Nature Contact and Adolescent Paper-Reuse Behavior: Place Attachment Versus Climate Anxiety in a Two-Wave Study of Chinese Adolescents

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Abstract

Background: Nature contact is often linked to pro-environmental behavior, but the psychological processes connecting these experiences to later behavior remain unclear. This study examined reusing paper and compared two theoretically distinct pathways: a positive-bonding pathway through place attachment and a threat-mobilization pathway through climate anxiety.

Methods: A two-wave longitudinal study was conducted among 504 Chinese adolescents nested in 15 classrooms. They reported their nature contact during school days, after school, and on weekends, place attachment, climate anxiety, and paper-reuse behavior. Classroom random-intercept models, cluster-adjusted parallel indirect-association models, and exploratory cross-level interaction models were used.

Results: Among the three contexts of nature contact, only weekend nature contact was positively associated with later paper-reuse behavior in the separate-context model ($p = .031$). The indirect association through place attachment was positive, whereas the corresponding estimate through climate anxiety was not significant. Continuous classroom friendship reciprocity did not reliably moderate the focal associations.

Conclusions: For adolescents, weekend nature contact was associated with later paper-reuse behavior and are consistent with an indirect-association account involving place attachment. Future research could further validate the underlying mechanisms involved.

Keywords: nature contact; place attachment; climate anxiety; paper-reuse behavior; adolescents; longitudinal study

1. Introduction

Climate change and biodiversity loss have been identified as defining challenges of the twenty-first century, and international policy frameworks position children and adolescents as critical agents of long-term ecological transformation (Calvin et al., 2023; United Nations, 2015). Against this backdrop, adolescence has emerged as a critical window for shaping lifelong environmental engagement (Chawla, 2020; Wells & Lekies, 2006). Young people today face accelerating climate change, biodiversity loss, and rapid urbanization, and they will spend most of their adult lives navigating the consequences of these processes (Hickman et al., 2021). At the same time, the everyday opportunities through which young people encounter the natural world have diminished, a trend Soga and Gaston (2016) describe as the *extinction of experience*. Formal schooling occupies a substantial share of adolescents' daily time, opportunities to spend unstructured time outdoors are limited and unevenly distributed across the week (Engemann et al., 2019; Vanaken & Danckaerts, 2018).

A growing public health and education agenda therefore asks how relatively small amounts of contact with nature might translate into durable habits that benefit the environment (Larson et al., 2015; Steg & Vlek, 2009). While recent meta-analytic evidence supports an overall positive association between nature contact, connectedness to nature, and pro-environmental behavior (Whitburn et al., 2020), the psychological mechanisms underlying this association remain contested. Two influential, but theoretically distinct, accounts coexist in the literature: a positive-bonding account anchored in place-attachment theory, and a threat-mobilization account anchored in protection motivation theory (Maddux & Rogers, 1983; Scannell & Gifford, 2010). These accounts make different predictions about the affect that drives behavior, the kinds of interventions most likely to work, and the developmental

processes most relevant to adolescents. They have, however, rarely been pitted against one another within a single empirical model, particularly in non-Western adolescent samples (Daryanto & Song, 2021; Henrich et al., 2010; Jarrett et al., 2024). The present study takes up this gap. Using a two-wave longitudinal design with Chinese adolescents, it compares the two pathways and examines whether the type of nature-contact context (during school, after school, on weekends) shapes the strength of the association.

2. Literature Review

2.1 Nature Contact and Pro-environmental Behavior in Adolescence

Pro-environmental behavior (PEB) is most commonly defined as behavior that harms the environment as little as possible, or even benefits it (Lange, 2024; Steg & Vlek, 2009). For adolescents, such behavior is largely confined to the private sphere rather than the public-sphere activism more typical of adults (Lange & Dewitte, 2019; Larson et al., 2015). These everyday actions are nonetheless important: they are the building blocks of lifelong sustainable habits and the most accessible behavioral outcomes for adolescents who have limited financial and political agency (Collado et al., 2019; van de Wetering et al., 2022). Pro-environmental behavior is multidimensional, spanning private-sphere conservation, consumption, mobility, civic action, and other domains (Lange, 2024; Lange & Dewitte, 2019; Larson et al., 2015). The present manuscript refers to paper-reuse behavior because paper reuse is a concrete resource-conservation behavior available to adolescents without parents (Denault et al., 2024; Van De Wetering et al., 2025), but associations with this behavior cannot automatically be generalized to other environmental actions.

Decades of cross-sectional and retrospective research suggest that direct experiences with nature during childhood and adolescence are reliably associated with

environmental concern and behavior later in life (Chawla, 2020; Rosa et al., 2018; Wells & Lekies, 2006). Whitburn et al.'s (2020) meta-analysis of 37 studies reported a moderate positive correlation between connection to nature and PEB, an estimate later corroborated in systematic reviews on Chinese, European, and Latin American samples. Yet the bulk of this evidence comes from adult or retrospective designs, and most studies measure nature contact globally rather than distinguishing the contexts in which it occurs (Yan et al., 2025).

