associated with some aspect of their sense of self. Like the participant below, connection to the survey site was often directly linked to distinct components of personality or personal history, demonstrating attachment via *place identity*:

Q1: I'm a New Englander, and I grew up on a large inland body of saltwater called Narragansett Bay. And this Puget Sound, and in particular where I live here, reminds me very much of where I grew up. So, my attachment I think is historical, as opposed to this exact place, it is more of a kind of a historical, my own history, living near the shore, and living on the shore.

For this participant, the Puget Sound region symbolizes an important component of their own personal story, particularly those formative childhood memories 'living on the shore' that clearly still resonate as a part of their current identity and sense of self. Haywood et al. (2016) also found that just over two-thirds (68%) of seasoned participants felt attached to their site because of their

history of personal investment in that place, linking attachment to the aspects of personal identity that emerge from repeated interaction and investment in place.

With respect to *place dependence*, two-thirds (64%) of participants shared that they felt a strong dependence on their data collection site for one-of-a-kind experiences. As expressed by the participant below, such dependence is the result of something unique and personal that occurs between person and place in a familiar and comforting way that they cannot exactly replicate elsewhere.

Q2: This is my beach, and I think of it as mine. Many times I'm out here and there is nobody here but me. And I can look for birds and, if I'm alone, I will take hours. But I am so happy. It's a happy I don't feel in the city, or in my home, or in the middle of the forest, you know?

More specifically, a third (29%) of participants relied on their site for physical and/or mental stimulation—'a place to exercise the body and mind' (Table 2, pp. 135: Haywood, 2019). He et al. (2019) found that the motivations of enjoyment and fun on the beach, and the desire to use the survey site to engage in healthy behaviour were significantly stronger in seasoned COASSTers relative to new participants, suggesting that the practice of COASST science on site may deepen place dependence.

In summary, the constructs of place identity and place dependence appear to be sufficient at encapsulating responses of COASST participants within the personal dimension. While we acknowledge that COASST is only one of many out-of-doors citizen science programmes in which individuals have the opportunity to select a location and repeatedly collect data there, our data to date do not suggest that there are other response groupings beyond these two. As such, in our proposed revised three-dimensional PAT model for citizen science, we do not advocate major adaptations to the two main constructs originally described as defining the personal dimension.

3.2 | Community dimension

Survey and interview responses that demonstrated a direct connection/bond/relationship between the COASST participant and survey site mediated specifically through a social relationship were all categorized as attachment within the community dimension.

Many COASST participants named or alluded to the importance of friends and family attached to their beach. He et al. (2019) found evidence for attachment via both friends and family as strong components of the social connections of new and seasoned COASST participants. Nearly half of seasoned participants (42%) interviewed by Haywood (2019) indicated they felt a certain sense of comfort and belonging at their survey site, with 17% suggesting that their site was particularly meaningful because it is where they regularly meet someone of import to them. In the quote below, a seasoned participant describes her more experienced COASST survey partner,

with whom a friendship has developed over time, demonstrating attachment via friend bonding.

Q3: She is a wonderful person, she teaches up at (university name)... so I feel like that has made us have a stronger connection as well. We both have an appreciation for music, but she is also very good at instructing, in a very clear and precise manner and she is very respectful, so even if it takes you a few times to remember something, she is so patient. She is so casual too. I love it, we just talk and do our survey and just enjoy it. She has definitely become a friend. This is where we get to come together.

Although Raymond et al. (2010), Raymond et al. (2011) distinguish between family and friend social bonding constructs within the community dimension of PAT, and there were clearly instances in our data that demonstrated one or the other (see above), we found clear distinctions between these constructs less obvious among most COASST participants in practice. Instead, our data suggest that COASST participants articulate a continuum of social connections established through their beach. These include the finer scale of immediate interaction with known individuals (e.g. strengthening or building relationships with a survey partner) out to a macro-level or coarse scale of social connectedness to individuals not directly known but specifically imagined (e.g. feeling more connected to the community of participants within the programme, or even to the community of science; Haywood, 2015; Haywood et al., 2016; He et al., 2019). Witness the participant below:

Q4: I'm really a big believer in community and to have all these people, all these various people, working on a project from so many different places—that is a community of people. I've met so many people in (name) county that do this, and they are great—some have even become friends. This is an odd thing that we have in common and so we are very different people but we are just a large family. That is very appealing to me. The community is a huge aspect of my connection to this place.

