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Authors
Fausey, K
Rippy, MA
Pierce, G
et al.

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Ecosystem service values support conservation and sustainable land development: Perspectives from four University of California campuses

K. Fausey [a], M.A. Rippy [a,b,c,*], G. Pierce [d], D. Feldman [e], B. Winfrey [f], A.S. Mehring [g], L.A. Levin [h], P.A. Holden [i], P.A. Bowler [j], R. Ambrose [k]

[a] Occoquan Watershed Monitoring Laboratory, The Charles E. Via, Jr. Department of Civil and Environmental Engineering, Virginia Tech, 9408 Prince William Street, Manassas, VA, USA
[b] Center for Coastal Studies, Virginia Tech, 1068A Derring Hall (0420), Blacksburg, VA, USA
[c] Disaster Resilience and Risk Management (DRRM), 1068A Derring Hall, 405 Perry Street, Blacksburg, VA 17 24061, USA
[d] UCLA Luskin Centre for Innovation, Luskin School of Public Affairs, Los Angeles, CA, USA
[e] Department of Urban Planning and Public Policy, School of Social Ecology, University of California Irvine, CA, USA
[f] Water Engineering, Department of Civil Engineering, Monash University, Clayton, Vic, Australia.
[g] Department of Biology, University of Louisville, Louisville, KY, USA
[h] Center for Marine Biodiversity and Conservation and Integrative Oceanography Division, Scripps Institution of Oceanography, University of California, San Diego, La Jolla, CA, USA
[i] Bren School of Environmental Science and Management, University of California, Santa Barbara, CA, USA
[j] Department of Ecology and Evolutionary Biology, University of California, Irvine, CA, USA
[k] Department of Environmental Health Sciences, Jonathan and Karen Fielding School of Public Health, University of California, Los Angeles, CA, USA

A R T I C L E I N F O

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A B S T R A C T

Urban landscapes homogenize our world at global scales, contributing to "extinction of experience", a progressive decline in human interactions with native greenspace that can disconnect people from the services it provides. College age adults report feeling disconnected from nature more than other demographics, making universities a logical place to explore interventions intended to restore a connection with nature. This study surveyed 1088 students and staff across four university campus communities in Southern California, USA and used multicriteria decision analysis to explore their landscape preferences and the implications of those preferences for combatting extinction of experience. Our results suggest that perspectives of, and preferences for, different greenspace forms vary significantly (i.e., they are not perceived as substitutable). Support for native ecosystems, particularly coastal sage scrub (top ranked landscape) was generally high, suggesting that disaffection with wild nature is not particularly widespread. Programs for replacing turf grass lawns (lowest ranked landscape) with native plants were also well supported, but support for stormwater bioswales was more moderate (and variable). This may reflect their relative newness, both on university campuses and in urban spaces more generally. Not all members of campus communities preferred the same landscapes; preferences differed with degree of pro-environmentalism and university status (undergraduate student, graduate student, staff). Even so, all respondents exhibited landscape preferences consistent with at least one approach for combatting extinction of experience, suggesting that ecologists, engineers and urban planners have a viable set of generalizable tools for reconnecting people with nature.

1. Introduction

Eighty-three percent of the U.S. population presently resides in urban areas (CSC UM, 2022, McKinney, 2002). The physical extent of these areas, and the agricultural land that supports them, has expanded faster than population growth, often encroaching on biodiversity hotspots (McKinney, 2002; Seto et al., 2013). The result has been an extensive loss of natural lands and associated plant and animal biodiversity. Native prairie cover in Iowa has dropped from 85 % to 0.1 % and native grassland cover in Illinois has dropped from 60 % to 0.04 % since the

* Corresponding author at: Occoquan Watershed Monitoring Laboratory, The Charles E. Via, Jr. Department of Civil and Environmental Engineering, Virginia Tech, 9408 Prince William Street, Manassas, VA, USA.
E-mail address: mrippy@vt.edu (M.A. Rippy).

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1860's (Miller, 2006). Less than 10 % of California's historical wetlands remain, and roughly 85–96 % of coastal sage scrub stands in California have been lost in the past 75 years, converted to urban and agricultural uses (Taylor, 2005; CWQMC, 2023).

This progressive loss of native landscapes and their replacement with managed greenspaces such as lawns and gardens can result in fewer opportunities for people to interact with wild nature, what some have termed an "extinction of experience" (Pyle, 1978; Miller, 2006; Gaston and Soga, 2020; Garfinkel et al., 2024). Extinction of experience disconnects people from the flows of services that native ecosystems provide in ways that cannot always be compensated for by other greenspace forms (Chan et al., 2018; Pratson et al., 2023). This is particularly true for cultural services such as spiritual enrichment and sense of place, which arise from the relationships people form with specific environments or their features (for instance, particular plant or animal species, vibrant flowers, or water; Stedman, 2003, Huss et al., 2018, Kaplan et al., 2023, Hursh et al., 2024, Stehl et al., 2024) that shape their understanding of themselves and their place in the world around them (Fish et al., 2016). When native ecosystems inform people's identities in this manner, loss of interaction with them can cause profound spiritual and psychological distress (Albrecht, 2005; Breth-Petersen et al., 2023), making efforts to combat extinction of experience important from a public health standpoint.

In the long term, extinction of experience may also contribute to a kind of generational amnesia (Kahn and Weiss, 2017), where lack of exposure to native ecosystems instigates a cycle of disaffection that results in people perceiving native ecosystems as progressively less valuable, either from the standpoint of their contribution to human wellbeing or their perceived utility for cultural practices (Fish et al., 2016; Soga and Gaston, 2016). Concern about the negative consequences of disaffection with wild nature, both for biodiversity and people, has motivated a range of interventions aiming to restore people's connection to nature (Soga and Gaston, 2016; Gaston and Soga, 2020). Some of these interventions are social and focus on changing people's behavior (e.g., creating opportunities for people to interact with nature through citizen science programming or wilderness therapies; Schuttler et al., 2018, Shanahan et al., 2019). Others involve changing the environment (i.e., environment-side approaches), such as conserving native ecosystems so that high quality nature is protected and available to people (Miller, 2006) or reintroducing nature into society through sustainable land development practices such as replacing turf grass lawns with native vegetation or ornamental sidewalk strips with green stormwater infrastructure (GSI) (Rosenzweig, 2003).

This study focuses on environment-side approaches for combatting extinction of experience and the extent to which people's landscape perceptions and values are supportive of such measures. Put another way, we aim to understand whether restoration or development activities that provide people with more opportunities to interact with native greenspace are likely to be perceived as beneficial or detrimental due to disaffection with wild nature. Our emphasis on environment-side approaches and increasing opportunities for nature interaction is a reflection of our collective interest as ecologists, ecological engineers, and urban planners in approaches for combatting extinction of experience that confer direct benefits to nature as well as people. However, it is important to recognize that reversing extinction of experience is likely to require enhancing both nature opportunities and nature orientation, making environmental education and policy changes that encourage native greenspace affinity and use as important as environment-side approaches that make it more abundant and accessible (Lin et al., 2014; Soga and Gaston, 2016; Martin et al., 2020).

Our target demographic is university campus communities (e.g., undergraduate students, graduate students, and staff), where environmental education is already prioritized and could provide an effective complement to environment-side approaches for combatting extinction of experience. Teenagers and college-aged adults (e.g., between 16 and 24 years of age) are a particularly important demographic with respect to extinction of experience because their perceptions are likely to play a key role in shaping the future of urban greenspace as they mature and play a greater role in policy-making (Rippy et al., 2021, 2022; Feucht et al., 2023), and yet, they are among the most likely to report feeling disconnected from nature (Barrable and Booth, 2022). Universities are pivotal socio-cultural settings with the potential to promote ecologically sustainable development and reconnect youth with nature as they enter adulthood (Colding and Barthel, 2017; Jones, 2013). They also support diverse greenspaces, forming a kind of natural experiment for evaluating and comparing the next generation's perceptions of different landscapes as well as their openness to restoration and sustainable development activities that may alter their relative abundance.

