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Site Use and Environmental Thresholds of the Asian Small-Clawed Otter (Aonyx cinereus) in the Polluted Ciliwung River, Jakarta

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Abstract

Urban rivers in Southeast Asian megacities are severely degraded, yet some still support unexpected wildlife persistence. This study examined site-use patterns and environmental thresholds of the Asian small-clawed otter (Aonyx cinereus) in the Ciliwung River, Jakarta, Indonesia, one of the region's most polluted urban waterways. We conducted systematic sign surveys at 60 sites across three river segments representing an urban pollution gradient from Bogor to Jakarta between May and November 2025. Environmental variables, including water quality and substrate heterogeneity, were measured at each site. Otter signs were detected at 33 of 60 sites (55%). Site use declined slightly along the gradient, from 60.0% in the upstream segment to 50.0% in the urban core, although differences among segments were not statistically significant. Total Dissolved Solids (TDS) emerged as the most important predictor of otter presence, with site use declining markedly beyond approximately 194 ppm. Substrate heterogeneity also showed a strong positive association with site use: sites with mixed substrates had 75.0% site use, compared with 41.7% at predominantly concrete sites. Site use was higher in the wet season (68.0%) than in the dry season (45.7%), suggesting seasonal variation in habitat suitability. These findings indicate that A. cinereus can persist in heavily modified urban river systems, but continued persistence likely depends on maintaining structural habitat complexity and improving water quality. The study provides quantitative benchmarks for urban river restoration and supports the relevance of reconciliation ecology in tropical megacities.

INTRODUCTION

Urbanization is among the most pervasive drivers of biodiversity change in the Anthropocene, particularly in tropical regions where expanding cities increasingly transform natural ecosystems into heavily modified landscapes. Rivers in Southeast Asian megacities are especially vulnerable to this process, often shifting from ecologically functional freshwater systems to highly engineered channels exposed to chronic pollution, habitat simplification, and intense human disturbance. Yet despite these pressures, some urban rivers continue to support remnant populations of wildlife, raising important questions about the ecological conditions that enable persistence in novel and degraded environments.

The Ciliwung River in Jakarta, Indonesia, represents a compelling example of this contradiction. Although the river is widely recognized as heavily polluted, otter signs have continued to be recorded along the watershed. This persistence is ecologically notable because the Asian small-clawed otter (*Aonyx cinereus*), a species listed as Vulnerable, is generally associated with freshwater habitats that provide suitable prey, relatively good water quality, and structurally complex riparian environments. Previous reports from the watershed have documented otter presence, but the environmental mechanisms supporting persistence in this highly degraded urban river remain poorly understood.

In particular, little is known about how otter site use varies along an urban pollution gradient, whether there are measurable environmental thresholds beyond which site use declines, and whether habitat structure can buffer the effects of poor water quality. Addressing these questions is important not only

for otter conservation, but also for broader discussions of reconciliation ecology and urban river restoration in tropical cities. This study therefore aimed to: (1) quantify otter site-use patterns along an urban pollution gradient, (2) identify environmental thresholds associated with otter presence, (3) evaluate the relative importance of water quality and habitat structural variables, and (4) assess seasonal variation in site use. We hypothesized that otter occurrence would decline with deteriorating water quality, but that structurally heterogeneous habitats would provide local refugia that support continued use of urban river sections..

METHODS

Study Area

The study was conducted along the Ciliwung River watershed, Indonesia (6°10'S–6°35'S, 106°45'E–106°55'E), spanning upstream to downstream sections from Bogor through Depok to Jakarta. To represent an urbanization and pollution gradient, the river was divided into three segments: Segment 3 (S3; upper watershed, Bogor), Segment 4 (S4; transitional middle reach, Depok), and Segment 5 (S5; lower urban core, Jakarta). These segments differ in channel modification, surrounding land use, and degree of anthropogenic disturbance, with S5 representing the most heavily modified and polluted section. The spatial distribution of survey sites across the three river segments is shown in Fig. 1.