Recent work increasingly treats nature contact as a contextually heterogeneous construct, distinguishing among the school-day, after-school, and weekend opportunities through which young people encounter the outdoors (Chawla, 2020; Soga & Gaston, 2016). The distinction matters because the affective texture of each context differs. School-day contact, typically brief and embedded in highly structured routines such as recess, physical education, and transitions between classes, tends to be more structured and institutionally organized than adolescents' self-directed encounters with nature (Liu & Green, 2025; Ramstetter et al., 2010). After-school contact, by contrast, is constrained by homework loads and the spatial limitations of high-density urban neighborhoods, particularly in Chinese urban contexts where academic pressure and compact residential environments restrict children's outdoor activity opportunities (Lu & Van Ameijde, 2025; Morgan & Jan, 2022; W. Wu & Wang, 2025). Weekend contact, by contrast, more often involves longer blocks of time, greater autonomy and visits to richer natural settings such as parks, coastal greenways, and peri-urban areas (Wells & Lekies, 2006). It is plausible, then, that the depth and quality of weekend contact more readily supports the kind of cumulative, emotionally invested engagement that fosters person–place bonds. Empirical evidence indicate that voluntary and self-directed nature experiences correlate more strongly

with environmental engagement than do classroom-based or institutionally mandated experiences (Yan et al., 2025). Recent field evidence also indicates that a green outdoor lesson can improve positive affect and learning-related outcomes, although such findings do not establish effects on later environmental behavior (Mason et al., 2026).

2.2 Place Attachment as the Positive-Bonding Pathway

Scannell and Gifford (2010) proposed a tripartite person–process–place framework in which place attachment comprises affective, cognitive, and behavioral components. Williams and Vaske's (2003) widely used measurement model further distinguished two facets: place identity, reflecting the symbolic and self-defining aspects of a place, and place dependence, reflecting its functional fit with valued activities. Subsequent work has extended this framework to encompass an emotional bond to place (Halpenny, 2010) and integrated it with related constructs such as connectedness to nature (Mayer & Frantz, 2004) and dispositional empathy with nature (Tam, 2013). A central proposition is that recurrent, meaningful interaction with a place produces a sense of belonging and personal investment that, in turn, motivates protective behavior (Lewicka, 2011; Stedman, 2002).

Empirical support for the link between place attachment and PEB is substantial. Daryanto and Song's (2021) meta-analysis of 85 studies estimated a positive average effect, though one moderated by context, culture, and measurement. Mechanistic studies in protected-area, urban, and community settings have repeatedly identified place attachment as a mediator linking environmental attitudes or experiences to behavior (Halpenny, 2010; Ramkissoon et al., 2012; Yoon et al., 2024). Recent Chinese research extends these findings to gateway communities of national parks and to urban residents (Chang et al., 2026; Xie & Wang, 2024). The mechanism aligns

naturally with developmental accounts of adolescence, a period in which identity formation and the construction of self-meaningful environments are central tasks (Lewicka, 2011). For Chinese urban adolescents whose daily geography is anchored in their home city, attachment to that city is likely to be the proximate affective product of repeated nature contact, and the most plausible psychological route through which such contact translates into behavior. Earlier environmental-education research likewise showed that attachment to a local natural resource was associated with environmentally responsible behavior in everyday life, with place identity playing a particularly important role (Vaske & Kobrin, 2001). This evidence supports the proposed bonding account while also indicating that place attachment may relate to both place-specific protection and broader daily conservation.

2.3 Climate Anxiety as the Threat Pathway

A contrasting account holds that nature contact promotes PEB by making the consequences of environmental change more concrete and emotionally salient, thereby raising threat appraisals and energizing action. Climate anxiety defined as persistent, distressing concern about anthropogenic climate change and its consequences (Clayton & Karazsia, 2020; Pihkala, 2020) is the most studied affective response in this domain. Large-scale surveys have documented its widespread presence among young people internationally (Hickman et al., 2021).

The theoretical link from climate anxiety to behavior is most often framed using protection motivation theory (Maddux & Rogers, 1983; Rogers, 1975), originally developed to explain health-protective behavior but increasingly applied to environmental contexts (Bockarjova & Steg, 2014; Kothe et al., 2019). The theory posits that threat appraisal (perceived severity and personal relevance) and coping appraisal (perceived efficacy of available responses) jointly produce protection

motivation. Climate anxiety can be understood as one component of the affective dimension of threat appraisal. Van Valkengoed and Steg's (2019) meta-analysis of 106 studies on climate-adaptation behavior identified negative affect as one of the strongest correlates of adaptation, alongside descriptive norms and efficacy beliefs. Ogunbode et al.'s (2022) 32-country survey similarly found that climate anxiety was positively associated with pro-environmental action in most countries surveyed, though the strength of the association varied substantially.

Yet the evidence is far from uniform. A growing body of work indicates that the climate-anxiety–behavior link is unstable across studies, populations, and operationalizations. Some studies report null or even negative associations (Hogg et al., 2024; Kühner et al., 2024), and reviews note that very high levels of climate anxiety may produce *eco-paralysis* rather than mobilization, particularly when accompanied by low coping efficacy (Brophy et al., 2023; Léger-Goodes et al., 2022; Pihkala, 2020). Ojala's (2012) work on adolescent coping suggests that meaning-focused strategies, rather than threat-based emotional responses alone, are most reliably associated with sustained environmental engagement. In adolescent samples specifically, climate anxiety is often expressed at low absolute levels, attenuating its potential mobilizing function (Léger-Goodes et al., 2022; Wullenkord et al., 2021). Evidence from Chinese adolescents further underscores this heterogeneity. Qin et al. (2024) reported a negative association between climate anxiety and broader pro-environmental behavior and identified green self-efficacy as an important boundary condition. Together with positive associations reported elsewhere (Becht et al., 2024), these findings suggest that anxiety is unlikely to mobilize action uniformly without attention to efficacy, coping, and behavioral context.