Our study was conducted across four university campuses in Southern California that maintain native ecological preserves, GSI, lawns, and ornamental gardens, allowing us to explore perceptions of these landscapes, and the implications of transforming them to combat extinction of experience (e.g., by conserving/restoring native ecosystems or implementing approaches from reconciliation ecology like replacing turf grass lawns with native vegetation or ornamental sidewalk strips with GSI; Miller, 2006, Pincetl et al., 2019, Grant et al., 2020, McPhillips and Matsler, 2018, Walsh et al., 2016). We use human subjects surveys and multicriteria decision analysis to reveal people's landscape preferences based on the ecosystem services they feel landscapes provide and the value they ascribe to different services. We then pose and answer three questions about the implications of those preferences for efforts to combat extinction of experience. First we ask, do campus communities strongly prefer specific greenspace types, or is greenspace perceived as substitutable? A key premise of this paper is that environment-side approaches that alter landscape form might be used to combat extinction of experience on university campuses – if landscapes are perceived as substitutable, this would obviously not be true. Given that different plant traits and landscape characteristics are variously perceived in other study populations (Nassauer, 1995b; Kendal et al., 2012; Hoyle et al., 2017; Rippy et al., 2021, 2022), we do expect campus communities to perceive different landscapes as different, which would make combatting extinction of experience using environment-side approaches feasible. Our second and third research questions look beyond feasibility and ask whether environment-side approaches for combatting extinction of experience are likely to be supported by campus communities and, if so, which approaches? Here we focus not only on aggregate community responses, but on the variability evident within communities and the potential factors driving it. Unpacking this variability allows us to zero in on young adults (undergraduate students), explore how their preferences differ from other demographics where connection to wild nature is reported to be high (for instance, pro-environmentalists; Kurz and Baudains, 2012, Barrable and Booth, 2022), and what this might mean for future efforts to strengthen youth relationships with nature as they enter adulthood. This work has important implications for efforts to combat extinction of experience and reverse generational amnesia on university campuses and can help guide the actions of restoration ecologists, ecological engineers, and urban planners who design and manage urban environments for both people and nature.

2. Methods

2.1. Study area

The four campuses included in this study were the University of California, Irvine (UCI), the University of California, San Diego (UCSD), the University of California, Santa Barbara (UCSB), and the University of California, Los Angeles (UCLA; Fig. 1). These campuses were selected because they support ecological reserves (see below) that are available to campus communities and they were participants in a Multicampus Research Initiative intended to transform campuses into living laboratories for evaluating sustainable development practices (e.g., GSI).

Fig. 1. Map of surveyed university campuses. Nature reserves that are on or immediately adjacent to each campus are highlighted (stippled: UC Natural Reserve System Reserves; white: other nature reserves or preserves). Photographs illustrate different landscape types from across these campuses that were included in our perceptions survey. They include native chaparral (present at Sage Hill), native coastal sage scrub (present at all UC reserves or preserves), green stormwater infrastructure (GSI1, GSI2), gardens (roses, palms), and lawns (lawn1, lawn2). Full size images can be viewed in Appendix.A3. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

These universities collectively span 15.59 km^2 and serve and employ between 25,000 and 45,000 students and 2500–24,500 staff (NCES IPEDS, 2018). Approximately 44–66 % of the land cover on each campus is impervious (buildings, parking lots, roads), with the remainder divided between irrigated landscapes (gardens, lawns) and native open space (coastal sage scrub, chaparral). All campuses are situated in urban areas, with UCLA being the most developed (i.e., located within the bounds of a megacity; Adler et al., 2020).

All campuses have sustainability initiatives that support design and implementation of GSI (Pierce et al., 2021). This includes bioswales (also called rain gardens), green roofs, constructed wetlands, and stream restoration. Campuses also support lawn replacement and tree planting initiatives that focus on revegetation with native species (UCI WAP, 2017; UC Sustainable Practices, 2022). This can take the form of native plantings in GSI or more ornamental landscapes that support native pollinators and fauna.

The University of California system also supports native ecosystems as part of 1) the UC Natural Reserve System (UC NRS; UCNRS, 2023) and 2) local (i.e., campus-specific) conservation programs. Several of these reserves are adjacent to (or part of) campus grounds (see Fig. 1), making them important resources for campus communities used for recreation, research, and education about native ecosystems (i.e., constituting classrooms without walls). A detailed description of each reserve as well as specific campus programs that leverage them or other natural resources on campus can be found in **Appendix A.1**.

2.2. *Data collection – human subjects survey*

The survey instrument used in this study was administered with Institutional Review Board approval (HS #2017–3998 and HS #18–1143) and was entirely anonymous to protect respondent privacy. The survey has been applied previously by Rippy et al. (2022) to evaluate engineering student perceptions. Here it is applied to a broader university demographic, including undergraduate students, graduate students and staff (any discipline or profession).

The survey collected information about the ecosystem services people perceive different landscapes provide and the relational value ascribed to each service, which can be used to infer landscape preferences via multicriteria decision analysis. Multicriteria decision analysis is often applied to identify options (in our case landscapes) that are "most preferred" because it can accommodate multiple dimensions of preference (e.g., multiple ecosystem services) as well as value pluralism (i.e., instances where services may be equally valued, but not co-provided by the same landscape, resulting in ties rather than objective preference ranks) (Chatzinikolaou et al., 2018). The survey also collected information about respondent characteristics to explore potential drivers of any observed variability in values, perceptions or landscape preferences. The characteristics evaluated include university status (undergraduate student, graduate student, staff), university affiliation (UCLA, UCSD, UCI, UCSB), academic discipline or profession, demographics (race, ethnicity, gender, nationality), and environmental worldviews. The following three sections of the methods describe how values, perceptions and respondent characteristics were assessed in our survey instrument.

2.2.1. *Assessing ecosystem service value*

Survey respondents were asked to quantify the importance (i.e., stated value) of seven ecosystem services (recreation, aesthetics, water quality, animal biodiversity, urban cooling, flood regulation, water conservation) and one disservice (allergies) by responding to the following prompt: "how much does each benefit or negative outcome of urban landscapes matter to you?". Responses were recorded on a 7-point

Likert scale (1 – not important to 7 – very important). Complete prompt text (formatted as seen by survey respondents) has been provided in **Appendix A.2**.

2.2.2. Assessing landscape perceptions

To determine what ecosystem services or disservices different landscapes were perceived to provide, respondents were asked to view eight color photographs of urban landscapes (one at a time, in random order) and rate the capacity of each landscape to provide the services and disservices noted above. Two photos were of native greenspace (coastal sage scrub and chapparal), two were of GSI (bioswales), two were of gardens (roses and palm trees), and two were of lawns (see Fig. 1 for small-format images of each photo; respondents were provided larger 9.9 cm by 19.8 cm images, which can be viewed in **Appendix A.3**). All photos were characteristic of landscapes as they appear in late spring. To keep the length of the survey manageable (< ½ hour on average) and avoid overburdening respondents (Galesic and Bosnjak, 2009), we did not include photos from other seasons. Landscapes that typically support flowers (rose gardens, coastal sage scrub, chapparal, and select GSI) were photographed in bloom whereas nonflowering landscapes (palm gardens, turf grass lawns) were not. Flowers provide an additional (often aesthetic; Hoyle et al., 2017, Kendal et al., 2012, Rahnema et al., 2019) visual cue that respondents can use to distinguish landscapes and associate them with different services. Including flowers in landscape photos may elicit differences in perceived services provisioning that would not be evident in other seasons.