Otter Sign Surveys

A total of 60 survey sites were established across the three river segments (S3 = 15 sites, S4 = 21 sites, S5 = 24 sites). Each site consisted of a 500-m river section selected to represent the range of habitat conditions present within each segment. Surveys were conducted monthly from May to November 2025 following standardized otter sign survey guidelines adapted from Reuther et al. (2000). At each site, fresh signs of *A. cinereus* were systematically searched for, including spraints, footprints, feeding remains, holts, and latrines. Site use was recorded as present when fresh signs, estimated to be less than two weeks old based on field appearance and consistency, were detected during at least one survey occasion. Because this study relied on field signs rather than repeated-detection occupancy models, the response variable should be interpreted as sign-based site use rather than formal occupancy probability.

Environmental Variables

At each survey site, pH, Total Dissolved Solids (TDS), and water temperature were measured using calibrated multi-parameter sensors. Habitat structure was characterized using a substrate heterogeneity score ranging from 0 to 3, where 0 indicated concrete-only substrate, 1 a rock–concrete mixture, 2 two natural substrate categories, and 3 mixed substrates with four or more categories. Additional site variables included channel width, elevation, vegetation cover, prey availability index, human disturbance level, and overall anthropogenic disturbance score. Surveys covered both the dry season (May–August

2025) and wet season (September–November 2025) to examine seasonal variation in environmental conditions and otter site use.

Statistical Analysis

Otter site use was analyzed as a binary response variable in relation to environmental predictors using logistic regression. Univariate relationships were examined first, followed by multivariable assessment of water-quality and habitat-structure variables. Differences among river segments were examined using chi-square tests for categorical comparisons and Kruskal–Wallis tests for continuous environmental variables. Seasonal differences in site use were assessed using Fisher's exact test. All analyses were conducted in Python using pandas, scikit-learn, and matplotlib, with significance evaluated at $\alpha = 0.05$. Given the sign-based nature of the survey, results are interpreted as associations with site use rather than direct estimates of abundance or long-term demographic viability.

RESULTS

Habitat Site-Use Patterns

Otter signs were detected at 33 of 60 survey sites, indicating sign-based site use at 55.0% of sampled locations. Site use varied modestly among river segments, with 60.0% of sites positive in Segment 3 (9/15), 57.1% in Segment 4 (12/21), and 50.0% in Segment 5 (12/24). Although a declining pattern was observed from upstream to downstream, differences among segments were not statistically significant ($\chi^2 = 0.51$, $p = 0.77$). These results indicate that *A. cinereus* continued to use sites even in the most urbanized downstream reach of the river (Fig. 2).

Water Quality and Environmental Thresholds

TDS showed the strongest association with otter site use among the measured water-quality variables. Mean TDS increased markedly toward the urban core, from 104.8 ppm in Segment 3 and 101.1 ppm in Segment 4 to 174.2 ppm in Segment 5, with maximum recorded values reaching 310 ppm in downstream sites. Logistic regression suggested a decline in the probability of site use at approximately 194 ppm TDS, indicating a threshold-like response to increasing dissolved solids. However, this relationship was not absolute, as some sites with TDS values above 200 ppm still showed fresh otter signs. This suggests that water quality alone does not fully explain otter presence and that additional habitat characteristics may mediate the effect of pollution. This negative relationship between TDS and otter site use is illustrated in Fig. 3.

Segment-level differences were also seen in other environmental factors (Fig. 4). The pH level fluctuated from 5.45 to 8.65, with S3 and S4 being more alkaline than S5 most of the time. The temperature stayed rather steady (23.5–30.8°C) in all parts. The scores for how easy it was to find prey were highest in S3

(mean: 9.5) and S4 (mean: 8.1), and then dropped to 6.0 in S5. Anthropogenic disturbance rose steadily from S3 (score: 2.3) to S4 (3.0) and then to S5 (4.3), showing the trend of urbanisation.

Substrate Heterogeneity

Substrate heterogeneity was positively associated with otter site use. The highest site-use rate was recorded at sites with highly heterogeneous substrates (score 3), where 12 of 16 sites (75.0%) were positive. Intermediate values were observed at sites with moderate heterogeneity (15/29; 51.7%), whereas concrete-dominated sites showed lower site-use rates (5/12; 41.7%). The lowest value occurred at sites characterized by rock–concrete mixtures (1/3; 33.3%). This pattern suggests that structurally diverse riverbeds may provide more suitable microhabitats for foraging, shelter, and marking behavior. The positive association between substrate heterogeneity and otter site use is summarized in Fig. 5.