2.4 Classroom Reciprocity as a Contextual Boundary

Adolescent development is densely embedded in peer relationships, and early adolescence is widely regarded as the period during which the salience of peers, the influence of peer norms, and sensitivity to social approval reach a developmental peak (Laursen & Veenstra, 2021). For Chinese students, this developmental pattern intersects with a distinctive institutional context: students typically belong to a single intact class, which they attend together for most subjects across multiple school years. This arrangement makes the classroom one of the most consequential daily social environments for Chinese adolescents, structuring not only academic life but also the formation of friendships, peer norms, and behavioral routines (Shin, 2022). Whether and how this social texture conditions the prospective association between nature contact and paper-reuse behavior is therefore a substantive theoretical question, and one that has rarely been addressed in the adolescent environmental-behavior literature. Recent studies also indicate that configurations of peer and teacher relationships are associated with early adolescent adjustment and that daily social connectedness is related to emotion regulation (Demol et al., 2025; Do et al., 2025).

A long tradition in peer-relations research treats friendship reciprocity as the defining feature of close peer relationships. In Hartup's (1996) influential framework, reciprocity and commitment are the essentials of friendship. Empirically, reciprocated friendships are characterized by greater interaction frequency, closer emotional bonds, higher friendship quality, and greater stability over time (Linden-Andersen et al., 2009). Classrooms with higher reciprocity tend to contain a dense web of mutual ties, in which most students belong to stable friend dyads; classrooms with lower reciprocity tend to feature more asymmetric, aspirational, or fragmented social structures (Shin, 2022). Mutually invested friendships are precisely the relationships through which descriptive and injunctive peer norms are most effectively transmitted

(Bergquist et al., 2023; Bicchieri & Dimant, 2022; Collado et al., 2019). In high-reciprocity classrooms, any tendency for adolescents to translate nature-based affective bonds into behavior could be amplified by peer reinforcement and shared expectations. Directly relevant school-based environmental research also shows that recycling and littering behavior can change across friendship networks and alongside perceived norms and encouragement (Long et al., 2014). Thus, classroom reciprocity was examined as one structural condition that might facilitate norm transmission, not as a direct measure of environmental norms themselves.

2.5 The Present Study

Building on the foregoing literature, the two accounts (place attachment and climate anxiety) generate competing predictions about the affective processes that may be associated with nature contact and behavior. The positive-bonding account predicts that the relevant affect is hospitable, identity-supportive, and tied to a specific local place. The threat-mobilization account predicts that the relevant affect is aversive, future-oriented, and tied to a global hazard. The two pathways imply different intervention strategies: the former emphasizes the cultivation of meaningful local nature experiences, the latter emphasizes risk communication paired with efficacy training. Despite the theoretical importance of distinguishing them, the two accounts have rarely been examined as parallel indirect pathways within the same model. Most prior studies have tested one mediator at a time, examined adult populations, or used cross-sectional designs that conflate within- and between-person variation (Daryanto & Song, 2021; Whitburn et al., 2020).

The present study makes three contributions. First, it tests, within a single two-wave model, whether place attachment and climate anxiety form parallel indirect associations between nature contact and paper-reuse behavior in Chinese adolescents.

Second, it disaggregates nature contact by context (school-day, after-school, weekend) to examine whether the association is uniform or context-specific. Third, it examines whether continuous classroom-level friendship reciprocity moderates the focal associations. Figure 1 illustrates the theoretical model of this study. The following hypotheses guide the analyses:

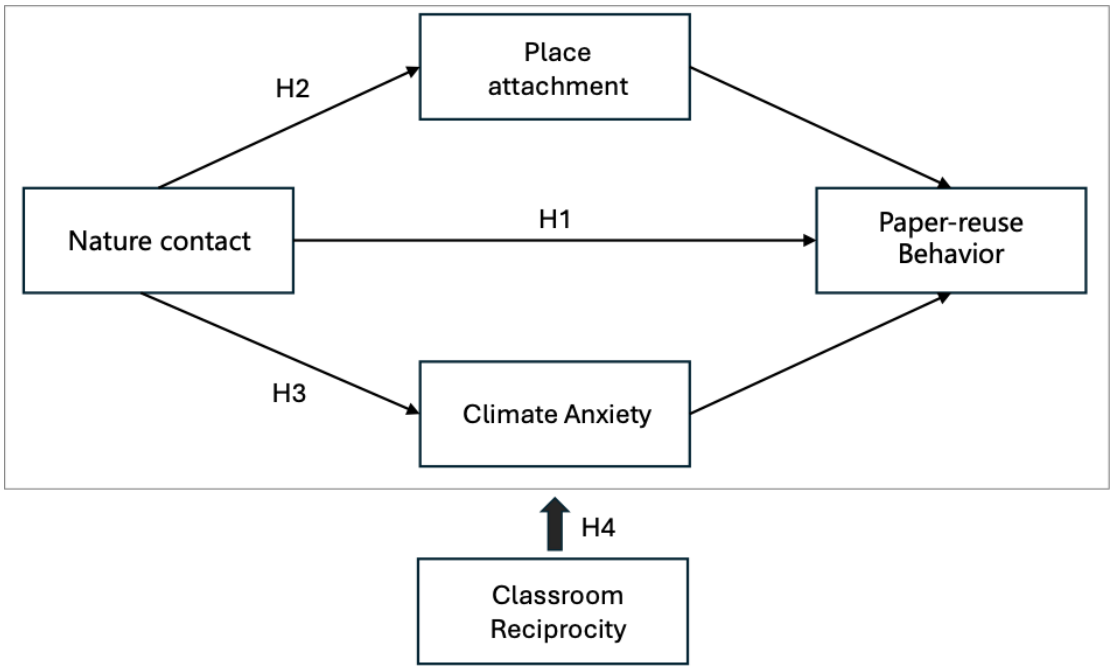
H1: Nature contact during each of the three contexts (school-day, after-school, weekend) is positively associated with later paper-reuse behavior.

H2: Nature contact shows a positive indirect association with later paper-reuse behavior through place attachment.

H3: Nature contact shows a positive indirect association with later paper-reuse behavior through climate anxiety.