This seasoned COASST participant indicates that a portion of their place attachment relates to the sense of community felt at the survey site through programme participation, and uses the words community, friend, and family to describe this social connection. Given the difficulty we found in distinguishing between friend and family as separate constructs and the fact that these relationships appear to influence PAT in similar (i.e. positive) ways, we propose adapting the three-dimensional model for a citizen science context to combine separate family and friend bonding constructs into one integrated construct (*family–friend bonding*) that includes all place-based social connections with others who are present and specifically known to the individual (e.g. family, friends, community members, co-workers), as well as those who are real but imagined (e.g. other participants within the programme).

Finally, we identified a cohort of responses that align with the concept of rootedness highlighted by Raymond et al. (2010) following from Hay (1998). Like the participant below, attachment, in these cases, can relate to a long lineage of social connection, a construct we are calling *social rootedness*.

Q5: Well I have indigenous heritage so this, just, finally somebody's asking. It's about the planet itself. It's about so much more than just me looking for stuff on the beach. It goes way, way, way, way back. So I think some people are very connected [to heritage] and some people are more connected to the science.

Other scholars have noted the significance of place some people feel because of connections to a cultural or ethnic heritage intertwined with that place (Billig et al., 2006; Hay, 1998; Mazumdar & Mazumdar, 2004); thus, we propose separating the construct of social rootedness within the community dimension as a distinct element of social bonding. We include in social rootedness a continuum of relationships from individuals once personally known to the participant who have since died (e.g. grandparents) all the way to past communities (personally unknown) to which the individual has a connection (e.g. ancestors or heritage).

3.3 | Natural environment dimension

Because the COASST programme is largely focused on natural science data collection in out-of-doors settings, it is not surprising that constructs of the natural environment were frequently identified among participants as key components allowing them to form strong attachments to place. However, we also found significant nuances in participant responses within this dimension, which we term natural environment. Included in this dimension was any response that demonstrated a direct connection/bond/relationship between the COASST participant and survey site, mediated specifically through some aspect of the environment, including the presence of a living or non-living feature or the ability to understand those features up through consideration of the system in its entirety.

For some COASST participants their sense of place attachment was mediated through connection to the biotic components (e.g. birds, wildlife, forest) of that place. We categorized these responses as *nature bonding*, the construct noted by Raymond et al. (2010) within the natural environment dimension of their original model. However, we propose refining this construct to explicitly define nature to be some part of the *living* world other than people.

When asked to report on the meaning found at their survey sites, seasoned participants frequently shared value associated with the natural environment, including meaning linked to the wildlife found at the place (49%), as well as the overall ecological value of the place (50%; Haywood, 2019). He et al. (2019) reported that nature bonding, in the form of attraction to viewing, finding or learning about birds, wildlife, and/or more generally 'nature' were strong motivators

to join the programme; sentiments reflected in the quotes of seasoned participants below.

Q6: I think this is the right beach for me because of my connection with the [Pigeon Guillemot] colony and being so close to knowing this colony and knowing some of the neighbors who can email me if there is something that has happened down here...In fact, I permanently marked myself with this place. This is a tattoo of a Pigeon Guillemot on my shoulder, so it is permanently on me. I guess you could say I took this beach home.

Q7: I always feel at home in nature. It's why I moved up here, because there is more nature than crowdedness. I mean the nature up here is just beautiful. I feel more at home here. It is home.

However, many COASST participants also demonstrated attachment to non-living elements at their survey site, a facet we refer to as 'environment' as distinguished from nature, or the living components. He et al. (2019) found that the strongest motivator of continued engagement for seasoned COASST participants was simply a desire to be outdoors on the beach, without reference to particular elements of nature. The seasoned participant below, for example, notes the sand, water and smell of the place as reasons for their attachment and desire to protect the survey site.