Seasonal Variation

Site use was higher in the wet season (17/25; 68.0%) than in the dry season (16/35; 45.7%), indicating a possible seasonal increase in habitat use or detectability during wetter months (Fig. 6). However, this difference was not statistically significant at the 0.05 level (Fisher's exact test, $p = 0.08$). Seasonal changes in TDS, which tended to be lower during the wet season, suggest that hydrological dilution may temporarily improve habitat conditions in some river sections.

DISCUSSION

This study shows that the Asian small-clawed otter continues to use multiple sections of the Ciliwung River despite severe urban modification and degraded water quality. Fresh signs were detected at 55% of surveyed sites, including locations in the most urbanized downstream reach, indicating measurable persistence within this altered river system. However, because the study was based on field signs rather than direct estimates of abundance, survival, or reproduction, these findings should be interpreted as evidence of site use rather than proof of long-term population security. That caution is consistent with the original manuscript's own acknowledgement that population density and reproductive success were not measured.

Among the environmental variables measured, TDS emerged as the clearest water-quality correlate of otter site use. The apparent decline in site use beyond approximately 194 ppm suggests that dissolved solids may provide a useful preliminary indicator for identifying river sections where habitat conditions become less favorable. At the same time, the persistence of otter signs at some high-TDS sites indicates that water quality alone does not determine site use. Otter persistence in urban rivers therefore appears to be shaped by interacting habitat constraints rather than by a single physicochemical threshold.

Substrate heterogeneity was one of the strongest habitat correlates in this study. Sites with mixed substrate types showed markedly higher site-use rates than concrete-dominated sites, suggesting that

physical habitat complexity may partially buffer the ecological effects of pollution. Structurally diverse river sections likely provide better shelter opportunities, more suitable marking sites, and a broader range of prey-associated microhabitats. From a restoration perspective, this finding is important because improving structural complexity may be more feasible in the short term than achieving rapid, watershed-wide restoration of water quality.

Seasonal differences in site use were suggestive but not statistically conclusive. The higher wet-season value may reflect temporary improvements in habitat quality through increased discharge and pollutant dilution, but it may also partly reflect seasonal differences in otter movement or sign detectability. Longer-term monitoring across multiple annual cycles is therefore needed before strong inferences can be made about seasonal habitat use in this river system.

Several limitations should be acknowledged. First, sign-based surveys may underestimate or overestimate true site use in urban environments where signs disappear rapidly or observer detection varies. Second, the study did not assess abundance, reproduction, or survival, and therefore cannot determine population viability. Third, the study covered only seven months and one seasonal cycle, limiting inference about interannual consistency. Future work should combine repeated detection surveys, camera trapping, non-invasive genetic approaches, and diet analysis from spraints to evaluate whether the Ciliwung population represents transient persistence or a demographically stable urban population.

In conclusion, the Asian small-clawed otter (Aonyx cinereus) continues to use multiple sections of the heavily modified Ciliwung River despite substantial urban pollution and habitat alteration. Sign-based surveys showed that otter presence remained detectable across the urban gradient, with overall site use recorded at 55% of surveyed locations. Among the environmental variables examined, TDS and substrate heterogeneity emerged as the most informative correlates of site use, suggesting that both water quality and physical habitat structure shape otter persistence in this tropical urban river. The apparent decline in site use beyond approximately 194 ppm TDS provides a useful preliminary benchmark for river management, while the higher site use observed in structurally heterogeneous sites highlights the importance of maintaining or restoring habitat complexity even where full water-quality recovery may be difficult in the short term. Together, these findings support the view that urban biodiversity conservation in highly modified rivers should combine pollution reduction with habitat-based restoration measures. However, because this study relied on field signs rather than direct estimates of abundance, reproduction, or survival, the results cannot determine long-term population viability. Even so, the study provides an important empirical basis for reconciliation ecology and urban river restoration in Southeast Asian megacities.