H4: Classroom friendship reciprocity moderates the focal associations.

Figure 1. Theoretical Model.



3. Method

3.1 Participants

Data were collected at two time points administered during regular school hours, with Wave 1 (T1) conducted in September 2025 and Wave 2 (T2) approximately seven months later in April 2026. From the initial pool of responses, 69 questionnaires were excluded due to substantial missingness on key study variables, and an additional 56 cases were excluded because participants did not complete both waves of data collection. The final analytic sample comprised 504 middle-school students (273 boys, 54.2%; 231 girls, 45.8%) attending a public middle school in Dalian, a coastal city in northeast China. Participants ranged in age from 11 to 15 years ($M = 12.85$, $SD = 0.68$) and were distributed across 15 intact classrooms with class sizes ranging from 27 to 40 students ($M = 33.6$). The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Nanjing University (No. NJUPSY202509004). Informed consent was obtained from participants and their legal guardians before participation.

3.2 Measurement

Nature contact. No widely adopted standardized instrument currently exists for assessing adolescents' day-to-day contact with nature, and the field continues to rely on context-specific self-report items rather than a single canonical scale (Liu & Green, 2025). Following this measurement tradition, three single items at T1 assessed how much time, on a typical day in each context, students actively spent in outdoor green environments. The items referred to school-day periods, after-school periods, and weekend days. Each item used a 5-point response scale: 1 = less than 15 minutes, 2 = 15–30 minutes, 3 = 31–60 minutes, 4 = 1–2 hours, 5 = more than 2 hours. Because the substantive interest of the study lies in distinguishing among contexts, the

three items were analyzed separately as predictors rather than aggregated into a composite. Because each context is represented by a single item, internal consistency cannot be estimated, and measurement error may attenuate the observed associations. The items also do not capture environmental quality, activity type, companions, or autonomy (Diamantopoulos et al., 2012).

Place attachment. At T2, place attachment was assessed using the Abbreviated Place Attachment Scale (APAS; Boley et al., 2021), a six-item measure developed and cross-culturally validated to capture place identity and place dependence with three items per facet. Sample items included "I am very attached to this city" and "This city is very special to me," with the target place specified as the city in which participants currently lived. Items were rated on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The scale showed acceptable reliability and structural validity in the present sample ($\alpha = .89$, $\omega = .90$; CFI = .953; TLI = .921; SRMR = .038).

Climate anxiety. At T2, climate anxiety was measured using the Climate Change Anxiety Scale – Short-Form (CCAS-S; Wu et al., 2023), a four-item adolescent-appropriate adaptation of Clayton and Karazsia's (2020) original Climate Change Anxiety Scale, developed in consultation with young people and therefore better suited to the developmental level of the present sample. The items assess the cognitive-emotional and functional impairment associated with climate-related distress (e.g., "I find myself crying because of climate change"; "My concerns about climate change interfere with my ability to get work or school assignments done"). Items were rated on a 5-point frequency scale ranging from 1 (never) to 5 (always or almost always). The scale showed acceptable reliability and structural validity in the present sample ($\alpha = .88$, $\omega = .89$; CFI = .998; TLI = .995; SRMR = .008).

Paper-reuse behavior. Given that the present sample comprised middle-school students whose daily activities are concentrated in home and classroom settings, and following the operational approach used in prior adolescent and school-based studies in similar contexts (Jia & Yu, 2021; Long et al., 2014), the present study focused on paper-saving behavior, a behaviorally specific and ecologically valid activity that adolescents can autonomously perform across both home and school settings (Kollmuss & Agyeman, 2002; Larson et al., 2015). Paper-reuse behavior was assessed at both T1 and T2 using two parallel items: "At home, I keep and reuse paper that still has a blank side" and "In class, I keep and reuse paper that still has a blank side." Items were rated on a 5-point frequency scale ranging from 1 (never) to 5 (always or almost always). Internal consistency was acceptable at both waves (T1: $\alpha = .86$, $\omega = .86$; T2: $\alpha = .83$, $\omega = .83$). These coefficients indicate inter-item covariance rather than adequate content coverage of multidimensional PEB; the outcome is therefore interpreted only as paper-reuse behavior in home and classroom settings.

Classroom friendship reciprocity. At T1, each student nominated up to three closest friends in their class. Friendship reciprocity was computed at the classroom level using social-network analysis: for each classroom, a directed graph was constructed in which a tie pointed from the nominator to the nominee, and the reciprocity rate was calculated as the proportion of directed ties for which the reverse tie was also present. Intuitively, this index captures how often, in a given classroom, friendship nominations were mutual rather than one-sided; higher values indicate more cohesive, mutually invested peer networks. Classroom reciprocity rates ranged from .24 to .62 ($M = 0.48$, $SD = 0.10$; median = 0.50). Reciprocity was standardized across the 15 classrooms and analyzed as a continuous variable. This avoided the information loss and arbitrary cut point created by dichotomization (MacCallum et al.,

2002). Because only 15 classrooms were available, moderation tests were treated as exploratory.

Covariates. Gender (0 = boy, 1 = girl), age in years, and T1 paper-reuse behavior were entered as covariates in all models. Including T1 behavior provided an autoregressive control for baseline differences (Cole & Maxwell, 2003).

3.3 Statistical Analysis

First, descriptive statistics, distributional indices, and classroom intraclass correlations (ICCs) were calculated for all key variables. To test whether nature contact in any of the three contexts was associated with T2 paper-reuse behavior (H1), linear mixed-effects models with a classroom random intercept were estimated; the three context variables were entered separately and then simultaneously. Second, to estimate H2 and H3, a parallel path model with robust maximum likelihood and standard errors adjusted for classroom clustering was fitted, with place attachment and climate anxiety entered simultaneously. Because both mediators and the outcome were measured at T2, these estimates are described as indirect associations. Last, H4 was examined using continuous standardized classroom reciprocity in exploratory cross-level interaction models that retained a classroom random intercept.