Q8: As I've collected this data, I've developed more of a love for the beauty of the coast in general and also how diverse it can be. In the past, when I thought of beaches I thought of sand and water. And then after being out here so often, it is like, OK, that is there, but there is also a lot more, especially on quiet beaches where you can appreciate the whole feel, and the smell—it all kind of overwhelms you. So I've gained a better appreciation of seeing why people here fight so much for their dunes and their coastline system. Before, I kind of understood, but I didn't completely understand. Now, I feel like if there was a protest to protect this beach, I would be there.

Because citizen science projects range substantially among abiotic to biotic environmental components of focus, and because the dynamics of interactions between abiotic and biotic elements of place are distinct, we propose adapting the natural environment dimension to include a construct we are calling *environment bonding*. We interpret the environmental bonding construct as something that contributes to attachment because of an individual connection to a non-living or physical aspect of the environment including both substantive elements (e.g. the cliffs behind my beach; the sand) and phenomenological elements (e.g. the sound of the waves).

Finally, and perhaps most unique to the practice of citizen science, we found a significant portion of COASST participants

indicated that the practice of environmental or ecological science was an important aspect of their attachment to place. As a citizen science programme soliciting long-term engagement in rigorous data collection by coastal residents, COASST is *a priori* connecting people to place through science. As a whole, seasoned COASST participants like the one below consistently ranked increased scientific learning and knowledge as one of the most frequently expressed outcomes of programme participation (Haywood, 2015).

Q9: So I'm constantly learning how to key the birds and how to identify them and then seeing new things—the new species or the conditions of the beach. A constant learning experience is probably the best big balloon I could put over it to describe it—the constant learning about the world around you. That is what gets me excited about this place.

We propose adding one final construct under the natural environment dimension, *science affinity*, which we define as a way of connecting to place through the practice of science and more generally knowledge of that place (e.g. via observation, investigation, monitoring or learning). Haywood et al. (2016) found that feelings of place attachment were often linked directly to learning more about the ecology of the place (62%) and seasoned participants reported a greater appreciation for their beach ecosystem through repeated visits and the chance to collect data on the birds there. Science affinity is an aspect of the participant experience that seems to increase with participation: seasoned participants tended to identify themselves more strongly with science, including as members of the 'science team' (He et al., 2019). Furthermore, Haywood et al. (2016) found that 66% of the seasoned participants interviewed perceived the information they were collecting through systematic science was an active way to help protect or conserve their beach and, more broadly, the coastal environment. Such pro-environmental behaviour has been identified as connected to the natural environment dimension (Raymond et al., 2011).

4 | CONCEPTUALIZING PLACE ATTACHMENT SHAPE AND TEMPORAL CHANGE

Changes in place attachment over time have been robustly documented in the place attachment literature and are consistently attributed to variables believed to predict place attachment including residence length (Lewicka, 2005), strength of community ties (Scopelliti & Tiberio, 2010), home ownership (Brown et al., 2003), mobility (Gustafson, 2002) and the presence of certain physical features like green spaces (Bonaiuto et al., 1999). However, given the relative dearth of theory and empirical research on the multiple attachment dimensions and the relative interactions that occur among the constructs therein over time, not much is known about how attachment shape might change along a temporal plane.

Evidence from our research suggests that the shape of PAT is not fixed and may shift as a function of the citizen science activities and place-based experiences individuals accrue over time. He et al. (2019) and Haywood et al. (2016) both demonstrated significant differences in thinking, place interaction and identity between the population of individuals just joining the COASST programme—‘new’ participants—and those who had engaged in the programme for one to several years—‘seasoned’ participants. These findings suggest that either PAT shape changes as participants grow into seasoned COASST data collectors, some attachment ‘shape profiles’ persist in the COASST participant population longer than others, or, most likely, both.