All photos were selectively blurred as in Kendal et al. (2012) using graphics editing software (GIMP 2.8). This was done to focus attention on features of interest (i.e., the greenspace itself) which always made up 50–75 % of total photo area. Urban infrastructure (roads, parking lots, buildings) was present in the background of all photos, including photos of native ecosystems, where it was digitally added. This was done to keep biases for or against the built environment from influencing perceptions of native ecosystems relative to other landscapes (Church, 2015). Photos were standardized to have the same sky color and brightness so that these elements would not influence how different landscapes were perceived.

Ecosystem service and disservice ratings were reported on a 7-point Likert scale (1 – this landscape will not provide this service or negative outcome to 7 – this landscape is very likely to provide this service or negative outcome). The following prompt was used: "I believe this system will [insert description of service or disservice]". Services and disservices were described in plain language to make them clear to respondents: flood regulation – *soak water into the ground, reducing flooding*; water quality regulation – *improve water quality*; water conservation – *conserve water, especially in summer*; urban cooling – *cool down the urban environment*; aesthetics – *make urban landscape more beautiful*; animal biodiversity – *increase diversity of animals*; recreation – *provide landscape for relaxation and recreation (walking, picnicking, biking, jogging, cycling or team sports)*; allergies – *cause allergies*. Complete prompt text for questions about landscape services and disservices has been provided in **Appendix A.4**.

2.2.3. Assessing personal characteristics

Respondents were asked to self-report gender, race and ethnicity, whether they are from the state of California, university status (undergraduate student, graduate student, staff), and university affiliation (UCI, UCSD, UCLA, UCSB) using multiple choice questions that included options such as 'Other' and 'Prefer not to state'. Country of origin, academic discipline, and job title/profession were solicited using open response questions.

Environmental worldviews (i.e., core beliefs that influence people's attitudes about the environment and environmental challenges such as climate change) were assessed using an abbreviated, 12 question, New Ecological Paradigm (NEP) questionnaire proposed by Saphores et al. (2012). The instrument captures five key facets of environmental worldviews: (a) limits to population growth, (b) anti-anthropocentrism, (c) the fragility of nature's balance, (d) rejection of human exemptionalism (i.e., the idea that people are exempt from the constraints of nature), and (e) belief in ecological crises (Dunlap et al., 2000; Saphores et al., 2012). Responses to NEP scale-questions were provided on a 7-point Likert scale (1: strongly disagree to 7: strongly agree). Complete question text has been provided in **Appendix A.5**. Principal component analysis (PCA; Matlab 2019b, Mathworks, MA) was performed on individual NEP responses to characterize dominant worldviews like pro-environmentalism and ecological modernism as described in Rippy et al. (2021, 2022). Pro-environmentalism is generally associated with anti-anthropocentrism, the belief that nature is delicate and requires our protection and the perspective that future ecological crises are likely (Rippy et al., 2021, 2022; Dunlap et al., 2000) whereas ecological modernism is associated with feelings of human exceptionalism and the perspective that Earth's resources are finite (i.e., that human innovation is needed to find viable global solutions) (Nordhaus et al., 2015; Rippy et al., 2021, 2022).

2.3. Survey deployment

Our survey was administered to graduate students, undergraduate students, and staff at UCI, UCLA, UCSD, and UCSB. A fifth campus (UC Riverside) was also surveyed, but is not evaluated here due to deployment restrictions that limited response rates. The survey was primarily distributed through campus email listservs using SurveyMonkey (SurveyMonkey, Inc). A detailed description of survey deployment efforts can be found in Pierce et al. (2021), Rippy et al. (2022) and **Appendix A.6**. The total number of survey respondents was 1088.

To ensure the quality of survey responses, finished surveys were curated prior to analysis as in Rippy et al. (2022). Briefly, respondents were excluded if their time to survey completion was more than one standard deviation below the median (i.e., they completed the survey in less than 15 min), they skipped more than five consecutive questions, they responded nonsensically to open ended questions, or they failed to answer question sets with built in consistency checks in a logical manner. The final respondent pool following these quality control measures included 734 university stakeholders. Although this final pool is relatively small, its composition does reflect the campuses overall (see section 2.4, below), suggesting it is appropriate for addressing targeted questions about ecosystem service values and their association with different landscapes on these campuses.

2.4. Respondent characteristics

Significantly more undergraduate students responded to our survey (54 %) than graduate students (28 %) or staff (18 %) (Table 1), consistent with campus population profiles, which tend to be undergraduate dominated (undergraduate students made up 58 $\pm$ 0.2 % of the population across all four campuses when this study was conducted; NCES IPEDS, 2018). Survey demographics (race, ethnicity, nationality, gender) were generally consistent with reported demographics for each campus, but did exhibit a slight bias towards female, white and Hispanic students and staff and away from black students and staff (Table 1; NCES IPEDS, 2018). Respondents were significantly more likely to be female than male across all four campuses (61–68 %) (Table 1). Most self-identified as White (38–58 %), followed by Asian/Asian American (19–34 %), and Black (0–2 %) or Native American/Pacific Islander (0–2 %). Fourteen to 24 % of respondents self-identified as Hispanic. The majority were born in the US (80–90 %), and most indicated they were from the state of California (41–80 %; highest for undergraduates), in keeping with the UC campuses being California state schools.

Undergraduate students, graduate students and staff were equally likely to express pro-environmental worldviews (53 %, 56 %, and 58 %, respectively - Table 1) whereas ecological modernism was somewhat less common, particularly among graduate students and staff

Table 1
The proportion of graduate students, undergraduate students, staff, and all respondents (columns) broken out by university, gender, ethnicity, race, nationality, and environmental worldviews (rows).

