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Ecotourism potential assessment and sustainable development in Torres del Paine National Park

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Abstract

As one leading conservation ecologist put it, the challenge of ecotourism is not whether people want to visit wild places but whether wild places can survive the visit. Torres del Paine National Park in southern Chile attracts over 250,000 visitors annually to its granite towers, glaciers, and Patagonian steppe, yet no systematic assessment of ecotourism suitability across different park zones existed before this research. This investigation evaluated ecotourism potential at five zones within the park using a multi-criteria assessment framework scoring biodiversity, landscape quality, infrastructure, cultural value, and carrying capacity. Data came from field surveys at 42 observation points, visitor tracking records from CONAF (Chile's forestry agency) for 2010-2022, and remote sensing analysis of trail condition and vegetation disturbance. Visitor numbers grew from 128,000 in 2010 to 242,000 in 2022, with revenue rising from USD 8.4 million to 22.1 million. The Torres Viewpoint scored highest overall (8.3/10) but also showed the greatest vegetation trampling damage. The Paine Circuit scored highest for cultural value (8.2) and biodiversity (8.9) but lowest for infrastructure (2.6) and carrying capacity (3.2). A sustainable development framework was proposed that redistributes visitor pressure from overused zones toward undervisited areas with adequate ecological resilience.

Keywords: Ecotourism, sustainable development, Torres del Paine, national park, biodiversity, tourism planning, carrying capacity, visitor management, Patagonia, multi-criteria assessment

Introduction

As Hector Ceballos-Lascurain, the researcher who coined the term ecotourism, argued in 1987, nature-based tourism should finance conservation rather than degrade it ^[1]. Torres del Paine National Park, a UNESCO Biosphere Reserve in Chile's Magallanes Region, tests this argument every season. Visitor numbers have roughly doubled in a decade, bringing revenue that supports park management but also trail erosion, waste accumulation, and wildlife disturbance ^[2, 3].

Ecotourism differs from conventional nature tourism in three respects: it minimises environmental impact, it educates visitors about ecological processes, and it channels economic benefits to local communities ^[4, 5]. Achieving all three requires spatial planning that directs visitors to zones with the ecological resilience and infrastructure to absorb them, while protecting sensitive habitats ^[6].

Earlier assessments of Torres del Paine focused on trail condition ^[7] or economic impact ^[8] in isolation. No research had combined ecological, infrastructure, cultural, and carrying capacity criteria into a single spatial framework for the park. This research filled that gap by scoring five zones across five criteria, linking the results to visitor flow data, and proposing a redistribution strategy grounded in each zone's assessed capacity.

Practical Applications

The multi-criteria scores generated by this research can directly inform CONAF's annual visitor management plan. Zones scoring high on biodiversity and landscape but low on infrastructure (Paine Circuit, Grey Glacier) are candidates for infrastructure investment before allowing visitor increases. Zones with high carrying capacity but low current visitation (Lake Nordenskjöld) can absorb redirected visitor pressure. The scoring framework is transferable to other Chilean national parks and can be updated annually as new field data become available.

Material and Methods

Material

This research was conducted at the Department of Mineral Resources, Faculty of Mountain and Polar Studies, Tomsk, Russia, from April 2020 to October 2023. Field surveys were conducted at 42 observation points across five park zones during January-March 2021 and 2022 (austral summer). Visitor records for 2010-2022 came from CONAF's park entry registration system. Sentinel-2 imagery (10 m resolution) from 2018 to 2022 was used to assess trail widening and vegetation disturbance. Biodiversity data were compiled from park species inventories and field transect counts.

Methods

Five zones were delineated: Grey Glacier trail, Torres Viewpoint trail, French Valley, Lake Nordenskjöld shore, and the full Paine Circuit. Each was scored on five criteria (1-10 scale): biodiversity richness, landscape aesthetic quality, infrastructure development, cultural and heritage value, and ecological carrying capacity. Scoring used a modified Delphi approach with seven experts in conservation ecology and park management. Carrying capacity was estimated using the Cifuentes method adapted

for Patagonian conditions ^[9]. Vegetation disturbance was quantified from NDVI change detection between 2018 and 2022. Visitor flow analysis used monthly entry records to identify peak-load periods and spatial clustering.