Figure 3 demonstrates the conceptual model highlighting directionality in PAT shape change over time in out-of-doors citizen science,

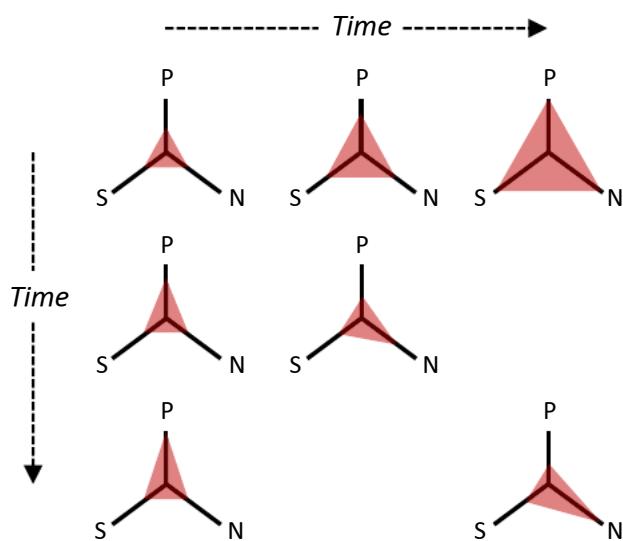


FIGURE 3 Conceptual shifts in PAT ‘shape’ through time as attachment intensifies along one or more poles: personal (P), social (S) and natural environment (N). Top row: all poles intensify. Left column: only the personal pole intensifies. Diagonal: only the natural environment pole intensifies

where three individual trajectories are laid out from a singular starting point in the upper left corner. Thus, growth in attachment strength or intensity along all dimensions is possible (horizontal axis), or growth in only one dimension (vertical: personal; diagonal: natural environment). We should note, however, that while we believe there is evidence that the strength of attachment among any given participant may vary across the three dimensions highlighted here and that those differences may have real impacts on the evolution of people-place relationships over time and through citizen science, we do not wish to assert that these dimensions should be treated as fully distinct and separate from one another. There is undoubtedly overlap among all three. It is hard to imagine a strong place bond based on components of the natural environment (natural environment dimension), for example, not also influencing a person’s sense of identity and belonging with that place (personal dimension). In fact, a strong body of literature exists that challenges such rigid distinctions (Bragg, 1996; Descola, 2013; Vining et al., 2008).

The degree to which PAT shape changes as a function of engagement in long-term citizen science activity, or more simply the possibility that the corps of participants could be categorized by shape along lived experience or other lines, remains unexplored. Finally, it should be noted that the vast majority of COASST participants most prominently hail from western cultural traditions, which undoubtedly influence their notions of identity and perceptions regarding the strength of and separation between the personal, social and natural environment components of a place (and see Quote 6 under social rootedness). As such, our data are not representative of non-Western cultures.

5 | CONCEPTUALIZING PLACE ATTACHMENT SCALE

Our re-analysis indicates that scale is a crucial concept in PAT, not only defining the geographical or spatial extent individuals realize connection to place (*sensu* Ardoin, 2014; Ardoin et al., 2012; Ardoin et al., 2019) but also specific to the community and natural

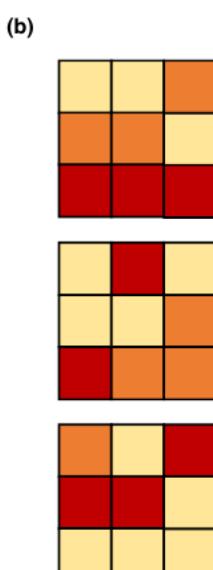
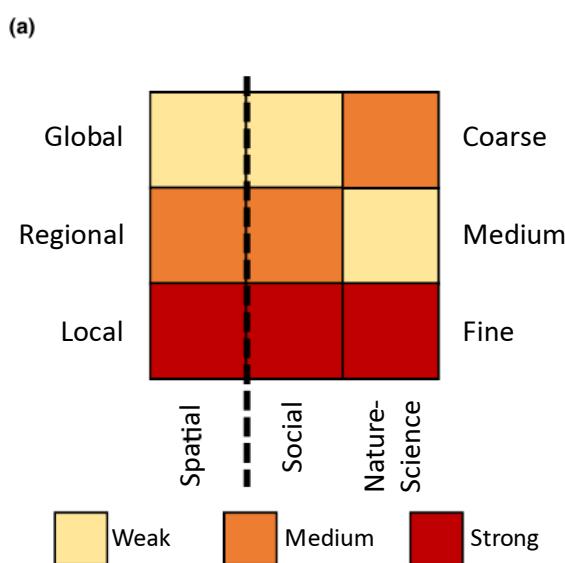