	Graduate	Undergraduate	Staff	All	Campus[1]
P(Responded)	0.28 *(0.21–0.34)*	0.54 *(0.49–0.60)*	0.18 *(0.11–0.25)*	–	–
P(from UCLA)	0.26 *(0.14–0.38)*	0.13 *(0.03–0.22)*	0.61 *(0.50–0.72)*	0.25 *(0.19–0.32)*	0.41
P(from UCSD)	0.24 *(0.12–0.37)*	0.32 *(0.24–0.40)*	0.17 *(0.01–0.33)*	0.27 *(0.21–0.34)*	0.26
P(from UCSB)	0.45 *(0.34–0.56)*	0.48 *(0.41–0.55)*	0.17 *(0.01–0.33)*	0.41 *(0.36–0.47)*	0.13
P(from UCI)	0.04 *(−0.10–0.18)*	0.08 *(−0.02–0.18)*	0.04 *(−0.13–0.21)*	0.06 *(−0.01–0.14)*	0.20
P(Female)	0.62 *(0.53–0.71)*	0.61 *(0.54–0.67)*	0.68 *(0.58–0.79)*	0.62 *(0.58–0.67)*	0.51–0.64
P(Male)	0.32 *(0.21–0.44)*	0.36 *(0.28–0.44)*	0.26 *(0.10–0.41)*	0.33 *(0.27–0.39)*	0.36–0.49
P(Other)	0.05 *(−0.03–0.12)*	0.03 *(−0.07–0.13)*	0.07 *(−0.11–0.24)*	0.05 *(−0.03–0.12)*	–
P(Hispanic)	0.16 *(0.03–0.29)*	0.24 *(0.15–0.33)*	0.14 *(−0.03–0.30)*	0.20 *(0.13–0.27)*	0.22–0.25
P(Black)	0.01 *(−0.14–0.15)*	0.02 *(−0.09–0.12)*	0.01 *(−0.17–0.19)*	0.01 *(−0.06–0.09)*	0.02–0.06
P(White)	0.58 *(0.48–0.67)*	0.38 *(0.30–0.46)*	0.57 *(0.45–0.69)*	0.47 *(0.42–0.53)*	0.18–0.40
P(Asian/AA)	0.24 *(0.11–0.36)*	0.34 *(0.26–0.43)*	0.19 *(0.03–0.35)*	0.29 *(0.22–0.35)*	0.17–0.33
P(NA/PI)	0.02 *(−0.13–0.16)*	0.01 *(−0.09–0.12)*	0	0.01 *(−0.06–0.09)*	0
P(Other)	0.16 *(0.03–0.29)*	0.24 *(0.15–0.33)*	0.23 *(0.08–0.39)*	0.22 *(0.15–0.28)*	–
P(US.national)	0.80 *(0.73–0.86)*	0.88 *(0.84–0.91)*	0.90 *(0.85–0.96)*	0.86 *(0.83–0.89)*	0.81–0.89
P(California)	0.41 *(0.30–0.52)*	0.80 *(0.76–0.85)*	0.66 *(0.56–0.77)*	0.67 *(0.63–0.71)*	–
P(Pro.Env)	0.58 *(0.49–0.67)*	0.53 *(0.46–0.60)*	0.56 *(0.44–0.68)*	0.55 *(0.50–0.60)*	–
P(Eco.Mod)	0.39 *(0.28–0.50)*	0.57 *(0.49–0.63)*	0.47 *(0.34–0.60)*	0.50 *(0.45–0.55)*	–

95 % confidence bounds about each proportion are shown in parentheses; [1]: actual campus population profiles.
Abbreviations: P – proportion, AA – Asian American, NA/PI – Native American or Pacific Islander, US.national – self-identified US citizen, Pro.Env – pro-environmental, Eco.Mod – ecological modernist.

(undergraduate: 57 %, staff: 47 %, graduate students: 39 %). Graduate and undergraduate students were primarily affiliated with the social sciences (economics, political science, psychology, sociology; 30 % graduates, 24 % undergraduates), applied sciences (engineering, marketing, medicine; 28 % graduates, 22 % undergraduates), and natural sciences (biology, ecology, chemistry, earth science, physics; 25 % graduates, 38 % undergraduates) (Fig. 2). Staff respondents were most likely to have jobs in Administration, Management, or Finance (61 %), followed by Research and Laboratory Services (19 %), Other (e.g., library, communications, etc.; 11 %), and Student Services (9 %) (Fig. 2).

2.5. Statistical analyses

A detailed description of all statistical analyses can be found in **Appendix A.7**. Briefly, PCA (Matlab 2019b, Mathworks, MA) was used to identify associations between (a) ecosystem service values (importance ratings, section 2.2.1) and (b) the services landscapes were perceived to provide (section 2.2.2) that captured a significant fraction of the shared variance across survey respondents. This approach is often used to characterize dominant patterns (principal components) in ecosystem service values and landscape perceptions (Kendal et al., 2012; Harris et al., 2018; Hoyle et al., 2017, 2019; Rippy et al., 2021, 2022), prompting our decision to use it here. The significance of each principal component was determined relative to random expectation using a resampling-based stopping rule (95 % confidence level; Rippy et al., 2017). The goal was to capture meaningful patterns in the way respondents valued services and perceived landscapes.

Environmental factor projection, also performed in Matlab (2019b), was used to identify individual respondent characteristics (demographic variables, university status, university affiliation, academic discipline/profession and environmental worldviews) that significantly influenced these patterns (i.e., loaded significantly on the ordinal plane for ecosystem service values or landscape perceptions) (Davis, 2002). Significance was determined using bootstrapped Pearson's correlations as described in Rippy et al. (2021) and **Appendix A.7**. Characteristics that were both significant ($p < 0.05$ level) and meaningful (Pearson's correlation >0.2) were used to identify groups of respondents that seemed likely to have different landscape preferences given their stated values and perceptions.

Multicriteria decision analysis (Electre III, package OutrankingTools, R Core Team v. 3.6.3; Bigaret et al., 2017) was performed separately for each respondent group with significantly different values or perceptions of landscapes as well as for the entire respondent pool to evaluate and compare landscape preferences. Particular attention was paid to preferences for native greenspace (which can be used to infer the degree of disaffection with wild nature) as well the rank of native greenspace relative to other landscapes (for instances lawns), which can be used to understand the extent to which land transformations intended to combat extinction of experience are likely to be supported by campus communities. Electre III is an outranking model (Roy et al., 1986; Roy, 1990) that requires weights for decision criteria (in our case ecosystem services) to establish their relative importance, a performance matrix that

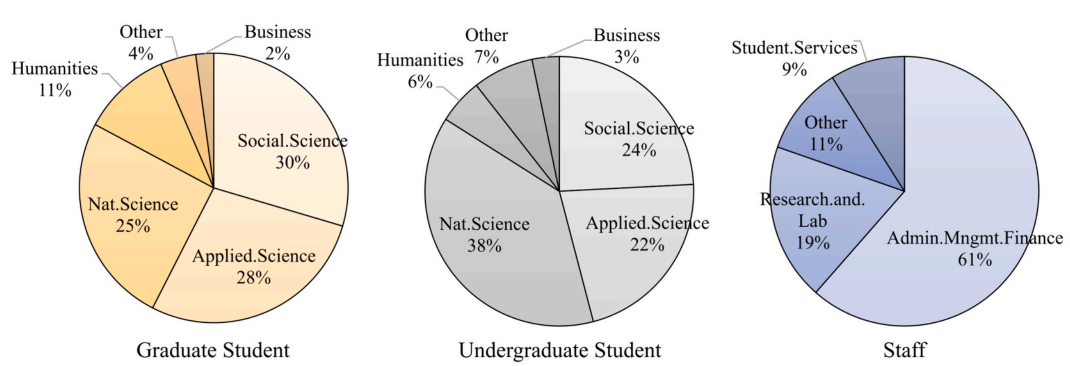

Fig. 2. Academic discipline and profession of each type of university respondent (graduate student, undergraduate student, staff).

captures the perceived performance of each landscape alternative relative to decision criteria, and thresholds that account for uncertainties in how people perform valuation assessments (Rogers and Bruen, 1998; Rogers et al., 2000). Decision criteria weights were determined by taking the geomedian of Likert-scale ratings for the value of each ecosystem service across all respondents in a given respondent group and normalizing the result so that the weights across all services summed to one (Roy, 1990). The performance matrix was estimated similarly, substituting median Likert-scale ratings for the perceived provisioning of each service by each landscape type for ecosystem service values. Because uncertainty thresholds are not precisely known, landscape rankings were evaluated multiple times for a range of possible threshold values and the resultant medians (and associated error) were used to determine landscape preferences for each respondent group and the entire respondent pool (see **Appendix A.7** for details).