STATEMENTS AND DECLARATIONS

Funding. The authors received no specific funding for this work.

Competing Interests. The authors have no relevant financial or non-financial interests to disclose.

Ethics Approval. This study was based on non-invasive field surveys of indirect signs of Aonyx cinereus and did not involve capture, handling, or experimental manipulation of animals. Formal animal ethics approval was therefore not required for this study. Fieldwork was conducted in accordance with applicable institutional and local regulations.

Consent to Participate. Not applicable.

Consent for Publication. All authors approved the manuscript for publication.

Data Availability. The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Figures

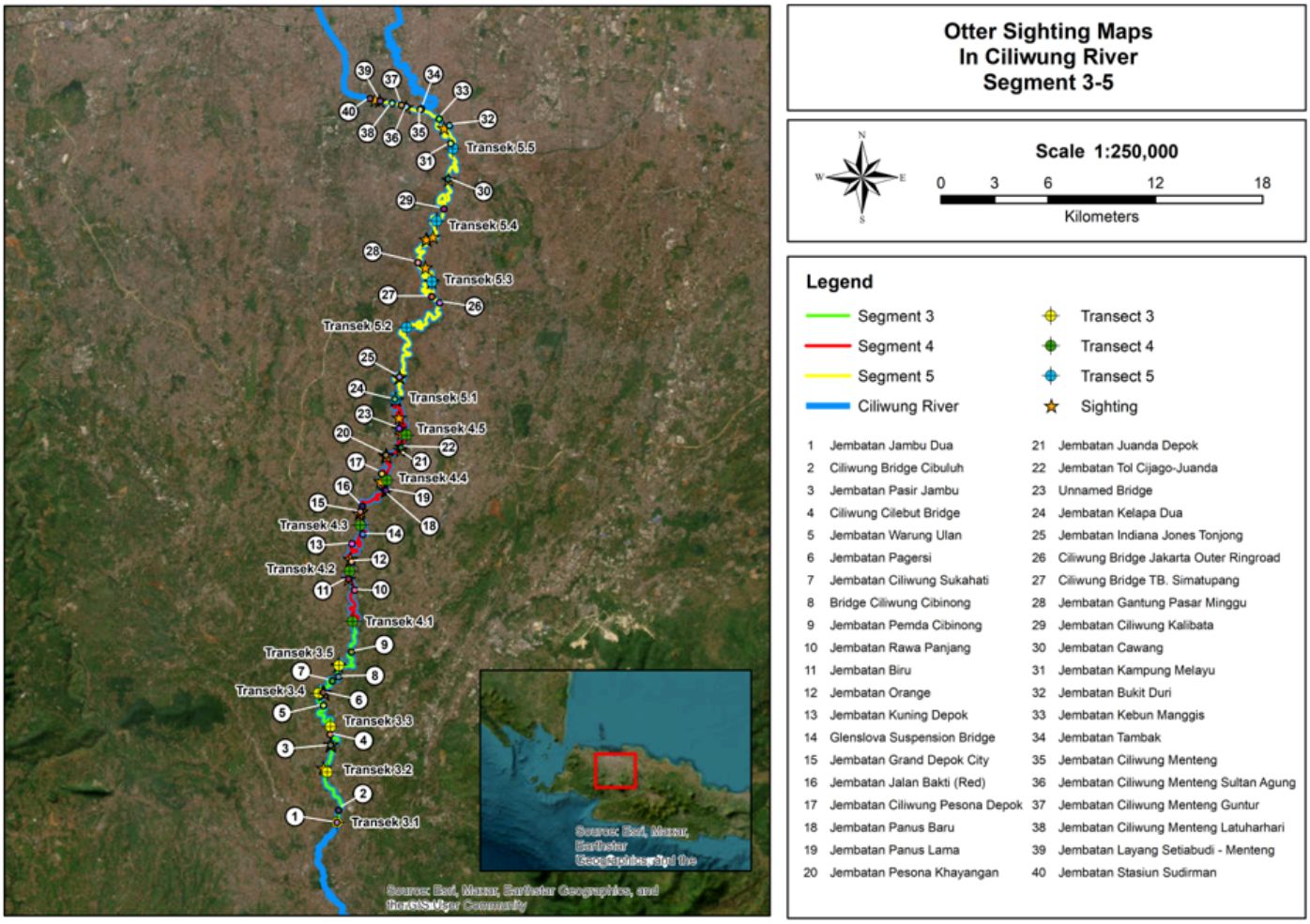


Figure 1