FIGURE 4 The scales over which an individual, group or population displays attachment to place shown as a ‘heatmap’. Spatial scaling is separated by a dashed line from the other scaling constructs to accentuate the difference in concept. Shading denotes the strength or intensity with which a particular scale is espoused. (a) An example individual or population with strong local (spatial scale) and fine scale (social scale and nature-science conceptual grain) references. (b) Examples of different ‘scale profiles’ displaying: top—strong local/fine scale references; middle—strong local spatial references tied to ancestral or heritage references; bottom—strong regional and community references tied to system-level nature, environment or science

environment dimensions. We refer to these latter two concepts as social scaling and nature-science 'conceptual grain' (Figure 4).

5.1 | Spatial scale

A sense of geographical or spatial scale was apparent along all three dimensions, as highlighted by the excerpts above. At the local scale, COASST participants referred to their survey beach as a possession, as in Quote 3: '*This is my beach, and I think of it as mine*'. perhaps akin to the scale of dwelling (Cuba & Hummon, 1993) or home (Anton & Lawrence, 2014). Thus, Quote 7 literally declares '*I guess you could say I took this beach home*'. However, as can be seen from Quote 1, attachment at the regional scale is also apparent: '*I'm a New Englander, and I grew up on a large inland body of saltwater called Narragansett Bay*'. In fact, this person scales beyond region to call out the coastal environment in general: '*...living near the shore, and living on the shore*' as does Quote 9: '*I've developed more of a love for the beauty of the coast in general...*' These statements highlight what other PAT researchers have also found—not only does PAT exist at unique spatial scales but also that these various geographical scales of attachment can influence the nature and scope of 'active engagement in efforts to protect and improve... places' (Ardooin, 2014, pg. 439).

5.2 | Social scale

Similar to, but more expansive than Ardooin's (2014) 'cultural' scale of attachment, the object of attachment along the community dimension varied from single known individuals to cultural heritage. We recognize this as social scaling.

At the fine scale, friend and family bonding is most apparent, as in Quote 4, '*She is a wonderful person, ... She has definitely become a friend. This is where we get to come together*'. However, it was also clear that persons immediately known to the participant were not the only social bonds mediating connection to place. Quote 5 typifies the medium scale as a more conceptual description of persons imagined but not actually known personally: '*I'm really a big believer in community and to have all these people, all these various people, working on a project from so many different places—that is a community of people*'. Here the social connections are via the corps of participants across the programme, not known to any individual participant, but imagined by some as people, like themselves, collecting data on their beaches in exactly the same manner and all towards a greater goal (Haywood et al., 2016). Thus, the social sense is of shared experience. At the largest social scale are individuals unknown to the participant and, to an extent, mythologized. Here culture and heritage blend to root the person in the place well beyond their lived experience, as is evident in Quote 6: '*Well I have indigenous heritage so this,... It goes way, way, way, way back. So I think some people are very connected...*' While this connection to the distant past is a minor component of the overall corps of COASST participants, it is especially apparent in the Indigenous populations.

5.3 | Nature-science scale

Along the natural environment dimension we have identified scaling in what we refer to as the 'conceptual grain' or the scale at which the individual considers the environmental system and the scientific activities that help unlock it, somewhat akin to Ardooin's (2014) ecological scale.

Within nature bonding, conceptual grain can be as fine scale as specific named components of the ecosystem, as in Quote 7: '*I think this is the right beach for me because of my connection with the [Pigeon Guillemot] colony... In fact, I permanently marked myself with this place. This is a tattoo of a Pigeon Guillemot on my shoulder, so it is permanently on me*'. However, many participants espouse connections to broader conceptions of place-based nature, a sense of the integrated whole, as in Quote 8, '*...the nature up here is just beautiful. I feel more at home here. It is home*'. A similar sense of scale is encompassed by participants' comments about their attachment to the physical environment (environment bonding), from the fine grain of system components such as waves or sand as in Quote 9, '*...you can appreciate the whole feel, and the smell—it all kind of overwhelms you*' up to the coarse scale of the system level, as Quote 6 demonstrates, '*It's about the planet itself. It's about so much more than just me looking for stuff on the beach*'.