Analyses were performed using the bruceR, lme4, lmerTest, lavaan, and igraph R packages (Bao, 2024; Bates et al., 2015; Csárdi & Nepusz, 2006; Kuznetsova et al., 2017; Rosseel, 2012). All continuous student-level predictors were grand-mean centered. Unstandardized and standardized coefficients, standard errors, 95% confidence intervals, and p values are reported. Bootstrap resampling used 5,000 replications. The small number of classrooms limits the precision of cross-level interaction estimates (McNeish & Stapleton, 2016).

4. Result

Descriptive statistics and classroom intraclass correlations (ICCs) are reported in Table 1. Climate anxiety was low on average and positively skewed (M = 1.74, SD = 0.85, skewness = 1.17, kurtosis = 0.92), indicating restricted information at the upper end of the scale. ICCs for the focal student-level variables ranged from .000 to .021. Although these ICCs were small, the nested design was retained in all primary analyses.

Table 1. Descriptive statistics and classroom intraclass correlations.

Variable	M	SD	Median	Range	Skew	Kurtosis	ICC
Age	12.85	0.68	13.00	11–15	0.11	-0.24	.409
Gender (girl = 1)	0.46	0.50	0.00	0–1	0.17	-1.98	.000
School-day nature contact	2.07	1.09	2.00	1–5	0.77	-0.20	.021
After-school nature contact	1.90	1.12	2.00	1–5	1.23	0.69	.011
Weekend nature contact	2.62	1.43	2.00	1–5	0.34	-1.25	.000
T1 paper reuse	3.27	1.35	3.00	1–5	-0.24	-1.12	.007
T2 place attachment	3.46	0.84	3.33	1–5	-0.06	0.11	.000
T2 climate anxiety	1.74	0.85	1.50	1–5	1.17	0.92	.008
T2 paper reuse	3.36	1.33	3.50	1–5	-0.33	-1.06	.009
Classroom reciprocity	0.48	0.11	0.50	.24–.62	-0.82	-0.48	—

Note. N = 504 students in 15 classrooms. Reciprocity is a classroom-level variable, so an ICC is not applicable. Nature-contact response categories represent increasing time ranges rather than equal-duration units.

Zero-order correlations are reported in Table 2. The three nature contact conditions were moderately intercorrelated (rs between .42 and .56, all ps < .001). T1 paper-reuse behavior strongly predicted T2 paper-reuse behavior (r = .40, p < .001), consistent with the substantial stability of this behavior and motivating the inclusion of T1 behavior as an autoregressive control. Among the three nature-contact items, only weekend contact correlated significantly with T2 paper-reuse behavior (r = .12, p = .008) and most strongly with T2 place attachment (r = .17, p < .001). Place

attachment was positively associated with T2 paper-reuse behavior (r = .31, p < .001), whereas climate anxiety was not (r = -.03, p = .500).

Table 2. Correlation Matrix.

Variable	1	2	3	4	5	6	7	8	9
1. Age	—								
2. Gender	–.09*	—							
3. NC_schoolday	.08	–.01	—						
4. NC_afterschool	.05	–.12**	.43***	—					
5. NC_weekend	.06	–.07	.42***	.56***	—				
6. T1_PRB	–.03	.12**	.04	.03	.11*	—			
7. T2_PA	–.02	–.12**	.05	.10*	.17***	.15***	—		
8. T2_CA	.11*	–.07	.05	.06	.08	–.01	.03	—	
9. T2_PRB	–.16***	.11*	–.01	.06	.12**	.40***	.31***	–.03	—
10. T1_CFR	.02	.02	.09	.07	.06	–.00	.04	–.03	.02

Note. * $p < .05$. ** $p < .01$. *** $p < .001$. NC, Nature contact; PRB, paper-reuse behavior; PA, Place attachment; CA, Climate anxiety; CFR, Classroom friendship reciprocity; Gender coded 0 = boy, 1 = girl.

Random-intercept analyses examined whether T1 nature contact was associated with T2 paper-reuse behavior (Table 3; Table S1 provides the standardised regression coefficients). Across separate models for each context, only weekend nature contact showed a statistically significant positive association (b = 0.082, 95% CI [0.008, 0.156], β = 0.088, p = .031). When all three contact items were entered simultaneously, the weekend coefficient was similar in magnitude (b = 0.087; β = 0.094), but its standard error increased from 0.038 to 0.047 and the confidence interval included zero (95% CI [-0.005, 0.179], p = .063). This is not a reversal in effect size: because the three context variables were correlated, the simultaneous model estimated unique context-specific variance and therefore reduced precision. H1 was supported for weekend contact in the separate-context model only. Subsequent

indirect-association and moderation analyses focused on weekend contact.

Table 3. Random-intercept models for T2 paper-reuse behavior

	(1) T2_PRB	(2) T2_PRB	(3) T2_PRB	(4) T2_PRB
(Intercept)	3.298***	3.288***	3.289***	3.283***
	(0.073)	(0.073)	(0.073)	(0.073)
NC_schoolday	–0.016			–0.085
	(0.049)			(0.056)
NC_afterschool		0.076		0.050
		(0.048)		(0.060)
NC_weekend			0.082*	0.087
			(0.038)	(0.047)
Gender (girl)	0.127	0.148	0.146	0.159
	(0.109)	(0.109)	(0.109)	(0.109)
Age	–0.286***	–0.292***	–0.297***	–0.289***
	(0.080)	(0.079)	(0.079)	(0.079)
T1_PRB	0.390***	0.386***	0.379***	0.379***
	(0.040)	(0.040)	(0.040)	(0.040)
Marginal R^2	0.188	0.192	0.195	0.199
Conditional R^2	0.188	0.192	0.195	0.199
AIC	1645.247	1642.931	1641.219	1650.487
BIC	1674.805	1672.489	1670.777	1688.491
Num. obs.	504	504	504	504
Num. groups: class_id	15	15	15	15
Var: class_id (Intercept)	0.000	0.000	0.000	0.000
Var: Residual	1.450	1.443	1.437	1.436

Note. Unstandardized regression coefficients are displayed, with standard errors in parentheses. * $p < .05$. ** $p < .01$. *** $p < .001$. NC, Nature contact; PRB, paper-reuse behavior.