3. Results

3.1. Ecosystem service values

PCA revealed two significant patterns in ecosystem service values ($p < 0.05$ level) that collectively explained 42 % of observed variance across respondents (Fig. 3a). The dominant pattern (PC1: 37 % variance explained) distinguished individuals who felt ecosystem services were valuable (positive PC1) from those who did not (negative PC1). Disservices (allergies) did not contribute significantly to this pattern. A secondary pattern (PC2: 15 % variance explained) separated out individuals who valued cultural services more (aesthetics, recreation; positive PC2) from those who valued biodiversity and regulatory services more (animal biodiversity, flood control, water quality, water conservation) and considered allergies an important ecosystem disservice (negative PC2). The only service that did not significantly contribute to PC2 was urban cooling. Water quality was valued the most and avoiding allergies the least, across all university respondents (Fig. 3b).

Two respondent characteristics (degree of pro-environmentalism and university status - undergraduate student, staff; cyan lines, Fig. 3a) loaded significantly and meaningfully ($p < 0.05$, Pearson's $r > 0.2$) on the ordinal plane for ecosystem service values, pointing to consistent relationships between these characteristics and the value assigned to specific ecosystem services or groups of services. Individuals with pro-environmental worldviews tended to value ecosystem services more, particularly regulatory services and animal biodiversity, as evidenced by the strong concordance between the projected vector for pro-environmental worldviews and service vectors for water quality, conservation, flood regulation, and animal biodiversity (positive PC1, negative PC2; Fig. 3a). Staff tended to value ecosystem services more than undergraduate students, particularly recreation (positive PC1, PC2 for staff; negative PC1, PC2 for undergraduates; Fig. 3a). Staff were also the least concerned about allergies of any respondent group (Fig. 3b).

Two of the six disciplinary groups we evaluated (applied sciences - engineering, marketing, and medicine, and social sciences - economics, political science, psychology, and sociology; Fig. 2) also loaded significantly, but weakly, on the ordinal plane for ecosystem service values (dashed grey lines, Fig. 3a; $p < 0.05$, Pearson's $r < 0.2$). This suggests that the influence of academic discipline on how services are valued is relatively minimal. Ecosystem services values were not significantly correlated with other demographic characteristics (race, ethnicity, gender, nationality), university affiliation (UCLA, UCI, UCSD, UCSB), or job/profession.

3.2. Landscape perceptions

Two significant patterns in landscape perceptions were detected ($p < 0.05$ level). The dominant pattern (37 % variance explained) mimicked the first principal component of ecosystem service values, distinguishing individuals who felt landscapes provide many services (positive PC1) from those who felt they provide few (negative PC1) (Fig. 4). Aesthetics, urban cooling, flood control, and water quality were the strongest contributors to PC1 (only the disservice allergies did not

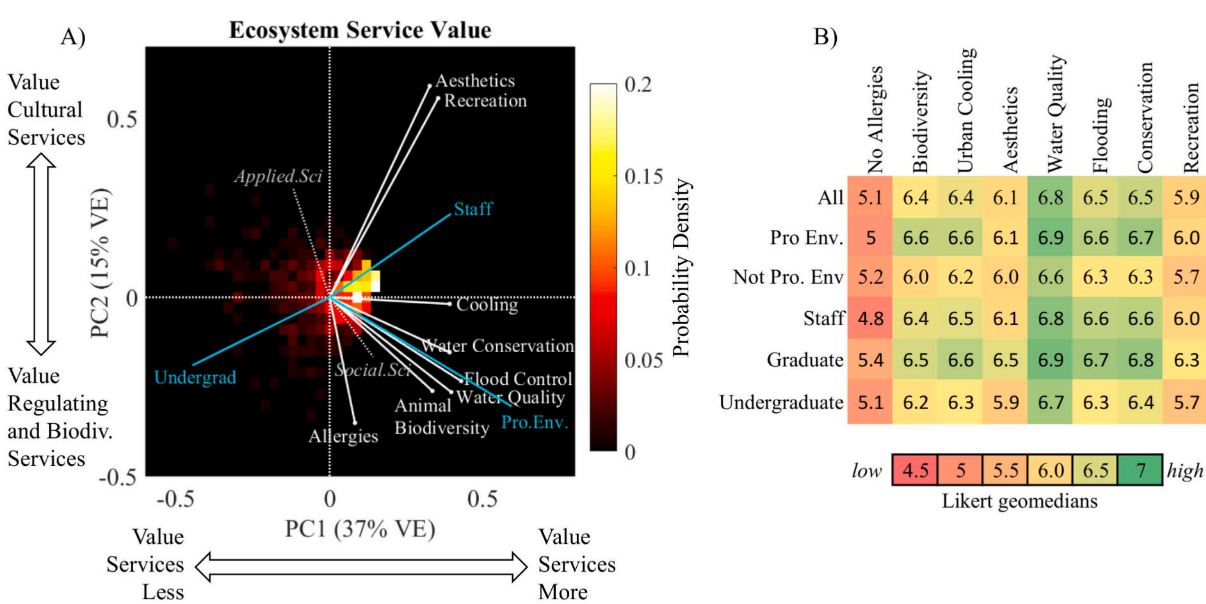

Fig. 3. A) Principal component analysis of ecosystem service values (dominant pattern - PC1: *x*-axis, secondary pattern - PC2: *y*-axis). White vectors are ecosystem services; Vectors that strike primarily in the horizontal (vertical) contribute more to PC1 (PC2). The probability that respondents felt particular services were valuable is shown using a heatmap (low probability = black to high probability = yellow/white). Respondent characteristics that were significantly and meaningfully correlated with ecosystem service value ($p < 0.05$, Pearson's $r > 0.2$) are in cyan. Characteristics that were significantly, but weakly correlated with value are in grey (dashed lines and text). B) Geometric median score for the value assigned to each ecosystem service by 1) all university respondents and 2) groups of respondents with significantly different ecosystem service values. Color: higher value services (green), lower value services (red). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

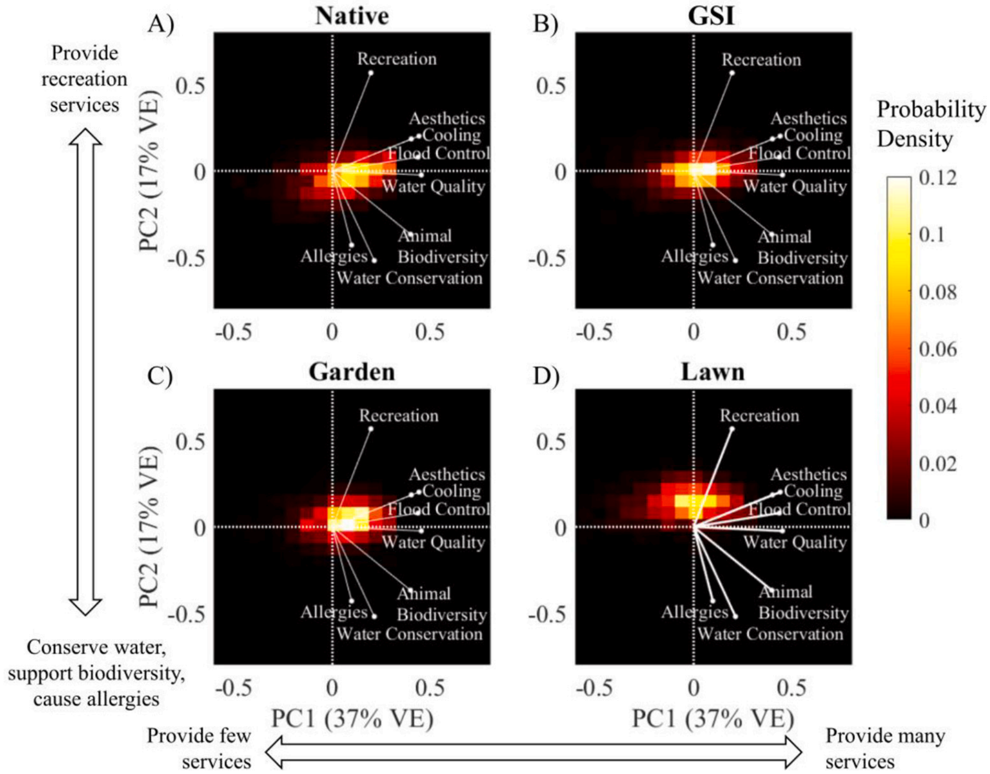

Fig. 4. Principal component analysis illustrating perceived services and disservices provisioning by landscape type across university respondents: A) native, B) green stormwater infrastructure (GSI), C) garden, D) lawn. The dominant pattern in landscape perceptions is on the *x*-axis (PC1). A secondary significant pattern is on the y-axis (PC2). White vectors denote specific ecosystem services or disservices. The probability that respondents felt a particular landscape provides services or disservices is shown using a heatmap (low probability = black to high probability = yellow/white). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