Finally, science affinity also has this conceptual grain scale structure. Some participants are quite specific about individual tasks of interest within one disciplinary strand of science that draw them to place or assist them in knowing their place, a fine grain exemplified by Quote 10: '*So I'm constantly learning how to key the birds and how to identify them and then seeing new things—the new species or the conditions of the beach*'. Other participants refer to broad-scale ideas within science, including disciplines or system-level concepts like ecology up through 'actionable science' as Quote 2 demonstrates, '*It must be just the pleasure of being out there and then if I do find anything I can contribute to knowledge and research, which makes me feel good*'.

The degree to which PAT differs by scale in spatial, social and nature-science arenas and whether or not that changes as a function of engagement in long-term citizen science activity may provide important clues about whether or not and/or how both the science produced through citizen science and the personal outcomes of those that participate (e.g. in the form of conservation action) can 'scale-up' from the hyper local context focused on fine-grain scientific processes to the regional or global context involving complex ecological systems.

6 | PAT PROFILE AND PROMISING RESEARCH DIRECTIONS

Our revised theoretical framework based on the three-dimensional model of Raymond et al. (2010), Raymond et al. (2011) arises from experiences of PAT within COASST participants, and provides a robust scaffold from which to develop methods that capture PAT nuance and dimensionality in out-of-doors, repeated activity citizen science.

We hypothesize that shape and scale are inherent parts of place attachment within the citizen science context, and may extend and/or shift as a person deepens their experience of place via programme participation over time. To encompass the elements of dimensionality, intensity and scale, we propose the concept of a *place attachment profile*, literally the combination of Figures 3 and 4 with respect to any single person. We believe research on the attachment profile of citizen scientists may increase the potential to understand the ways in which PAT can facilitate and sustain citizen science engagement.

The ability to measure the place attachment profile among citizen science participants, as well as if/how that profile changes over time opens up a host of research avenues from which to explore both the impact of citizen science on participants and the personal dynamics of people-place relationships that may influence citizen science engagement and outputs. Four major research questions have emerged from our work on COASST and PAT that we believe may lead to important theoretical and applied advancements in the field.

1. Does place attachment help initiate engagement in citizen science?

Among environmental volunteers, Measham and Barnett (2008) have suggested that place attachment is a central motivating factor, connecting people to place via ethics of stewardship and conservation. With 66% (46 out of 70) of COASST interviewees linking the process of data collection directly to conservation and stewardship of their survey site, programme engagement appears to be a way to protect a valued place for many participants (Haywood et al., 2016). However, there is little research on place attachment as a motivator to *begin* engagement in citizen science, where environmental ethics may, or may not, be primary to the work. Does a pre-existing attachment to a site motivate individuals to join citizen science programmes offering activities at that site? Does the attachment profile of an individual influence the nature of the programme they select, their data collection accuracy or the duration of their participation? Are particular profiles typical 'entry points' for citizen science, and/or for particular types of citizen science?

2. Does continuing participation in citizen science alter attachment profile?

As noted above, our work with COASST participants to date indicates a demonstrative, multidimensional and multiscalar attachment to place (Haywood, 2015, 2019), and a shift in the motivating factors and situated identity of participants as they move from who they were when they joined the programme to who they are years later as central members of the community of practice (Wenger, 1998) that is COASST (He et al., 2019). While our research indicates a correlation, we have not yet established a causal link between participation and PAT. Specifically, can citizen science lead to increased/decreased place attachment; or catalyse shifts in attachment intensity and/or scale? How does the 'landscape' of PAT profile distribution shift as a function of engagement strength (e.g. in COASST: years in programme, number of surveys performed, number of bird carcasses found). And finally, do different 'types' of citizen science programmes

entrain and/or maintain different profile landscapes? The latter question allows expansion of PAT to include citizen science programmes in which the participants are not physically connected to the place, as in the highly popular Zooniverse programme Snapshot Serengeti (Swanson et al., 2015) in which nearly 30,000 participants help to definitively identify camera-trapped animals in locations they have never (or rarely) visited except within the online environment.