The parallel path model simultaneously estimated indirect associations of weekend nature contact through T2 place attachment and T2 climate anxiety with T2 paper-reuse behavior (Table 4; Table S2 provides the standardised regression coefficients). Weekend nature contact was positively associated with place attachment (b = 0.087, 95% CI [0.026, 0.147], β = 0.147), whereas its association with climate anxiety was imprecise (b = 0.040, 95% CI [-0.017, 0.097], β = 0.067). Place attachment was positively associated with paper reuse after adjustment for the other variables (b = 0.411, 95% CI [0.274, 0.548], β = 0.259); the climate-anxiety

coefficient was close to zero (b = -0.026, 95% CI [-0.139, 0.087], β = -0.017). The indirect association through place attachment was positive (b = 0.036, 95% CI [0.009, 0.062], β = 0.038), whereas the indirect estimate through climate anxiety included zero (b = -0.001, 95% CI [-0.006, 0.004], β = -0.001). H2 was supported at the level of statistical indirect association; H3 was not supported. Because the mediators and outcome were measured concurrently at T2, the contrast between the estimates cannot establish that one causal mechanism is superior.

Table 4. Regression models of parallel multiple mediation.

	(1) T2_PA	**(2) T2_CA**	**(3) T2_PRB**	**(4) T2_PRB**
(Intercept)	3.555***	1.786***	3.289***	3.250***
	(0.051)	(0.052)	(0.073)	(0.071)
Gender (girl)	–0.214**	–0.092	0.146	0.232*
	(0.074)	(0.077)	(0.109)	(0.106)
Age	–0.041	0.132*	–0.297***	–0.276***
	(0.055)	(0.056)	(0.079)	(0.077)
T1_PRB	0.094***	–0.005	0.379***	0.340***
	(0.027)	(0.028)	(0.040)	(0.039)
NC_weekend	0.086***	0.040	0.082*	0.047
	(0.026)	(0.027)	(0.038)	(0.037)
T2_PA				0.411***
				(0.063)
T2_CA				–0.026
				(0.061)
Marginal R^2	0.064	0.021	0.195	0.257
Conditional R^2	0.066	0.021	0.195	0.257
AIC	1257.312	1293.412	1641.219	1611.940
BIC	1286.870	1322.970	1670.777	1649.943
Num. obs.	504	504	504	504
Num. groups: class_id	15	15	15	15
Var: class_id (Intercept)	0.002	0.000	0.000	0.000
Var: Residual	0.664	0.716	1.437	1.330

Note. Unstandardized regression coefficients are displayed, with standard errors in parentheses. * $p < .05$. ** $p < .01$. *** $p < .001$. NC, Nature contact; PRB, paper-

reuse behavior; PA, Place attachment; CA, Climate anxiety.

Classroom friendship reciprocity was examined as a continuous standardized moderator (Table 5). None of the interaction confidence intervals excluded zero. The weekend-contact-by-reciprocity interaction in the paper-reuse model was positive but imprecise (b = 0.076, 95% CI [-0.002, 0.154]). With only 15 classrooms, these estimates do not provide reliable evidence either for or against moderation; H4 was not supported, but the test should be regarded as exploratory.

Table 5. Classroom-reciprocity moderation models.

	(1) T2_PA	**(2) T2_CA**	**(3) T2_PRB**
(Intercept)	3.560***	1.784***	3.241***
	(0.052)	(0.052)	(0.071)
NC_weekend	0.088***	0.040	0.041
	(0.026)	(0.027)	(0.037)
Reciprocity	0.028	–0.032	0.015
	(0.041)	(0.040)	(0.055)
Gender (girl)	–0.220**	–0.089	0.241*
	(0.074)	(0.077)	(0.106)
Age	–0.041	0.133*	–0.276***
	(0.055)	(0.056)	(0.077)
T1_PRB	0.093***	–0.005	0.344***
	(0.027)	(0.028)	(0.039)
NC_weekend * Reciprocity	–0.040	0.011	0.076
	(0.027)	(0.028)	(0.040)
T2_PA			0.419***
			(0.063)
T2_CA			–0.025
			(0.061)
T2_PA * Reciprocity			0.011
			(0.062)
T2_CA * Reciprocity			0.067
			(0.061)
Marginal R^2	0.069	0.022	0.264
Conditional R^2	0.073	0.022	0.264
AIC	1268.447	1306.454	1630.264
BIC	1306.450	1344.457	1685.157
Num. obs.	504	504	504
Num. groups: class_id	15	15	15
Var: class_id (Intercept)	0.003	0.000	0.000

	(1) T2_PA	(2) T2_CA	(3) T2_PRB
Var: Residual	0.662	0.717	1.325

Note. Unstandardized regression coefficients are displayed, with standard errors in parentheses.* $p < .05$. ** $p < .01$. *** $p < .001$. NC, Nature contact; PRB, paper-reuse behavior; PA, Place attachment; CA, Climate anxiety.