significantly contribute). The second pattern (17 % variance explained) distinguishes different bundles of services and disservices that people feel landscapes provide, separating out recreation services (positive PC2) from allergies, animal biodiversity, and water conservation (negative PC2). No respondent characteristics loaded significantly and meaningfully ($p < 0.05$, Pearson's $r > 0.2$) on the ordinal plane characterized by these patterns.

Different landscapes were perceived to provide different ecosystem services (i.e., the probability hotspot for each landscape lies in a different region of PC space; Fig. 4). Native landscapes were considered more likely to provide many services than few, particularly biodiversity services and water conservation, but were also more likely to be associated with the disservice allergies (positive PC1, negative PC2; Fig. 4a). Gardens were also perceived as more likely to provide many services than few, but were more associated with recreation and aesthetics than water conservation, animal biodiversity, and allergies (positive PC1, positive PC2; Fig. 4c). GSI and lawns were split about PC1, with GSI perceived as slightly more likely to provide many services (i.e., the highest probability density for GSI is to the right of the origin in Fig. 4b whereas the probability density for lawns is centered about the origin in Fig. 4d). Lawns, however, were clearly biased towards positive PC2 (recreation services), whereas GSI were not (i.e., respondents appear as likely to associate GSI with recreation as they are with allergies, water conservation and animal biodiversity).

Although each landscape type had its own unique ecosystem service signature, difference plots comparing perceptions of native landscapes to other landscape types (paler color = less difference) illustrate that GSI were perceived most similarly to native landscapes (Fig. 5a), followed by gardens (Fig. 5b) and lawns (Fig. 5c).

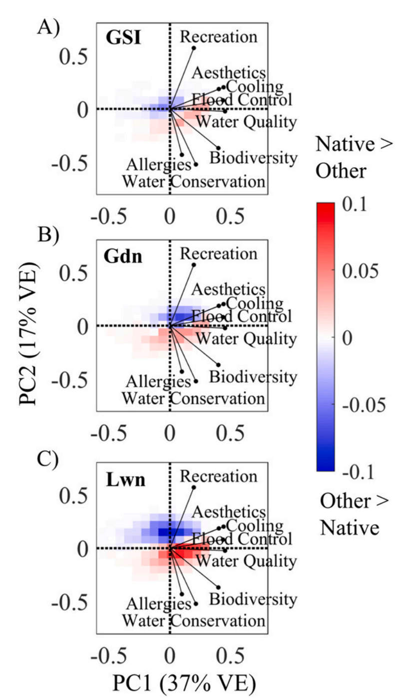

Fig. 5. Difference plots illustrating how perceptions of ecosystem services provisioning by native landscapes are different from perceptions of A) GSI, B) gardens, and C) lawns. Plots are oriented as in Fig. 4. The red-blue color scale indicates instances where native (red) or other landscapes (blue) are perceived to provide services more. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

3.3. Multicriteria decision analysis (MCDA)

Multicriteria decision analysis based on the ecosystem service values of university respondents and the services they associated with different landscape types suggests that native coastal sage scrub is best able to meet the ecosystem service needs of campus communities (i.e., it was the most preferred landscape), followed by gardens containing palm trees, GSI 1, and native chapparal (second best landscapes), GSI 2, gardens containing roses, and Lawn 1 (third best landscapes), and Lawn 2 (least preferred landscape) (compare median values (targets) and associated 95 % confidence bounds (triangles) for each landscape type in Fig. 6a). When university respondents are separated out into groups with different ecosystem service values (i.e., in accordance with the results of section 3.2), different patterns in relative landscape preference emerge. For instance, when the landscape preferences of individuals who did and did not possess pro-environmental worldviews are compared (blue and red colors, respectively, Fig. 6b), we see that pro-environmental individuals generally follow the afore-mentioned pattern in landscape preferences (an exception being lawns, which both received the lowest possible preference score), but non-pro-environmental individuals do not. This is evident in the significantly elevated scores for gardens with palm trees in the non-pro-environmental group, which became a top landscape choice. Gardens with roses also moved up, becoming second-most preferred (alongside GSI), and replacing native chaparral, which dropped from second to last place (alongside lawns).

Landscape preferences also differed among staff, graduate students, and undergraduate students. Undergraduate students (green, Fig. 6c) were the only respondent group that significantly preferred an exotic landscape to coastal sage scrub (palms were their highest ranked landscape). They also had markedly different preferences for lawns (higher) and native chapparal (lower) than other respondent groups. Staff and graduate student preferences differed minimally by comparison (note small, but significant differences in the relative rank of coastal sage scrub, roses, palms, and GSI 1 for these respondent groups; pink versus cyan, Fig. 6c).

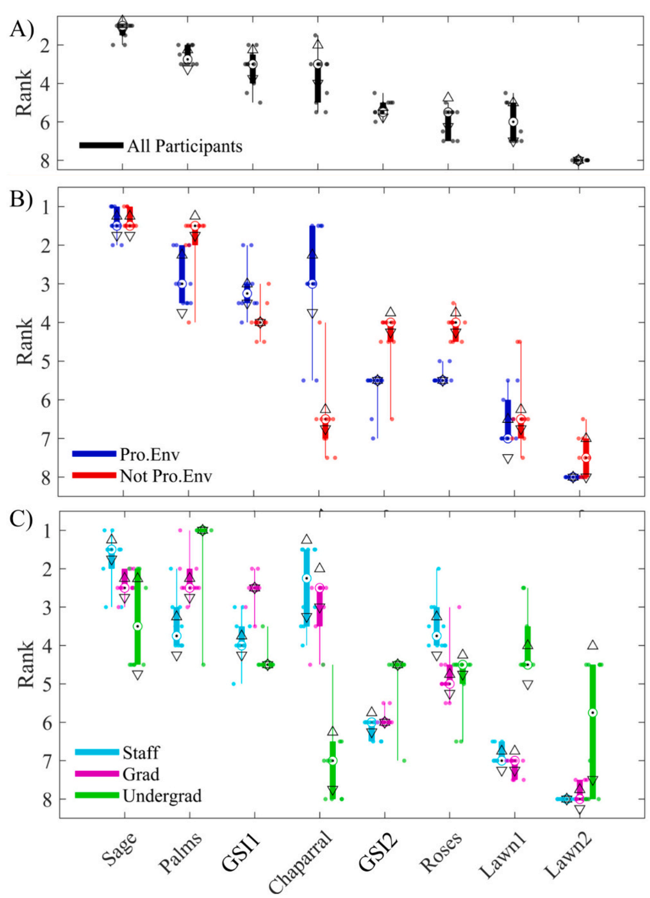

Fig. 6. Box and whisker plots illustrating the rank order of landscape preferences (sage scrub, chaparral, green stormwater infrastructure; GSI, lawns, palm trees, and roses) given the ecosystem services respondents value and their perceptions about the services each landscape provides. The photographs associated with each landscape code are provided in Fig. 1. Results are shown for A) the entire pool of university respondents, B) respondents with environmental worldviews that are more (blue) or less (red) pro-environmental, and C) different respondent types (staff – cyan, graduate student – magenta, undergraduate student – light green). Target symbols indicate the median rank of each landscape, triangles indicate the 95 % confidence bounds about each median, the upper and lower bounds of each box are the 75th and 25th percentile bounds of our ranking estimates, and the whiskers span the full range of observed ranks (max to min). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