Study Area and Survey Sites Along Ciliwung River

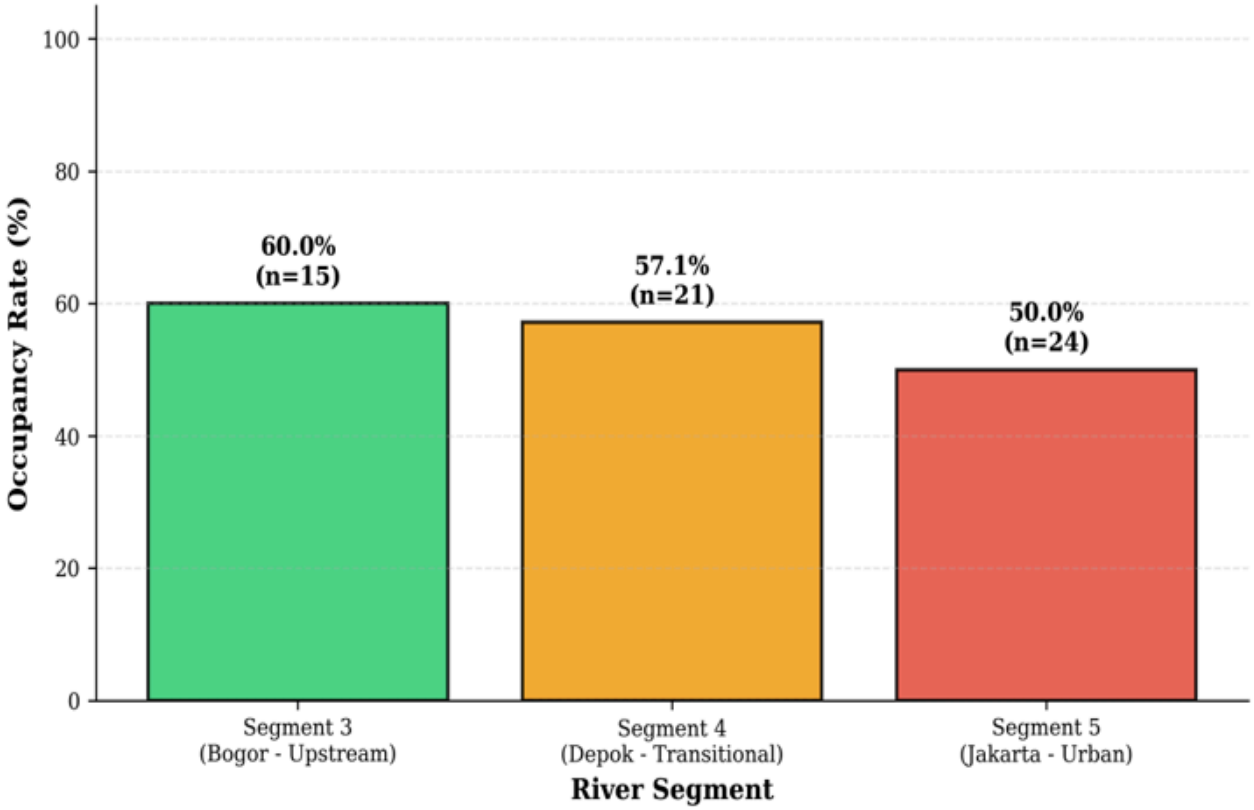


Figure 2

Otter Site-Use Rate Across River Segments

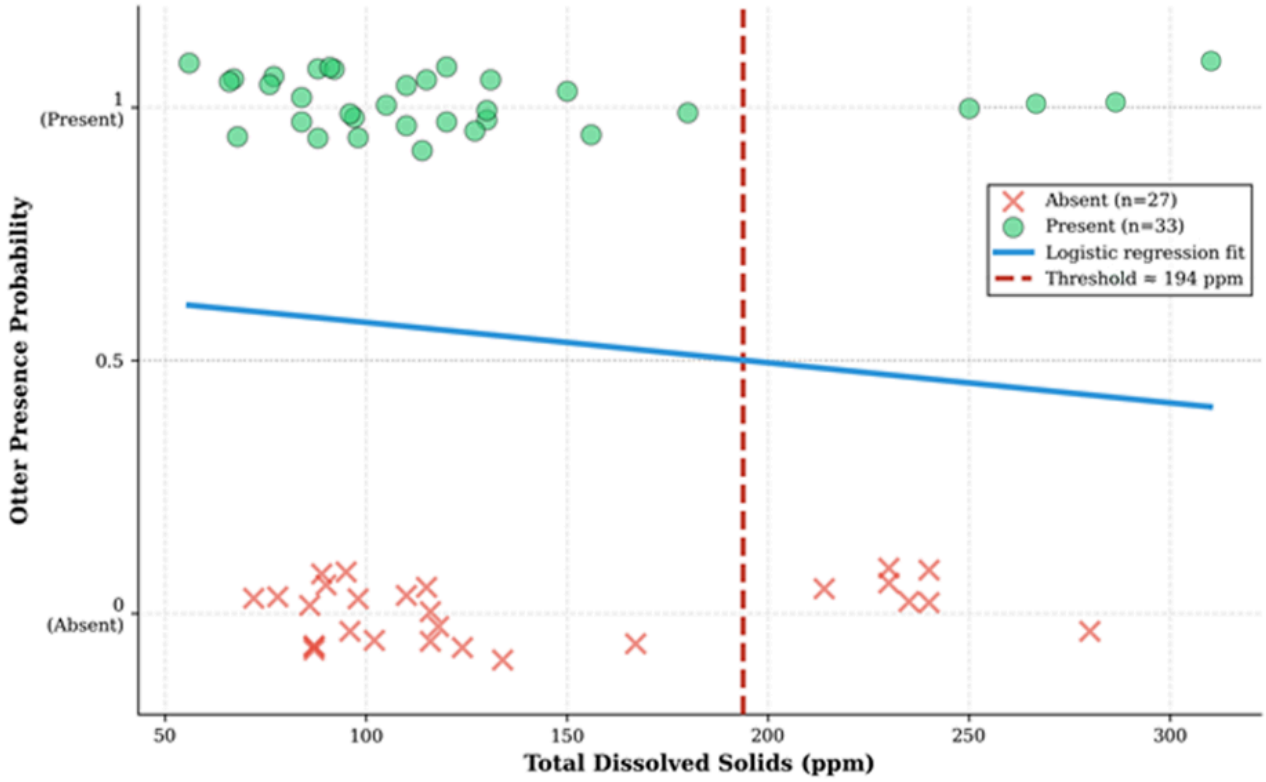


Figure 3

Relationship Between Water Quality (TDS) and Otter Site Use

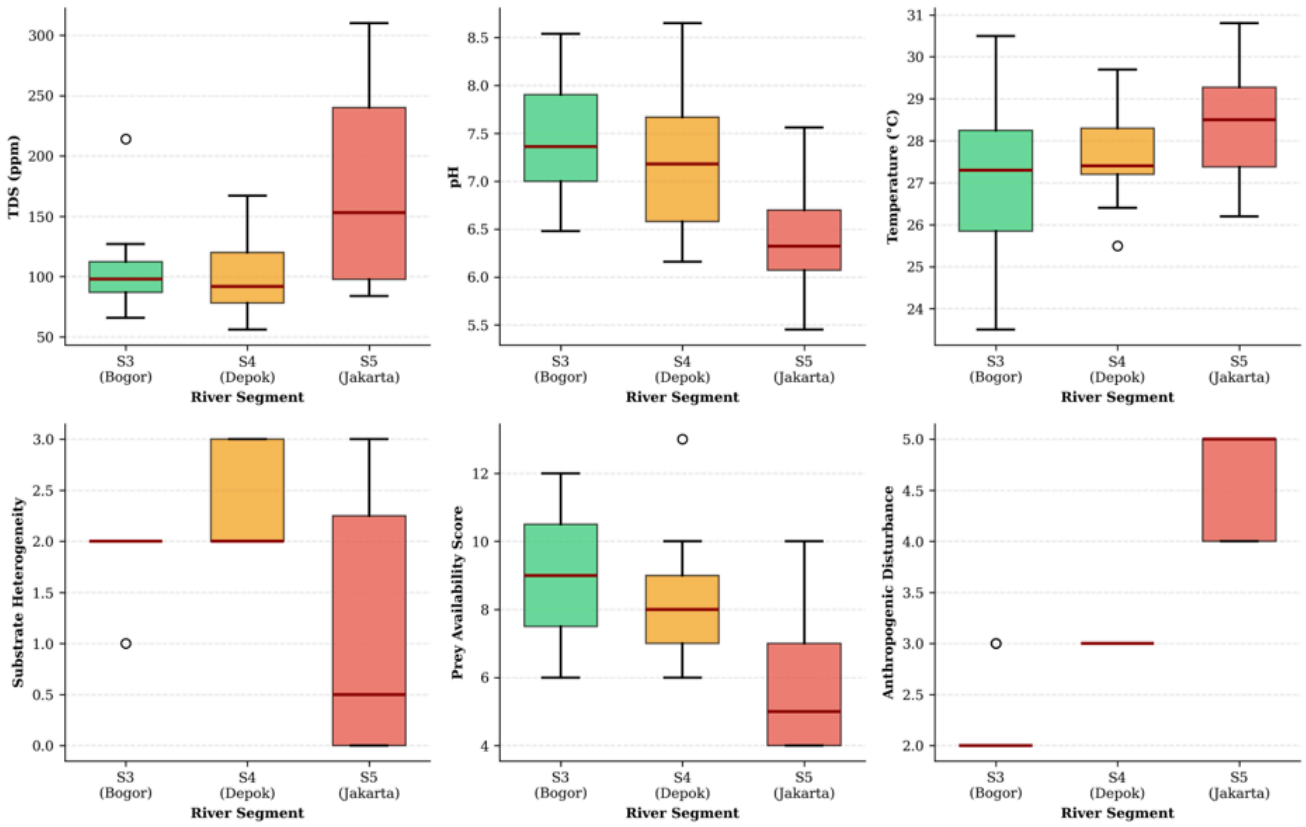