5. Discussion

The present study used a two-wave longitudinal design with Chinese adolescents to compare two psychological pathways that have been theorized to link nature contact with environmentally relevant behavior: a positive-bonding pathway anchored in place-attachment theory and a threat-mobilization pathway anchored in protection motivation theory. First, weekend nature contact showed a small positive association with later paper-reuse behavior in the separate-context model; its coefficient remained similar but less precise when all contexts were entered together. Second, the observed pattern was consistent with a positive indirect association through place attachment, whereas the climate-anxiety indirect estimate included zero. Third, continuous classroom friendship reciprocity did not reliably moderate the focal associations, although the small number of classrooms limits this conclusion.

The finding that weekend nature contact was associated with later paper-reuse behavior in the separate-context model reframes the often-undifferentiated claim that nature exposure promotes environmentalism. The result is consistent with arguments by Chawla (2020) and Wells and Lekies (2006) that the quality, autonomy, and duration of nature experience matter at least as much as its sheer frequency. School-day contact in Chinese middle schools is necessarily brief, structured, and instrumental. Weekends, by contrast, more readily afford longer blocks of time and greater autonomy, and access to richer natural settings such as coastal greenways and

parks. These conditions resemble what Soga and Gaston (2016) describe as the kinds of experience most conducive to the formation of meaningful, lasting person–nature bonds. The pattern observed here suggests that weekend contexts merit attention in future environmental-education research. This context-specific pattern is also compatible with evidence that incidental, intentional, and indirect forms of nature contact are not interchangeable in their associations with sustainability outcomes (Martin et al., 2020). However, the nature-contact items measured time categories only; they did not assess autonomy, activity, companions, or environmental quality, and the simultaneous-context estimate was imprecise. These features should therefore be tested directly rather than assumed as mechanisms.

The central theoretical contribution of the study lies in directly comparing the two proposed indirect pathways within the same model. Whereas previous research has examined each pathway in isolation place attachment in tourism, recreation, and community contexts (Daryanto & Song, 2021; Halpenny, 2010; Ramkissoon et al., 2012) and climate anxiety in cross-national surveys of young people (Hickman et al., 2021; Ogunbode et al., 2022), few studies have asked how the two estimates appear when modeled simultaneously. The present findings were consistent with a positive indirect association through place attachment: weekend nature contact was associated with stronger attachment to the home city, which was concurrently associated with greater paper reuse. The indirect estimate through climate anxiety included zero. Because place attachment, climate anxiety, and the outcome were measured concurrently, these findings do not establish mediation or show that one causal mechanism is superior.

This pattern aligns with several converging lines of evidence. First, place-attachment theory holds that recurrent, meaningful interaction with a place produces

an identity-relevant, behaviorally motivating bond (Lewicka, 2011; Scannell & Gifford, 2010; Stedman, 2002). Environmental-psychology and environmental-education studies have linked place identity and place attachment with both everyday environmentally responsible behavior and protection in specific settings (Halpenny, 2010; Vaske & Kobrin, 2001). One possible interpretation is that weekend contexts may provide more opportunities for repeated or self-directed encounters that become integrated into adolescents' sense of the home city. However, autonomy and experience quality were not measured and should not be treated as established mechanisms. Second, the developmental logic of early adolescence accords with the positive-bonding pathway. Identity formation, the construction of self-meaningful environments, and an expanding sense of belonging are central tasks of this period (Lewicka, 2011), and place-based affective bonds appear developmentally well suited to integrate these tasks. The present association is consistent with this account, but the design cannot establish that place attachment temporally preceded paper-reuse behavior.

The relative weakness of the climate-anxiety pathway calls for careful interpretation. Climate anxiety has been documented as widely prevalent among young people in cross-national samples (Hickman et al., 2021), but reported levels in the present sample were low ($M = 1.74$, $SD = 0.85$) and positively skewed (skewness = 1.17), which restricted the available range. The theoretical premises of protection motivation theory further suggest that threat appraisal alone may be insufficient to produce protective behavior unless paired with coping appraisal and efficacy (Maddux & Rogers, 1983; van Valkengoed & Steg, 2019). Consistent with this distinction, Ojala (2012) found that problem-focused and meaning-focused coping were more closely tied to young people's environmental engagement than threat-

focused emotion alone. Recent adolescent studies also point in different directions: Becht et al. (2024) reported small positive associations between climate anxiety and pro-environmental behavior, whereas Qin et al. (2024) reported a negative association in a Chinese adolescent sample and highlighted green self-efficacy as a boundary condition. Because the present study did not measure efficacy or coping, the null indirect estimate is best treated as sample-, measurement-, and behavior-specific; it does not establish that climate anxiety is behaviorally unimportant or that the place-attachment account is generally superior.

The moderation analysis did not provide reliable evidence that classroom friendship reciprocity altered the focal associations. Peer-relations and adolescent-development theory has long held that peer norms and social-network properties shape adolescent behavior, including prosocial and environmental behavior (Collado et al., 2019; Laursen & Veenstra, 2021). School-based environmental research provides a more proximal rationale: recycling and littering behavior changed across a high-school social network alongside perceived norms and encouragement (Long et al., 2014). Recent evidence also links relationship profiles and daily social connectedness with adolescent adjustment and emotion regulation (Demol et al., 2025; Do et al., 2025). However, reciprocity captures only the mutuality of classroom ties; it does not measure whether those ties carry pro-environmental norms, behavioral modeling, or teacher-supported expectations. All interaction confidence intervals included zero, and with only 15 classrooms the estimates were imprecise. The result should therefore be read as an inconclusive test of this specific network property rather than evidence that classroom social context is unimportant. Future studies should include more classrooms and direct measures of environmental norms, friendship quality, and teacher support.