4. Discussion

The principal goal of this study was to evaluate how native ecosystems are perceived relative to different urban landscape forms (lawns, gardens, GSI), and gain insight regarding the degree to which measures that have been proposed to bring people closer to nature and combat extinction of experience (e.g., native ecosystem conservation, GSI installation or replacement of lawn with native plants) are supported by campus communities. Our results indicate that native ecosystems, lawns, gardens, and GSI are all perceived to provide different groups of services such that no one landscape type can truly replace what is provided by the others (Fig. 4). This finding is consistent with Rippy et al. (2022) (engineering student demographic), as well as other studies addressing landscape perceptions by the general public, many of which reveal strong, consistent perceptions of specific landscape types (Nassauer, 1993, 1995a; Özgüner and Kendle, 2006; Nassauer et al., 2009; Kurz and Baudains, 2012; Kendal et al., 2012; Peterson et al., 2012; Bertram and Rehdanz, 2015; Avolio et al., 2020).

Landscape perceptions on university campuses were generally comparable to those of other post-secondary educated demographics, which tend to favor biodiverse, drought tolerant, native plantings more (and manicured landscapes less) than the general public (Kendal et al., 2012; Suppakittpaisarn et al., 2019). This suggests that campus communities may be more supportive of land transformations that augment native greenspace than society writ-large, making universities a logical environment for trialing and testing environment-side approaches for combatting extinction of experience. Subsequent sections of this discussion focus on the specific kinds of land transformations campus communities supported most and what they might imply for future efforts to reconnect people with nature on university campuses.

4.1. Support for native ecosystem conservation

Affinity for coastal sage scrub was prevalent on Southern California campuses, suggesting that support for its conservation is likely to be high (Fig. 6). This is an important finding given the dramatic loss of coastal sage scrub in California over the past 75 years, which has made it one of the most threatened ecosystems in the state (Taylor, 2005; Mooney and Zavaleta, 2016). Preferences for native chaparral were more variable (Fig. 6b,c), which could reflect limited exposure (chaparral was only present on two of four campuses) or its phenotype, which tends to be bushier and browner than coastal sage scrub, traits that are not typically preferred (Rippy et al., 2021; Kendal et al., 2012; Hoyle et al., 2017; Li and Nassauer, 2020; Nassauer, 1995b). Variable preferences for chaparral suggest that efforts to increase its relative abundance could face perceptual barriers, complicating efforts to combat extinction of experience for this landscape using environment-side approaches alone. Educational programs and policies that encourage affinity and use of chapparal ecosystems are also likely to be needed. This finding is in line with work by Soga and Gaston (2016), who emphasize the importance of complementary socio-environmental approaches for combatting extinction of experience that focus both on nature orientation and opportunities to experience nature.

Support for chapparal was lowest among undergraduate students, consistent with the decline in connection to wild nature observed among teens and young adults in other studies (Barrable and Booth, 2022; Hughes et al., 2019). This suggests that educational programs that provide immersive learning experiences in chaparral ecosystems may be particularly important for combatting extinction of experience on Southern California campuses (e.g., Hartig et al., 2001; Bowler et al., 1999). Education in outdoor nature settings is often associated with gains in nature connection (Hartig et al., 2001; Preston, 2004; Lin et al., 2014; Kleespies and Dierkes, 2023), particularly when programs encourage active engagement with nature (Richardson et al., 2022), facilitate long term or repeated nature exposure (Hatty et al., 2022; Chawla, 2020), and allow students to explore nature at both personal and cultural levels (Kleespies and Dierkes, 2023). The latter requires students to grapple with different cultural perspectives (including local or indigenous people's concepts of nature; Hill et al., 2020) as well as different kinds of human-nature relationships, including those that are relational in content (i.e., where one's relationship to nature is about more than what nature provides in a strict biophysical sense; Chan et al., 2016, 2018). Facilitating this broader, more multidimensional view of our collective connection to nature is something that universities are particularly well suited to provide through interdisciplinary or transdisciplinary courses and cooperative multi-university programs that allow students from different backgrounds to exchange ideas and perspectives about nature (Kleespies and Dierkes, 2023; MRPI, 2018; UCI Water PIRE, 2013).

4.2. Support for turf replacement

Lawns were one of the least preferred landscape types across all respondent groups (Fig. 6), suggesting that campus communities may be particularly open to combatting extinction of experience by reducing lawn cover. This is consistent with present land development practices across all four campuses, where replacing decorative turf with native plants to conserve water resources is a priority (UCI WAP, 2017; UC Sustainable Practices, 2022).

Disaffection with lawns on university campus may reflect their association with relatively few services (most notably recreation, but also aesthetics, consistent with Monteiro, 2017; Fig. 4d). This makes lawns unlikely to emerge as “a most preferred landscape” in a multi-service context where being multifunctional confers added benefit, despite their importance for university sports programs, which are often highly regarded. This of course presumes that the value assigned to services other than aesthetics and recreation is relatively high. This was certainly the case in our study, but is not universally true (see Hayden et al., 2015), reflecting the diverse ways that people feel nature and its services contribute to wellbeing, which include nature's direct contributions to our pleasure or satisfaction (instrumental value) as well as reciprocal relationships with nature that shape our personal and cultural identity (relational value) (Chan et al., 2016).

4.3. Support for iconic exotics

Although turf replacement programs were generally supported on university campuses, exotic garden species like ornamental palms continue to resonate with campus populations. Attempts to combat extinction of experience by replacing them are unlikely to be viewed favorably, particularly by undergraduate students (Fig. 6c). Widespread support for palm trees may reflect their iconicness in Southern California. They were originally imported to evoke a tropical paradise, and (ironically) have taken the place of California natives as symbols of the region (Pataki et al., 2013; McCumber, 2017; Avolio et al., 2020). Support for palms is likely also a reflection of the value respondents assigned to urban cooling in Southern California's warm Mediterranean climate (Manning, 2008) (Fig. 3b). Palms were the only prominent tree in the foreground of evaluated landscape photographs (all other trees were blurred background elements), which may have made palms evoke shade more than other landscape types.

The other ornamental garden (roses) was generally less preferred, despite having bright, colorful flowers, which often have appreciable aesthetic value (Kendal et al., 2012; Hoyle et al., 2017; Rahnema et al., 2019; Rippy et al., 2021). Flowers also attract butterflies, bees, and birds that provide valuable pollination services not factored into the landscape preference rankings evaluated here. Given the present global decline in pollinators and pollination services (Potts et al., 2010), and the importance of pollinators to campus communities (several UC campuses are Bee City certified, underscoring their commitment to bee-friendly landscaping; Bee City USA, 2022, UCI BCC, 2023), this is something that should be revisited. It could elevate flowering greenspace in the landscape preference rankings detailed here (e.g., the rose garden, sage scrub, chaparral and GSI 2, Fig. 1), and impact our assessment of community support for specific land transformations intended to combat extinction of experience that involve these landscape types.