Figure 4

Environmental Variables Across River Segments

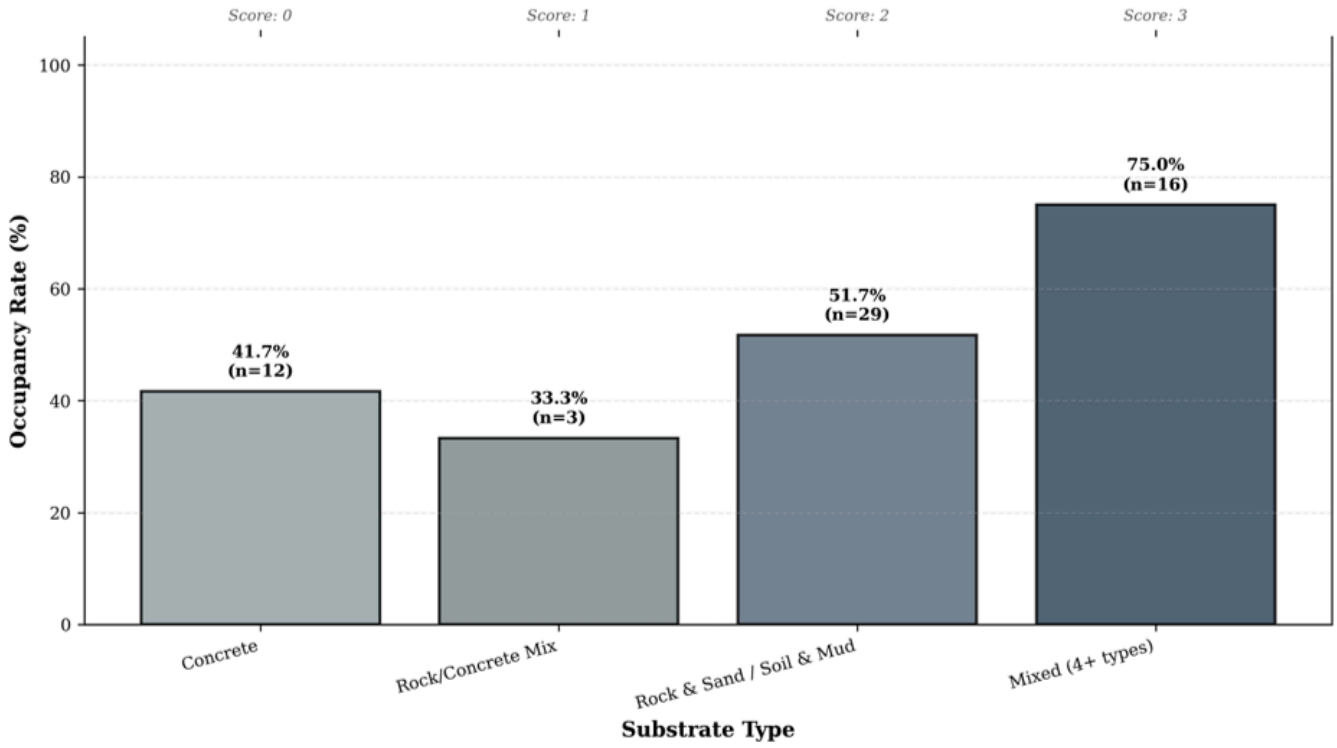


Figure 5

Otter Site-Use Rate by Substrate Heterogeneity

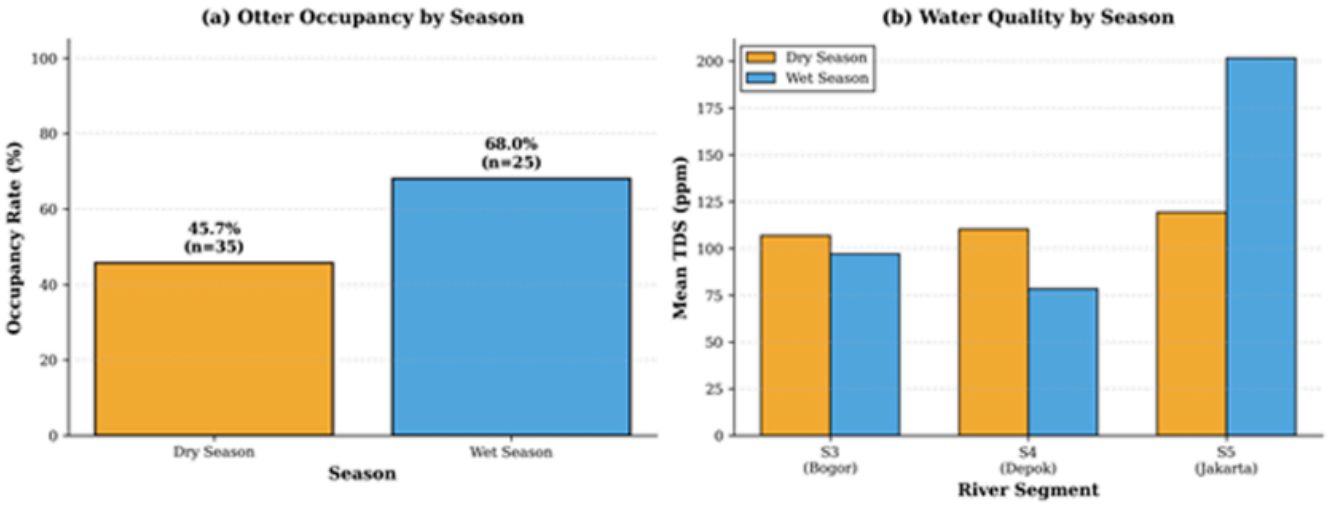


Figure 6

Seasonal Patterns in Otter Site Use and Water Quality