3. Does place attachment profile influence citizen science participant outcomes?

Are the knowledge, skills or personal benefits gained from participation in citizen science a function of PAT presence/absence or attachment profile? Does this vary based on whether place attachment is pre-existing or develops over the course of participation in a particular way? Does an individual's place attachment profile influence these outcomes? In particular, three important areas of potential inquiry exist with regard to how place attachment profile influences participant outcomes, including connections to *learning, critical thinking and pro-environmental behaviour*.

Several studies have demonstrated that learners in hands-on citizen science projects can master the knowledge and skills needed to successfully perform project tasks at or above a level necessary for the project to deliver scientific outcomes (Dickinson et al., 2010). Our research to date indicates that non-expert participants in the COASST programme not only learned the science content and skills needed to identify dozens of marine bird species with high accuracy but also that the monthly practice of surveying 'their beach' facilitated the development of species-specific mental models of beach-cast marine bird occurrence that statistically matched long-term regional averages (i.e. the baseline pattern), suggesting more developed critical thinking abilities (Char et al., 2014). Even still, we do not yet know whether the development of critical thinking skills are related to a *priori* demonstration of PAT—that is, a propensity to learn/think about a place—and/or to the concomitant development of a PAT profile.

Other studies have demonstrated a correlation between place attachment and environmentally responsible behaviours and attitudes (Budruk et al., 2009; Halpenny, 2010; Schultz, 2001), and specifically the link between the nature bonding dimension of PAT and environmental stewardship (Raymond et al., 2011). Our own work has demonstrated that engagement in the COASST programme can influence the sense of stewardship and environmental responsibility felt by participants (Haywood, 2015; Haywood et al., 2016), as is so apparent in Quote 9 (above). Within a citizen science context, could place attachment profile predict the likelihood that pro-environmental behaviour develops or how/when it is expressed?

4. Does participant place attachment profile influence programme outputs?

Haywood et al. (2016) demonstrated that almost all (98%) COASST participants readily share their on-the-beach experiences (38%) up through programme-level information (36%) with others, expanding

the reach and relevance of the information collected to broader programme-level outputs. Impressively, 20% of participants reported talking with resource managers, politicians or the news media about the data they collect and significance of that information, which has the potential to lead to much larger systemic change. In what ways might these larger programme outcomes be a function of the place attachment profiles of participants? Specifically, could PAT intensity correlate with the likelihood that participants will share information or interpret the significance of data collected for communicators and decision-makers?

7 | CONCLUSION: PAT PROFILE SIGNIFICANCE?

There is a growing evidence that active, place-based citizen science participants have a strong sense of place attachment (Haywood, 2019), are capable of learning and thinking at advanced levels for scientific analysis (Trumbull et al., 2000) and exhibit pro-environmental protective behaviours (Halpenny, 2010). However, it is not known the degree to which those abilities are related to each other, whether they grow/shift over time, and the specific dimensions of a place that are implicated therein. Data from the COASST programme highlighted herein demonstrate that place attachment is indeed multidimensional, occurring at multiple and disparate scales, with the potential to impact the citizen science experience.

In order for the informal science learning community to adequately consider the potential role of people-place connection in shaping citizen science engagement, participant outcomes and programme outputs a holistic model of attachment that moves beyond one solitary measure of the affective bond felt with a particular place and one spatial or social scale is required. We believe that using the revised three-dimensional place attachment model and concept of attachment profile presented here as a conceptual and theoretical framework will not only enhance understanding about the role of the citizen science learning environment and what diverse factors influence that process but also how place attachment combined with other experiential elements of citizen science at various scales shape outcomes and impacts. Finally, we suggest that inquiry into these hypothesized relationships has significant potential to reach beyond the practice of citizen science into multiple informal and formal learning environments to enhance both pedagogical and programmatic design and the assessment of critical metrics of science and environmental knowledge and application.

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CONFLICTS OF INTEREST

None of the authors have any conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

Original research audio files, interview transcripts and digital survey responses discussed in this manuscript are kept in a secure cloud-based data management archive, with access limited to senior project personnel and project staff via a secure password and two-step verification. Original raw data cannot be shared without written consent of the research participants and a data use agreement. Aggregate data can be shared upon request, under the terms outlined in the original informed consent process.

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SUPPORTING INFORMATION

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

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