4.4. Uncertainty about GSI

GSI are not viewed as similar enough to native ecosystems at present for GSI exposure to act as a stand-in for native ecosystem exposure (Fig. 5). This finding is consistent with Rippy et al. (2022), where perceptions of GSI and native ecosystems were found to differ among engineering students, but is broader in scope, being evident at the scale of entire campus communities rather than specific student disciplines.

One possible explanation for this mismatch concerns the stage of GSI implementation. GSI are still a relatively new feature of urban California landscapes, which makes people unfamiliar with them and their intended functions, resulting in social norms for their perception that are not well developed (Kim and Tran, 2018; Zuniga-Teran et al., 2020; Suppakittpaisarn et al., 2020; Rippy et al., 2022). This is evident in the centrality of the probability hotspot in Fig. 4b, which suggests people still view GSI relatively neutrally (i.e., not strongly associated with any given service). This situation could change as GSI becomes more mainstream, resulting in more or fewer parallels being drawn between GSI and native ecosystems. Education about GSI and sustainable land development will play an important role in determining this outcome, as an ecologically informed aesthetic is something that is learned (Gobster et al., 2007; Gobster and Westphal, 2004; Nassauer et al., 2001). We must be taught to associate important functions and services with GSI so that the perceptual norms that eventually develop appropriately reflect them (Rippy et al., 2022). In this sense, GSI faces similar challenges to chaparral. Simply increasing its abundance is unlikely to strengthen people's connection to native greenspace. Such efforts must be done in consort with education and use-centered programs that foster appreciation of GSI's natural elements and the services it provides.

4.5. Future research opportunities

People's landscape preferences are relational, reflecting their own personal characteristics (e.g., values, beliefs, culture) as well as specific landscape traits (Chan et al., 2016). This study explores the former more than the latter (i.e., the visual cues that people based their preferences of specific landscapes on remain largely unknown). We can be reasonably confident that elements of photo composition like viewing depth did not influence landscape preferences (the two landscapes with the highest preference rankings also had the most divergent viewing depths). Differences in background infrastructure (e.g., roads versus buildings) also appear to have had minimal influence. The two most and least preferred landscapes variously featured roads and buildings, suggesting they were not differentiated by built infrastructure, but by properties of the greenspace itself. Identifying these properties and if/how they might be leveraged to improve efforts to combat extinction of experience, is an important area for future research. Prior studies of landscape preference provide an excellent starting point for these efforts, highlighting a variety of candidate plant traits (leaf color, plant height, flowers), landscape characteristics (nativeness, biodiversity, vegetation density), and cues to care (orderly rows, clean edges, mowing/pruning) that have been shown to influence landscape preferences in different populations (Kendal et al., 2012; Hoyle et al., 2017; Li and Nassauer, 2020; Suppakittpaisarn et al., 2020; Rippy et al., 2021).

Future research on extinction of experience would also benefit from explicitly considering season, which was not evaluated here. Seasonal variability is often omitted from studies of landscape preferences (Brassley, 1998, Xu et al., 2022), but has been shown to influence visual aesthetic quality when evaluated (Schupbach et al., 2021; Xu et al., 2022; Fry et al., 2009). Most studies of seasonal effects have focused on temperate landscapes, where seasonality is more pronounced (Xu et al., 2022). Less is known about areas with semi-arid or Mediterranean climates where seasonal variability is weaker (for instance, Southern California, where this study was conducted). Characterizing the influence of season on people's landscape perceptions (and openness to combatting extinction of experience) in these climates would fill an important knowledge gap.

A final point worth considering with respect to extinction of experience, is the role perceived vs measured services should play in evaluating approaches intended to combat it. This study focused on perceived services and their stated value, which captures what people think they want, but is not necessarily the same as what they actually want because perceptions and reality do not always align. Perception-reality mismatches pose challenges for extinction of experience because people tend to be loss-averse (i.e., land transformations intended to combat extinction of experience that do not live up to people's expectations have the potential to seed disaffection with native greenspace, the opposite of their intended goal) (Kahneman and Tversky, 1979; Soga and Gaston, 2016). Addressing this issue requires increasing community awareness of hard to perceive services (for instance nutrient processing by belowground invertebrate communities; Ge et al., 2019, Mehring and Levin, 2015). In the short term, this might be accomplished by presenting factual information to people at the time landscape preferences are being assessed. In the longer-term, educational programs that teach people to associate key functions and services with specific landscape types are needed, fostering an ecologically informed aesthetic. Both approaches require a deeper understanding of the ecosystem service profiles different landscapes provide. This is particularly true for novel designed landscapes like GSI, where multifunctionality and tradeoffs across services are not as well understood (Keeler et al., 2019; Tran et al., 2020; Kvamsas, 2022; Krauss and Rippy, 2022; Rippy et al., 2022). Further research is needed to help identify and address perception-reality mismatches and improve our capacity to combat extinction of experience in a manner consistent with community preferences.

5. Implications and conclusions

Our findings reveal a high degree of support for native ecosystems on university campuses in Southern California. This bodes well for ongoing conservation efforts in ecological preserves and suggests that affection for wild nature is relatively widespread in campus communities. There was strong support for replacing turf with native plants (reconciliation ecology), as lawns were preferred significantly less than native ecosystems, and there was moderate support for implementation of GSI with native plants (an alternative reconciliation ecology approach). These results suggest that universities have a variety of viable approaches they can use to increase native ecosystem exposure and combat extinction of experience that are consistent with community preferences. Universities are also well equipped to implement the kinds of educational programs/policies needed to encourage native greenspace affinity and use, making them well situated to become agents of change with respect to extinction of experience and to show other communities what's possible.

Although our results could be used to prioritize approaches for combatting extinction of experience (i.e., do this, not that), we caution against this strict interpretation. Campus populations are dynamic, and perspectives may change over time (for instance, as GSI becomes more mainstream), which would make the “best” strategy for combatting extinction of experience mutable. As estimated here, community priorities are also a function of the services being evaluated. This means that the rank of individual landscapes could change if additional services were assessed, making some approaches for combating extinction of experience more/less palatable than they presently appear. Given this, we think our results are better used to distinguish approaches for combatting extinction of experience that are likely to be easy to put into practice from those that are expected to require additional effort to successfully execute. It is not our intent to suggest that approaches with less support should not be implemented. This is particularly true of GSI, which are extremely important for sustainable stormwater management above and beyond their potential utility for combatting extinction of experience.

CRediT authorship contribution statement

K. Fausey: Writing – original draft, Formal analysis, Data curation. **M.A. Rippy:** Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **G. Pierce:** Writing – review & editing, Methodology, Conceptualization. **D. Feldman:** Writing – review & editing, Methodology, Conceptualization. **B. Winfrey:** Writing – review & editing, Methodology. **L.A. Levin:** Writing – review & editing, Funding acquisition. **R. Ambrose:** Writing – review & editing, Funding acquisition. **A.S. Mehring**: Writing – review & editing, Methodology. **P. A. Holden**: Writing – review & editing, Funding acquisition. **P.A. Bowler**: Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Our IRB-approved protocol and corresponding consent form do not allow human subjects data to be shared in non-aggregated forms. As such, aggregate responses to survey questions (medians with 95 % confidence bounds) have been provided in lieu of discrete responses in manuscript tables and figures (see Table 1 and Fig. 3b).

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Appendix A. Supplementary data

Supplemental text, landscape photographs (8), and tables (3) have been provided in Appendix A. Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecoleng.2024.107379.

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