5.1 Implications

The pattern of findings has implications for environmental-education policy and practice in Chinese schools and international contexts, but those implications should remain behavior-specific and non-causal. First, the null unique coefficient for school-day contact does not show that green school environments are ineffective; such settings may influence affect, learning, or connectedness without producing a detectable association with the paper-reuse outcome measured here (Mason et al., 2026). Weekend, family, and community settings could be evaluated as complements to school activities rather than presumed to be more effective. Second, place-based, identity-supportive content may be worth testing, but the current data do not establish intervention effects. Such interventions should preserve meaningful choice rather than assume that exposure alone is sufficient, consistent with evidence that developmentally salient autonomy motives can influence adolescents' environmental engagement (Van De Wetering et al., 2025). Third, although the climate-anxiety indirect estimate included zero in this sample, climate emotions remain a significant aspect of adolescent mental health (Hickman et al., 2021), and educational practice should attend to them with care, supporting hope, efficacy, and feasible action rather than threat amplification alone (Brophy et al., 2023; Pihkala, 2020).

5.2 Limitations and Future Directions

Several limitations qualify these conclusions. First, place attachment, climate anxiety, and paper-reuse behavior were measured concurrently at T2, which limits inferences about the temporal precedence of the mediator–outcome relations; the indirect estimates therefore cannot establish temporal mediation or causality (Cole & Maxwell, 2003; Maxwell et al., 2011). Future research using three or more waves and baseline measures of the mediators would more rigorously separate temporal

ordering. Second, the behavioral outcome comprised two closely related paper-reuse items. Their internal consistency reflects inter-item covariance rather than adequate coverage of multidimensional PEB, and the findings cannot be generalized to energy conservation, consumption, transportation, activism, or other public-sphere behavior. Third, each nature-contact context was measured with a single item, so reliability cannot be estimated and measurement error may attenuate coefficients; the items also did not capture environmental quality, activity, companions, or autonomy (Diamantopoulos et al., 2012). Fourth, climate anxiety was low and positively skewed, which may have reduced power and limits generalization to adolescents with moderate or high climate distress. Fifth, the 15-classroom design limits precision for cross-level interactions despite the use of random-intercept and cluster-adjusted models (McNeish & Stapleton, 2016). Sixth, all measures were self-reported; future work would benefit from behavioral observations or school records of paper reuse. Last, the sample was drawn from a single middle school in one Chinese coastal city, so replication is required across other geographic and school contexts.

6. Conclusion

Drawing on a two-wave longitudinal study of Chinese middle-school students, this work examined two proposed indirect pathways in the prospective association between nature contact and paper-reuse behavior. Weekend nature contact showed a small positive association with later paper reuse in the separate-context model, while the simultaneous-context estimate was similar but less precise. The pattern was consistent with a positive indirect association through place attachment, but the concurrent measurement of the mediators and outcome precludes temporal-mediation claims. The climate-anxiety indirect estimate included zero in a sample with low, positively skewed anxiety. The findings are limited to paper-reuse behavior and

584 support further longitudinal, multilevel, and behaviorally comprehensive research

585 rather than broad causal or intervention conclusions.

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Table S1. Random-intercept models for T2 paper-reuse behavior with standardized regression coefficients

	School day	After school	Weekend	All contexts
NC_schoolday	–.013			–.070
	(.040)			(.046)
NC_afterschool		.064		.042
		(.041)		(.051)
NC_weekend			.088*	.094
			(.041)	(.050)
Gender (girl)	.047	.055	.055	.060
	(.041)	(.041)	(.041)	(.041)
Age	–.145***	–.149***	–.151***	–.147***
	(.041)	(.040)	(.040)	(.040)
T1_PRB	.395***	.392***	.384***	.385***
	(.041)	(.041)	(.041)	(.041)
Marginal R^2	0.188	0.192	0.195	0.199
Conditional R^2	0.188	0.192	0.195	0.199
AIC	1645.247	1642.931	1641.219	1650.487
BIC	1674.805	1672.489	1670.777	1688.491
Num. obs.	504	504	504	504
Num. groups: class_id	15	15	15	15
Var: class_id (Intercept)	0.000	0.000	0.000	0.000
Var: Residual	1.450	1.443	1.437	1.436

Note. Standardized regression coefficients are displayed, with standard errors in parentheses. * $p < .05$. ** $p < .01$. *** $p < .001$. NC, Nature contact; PRB, paper-reuse behavior.

Table S2. Regression models of parallel multiple mediation with standardized regression coefficients

	(1) T2_PA	(2) T2_CA	(3) T2_PRB	(4) T2_PRB
Gender (girl)	–.127**	–.054	.055	.087*
	(.044)	(.045)	(.041)	(.040)
Age	–.033	.105*	–.151***	–.141***
	(.044)	(.045)	(.040)	(.039)
T1_PRB	.152***	–.008	.384***	.345***
	(.044)	(.045)	(.041)	(.040)
NC_weekend	.147***	.067	.088*	.051
	(.044)	(.045)	(.041)	(.040)
T2_PA				.259***
				(.040)
T2_CA				–.017
				(.039)
Marginal R^2	0.064	0.021	0.195	0.257
Conditional R^2	0.066	0.021	0.195	0.257
AIC	1257.312	1293.412	1641.219	1611.940
BIC	1286.870	1322.970	1670.777	1649.943
Num. obs.	504	504	504	504
Num. groups: class_id	15	15	15	15
Var: class_id (Intercept)	0.002	0.000	0.000	0.000
Var: Residual	0.664	0.716	1.437	1.330

Note. Standardized regression coefficients are displayed, with standard errors in parentheses. * $p < .05$. ** $p < .01$. *** $p < .001$. NC, Nature contact; PRB, paper-reuse behavior; PA, Place attachment; CA, Climate anxiety.