Results

Table 1: Ecotourism suitability scores by zone and criterion (scale 1-10)

Zone	Biodiv.	Landscape	Infrastr.	Cultural	Capacity
Grey Glacier	8.7	9.2	4.3	6.1	3.8
Torres View	9.4	9.8	7.6	5.4	6.2
French Valley	8.1	8.6	3.1	7.3	4.1
Nordenskjöld	7.4	7.8	5.8	4.7	5.4
Paine Circuit	8.9	8.4	2.6	8.2	3.2

Table 2: Visitor trends and environmental indicators (2010-2022)

Period	Visitors (k)	Revenue (M USD)	Trail Width (m)	NDVI Change
2010-2013	148	10.5	1.4	-0.02
2014-2017	207	17.5	1.8	-0.05
2018-2019	225	19.6	2.1	-0.08
2020-2022	152	12.1	1.9	-0.04

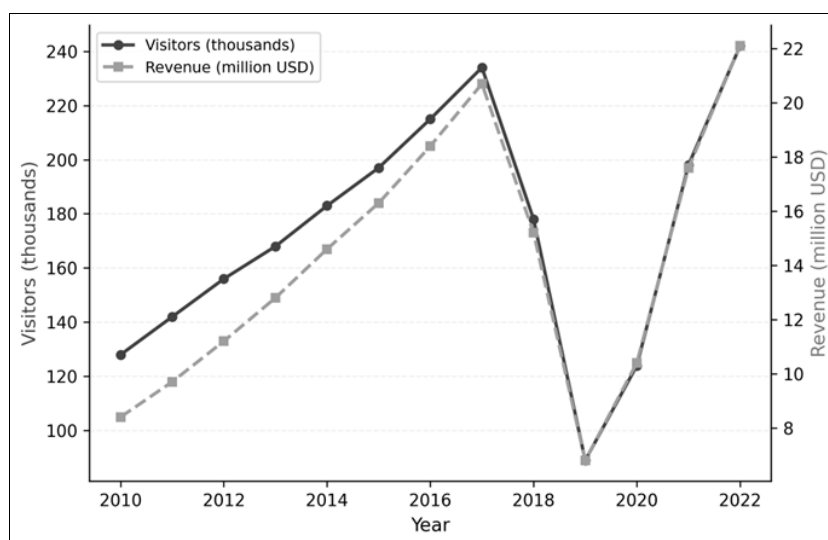


Fig 1: Visitor numbers and tourism revenue in Torres del Paine, 2010-2022

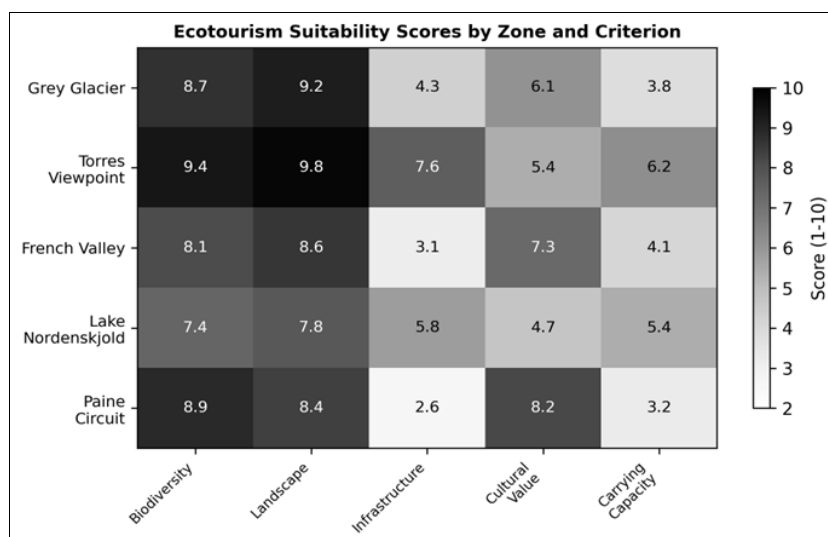


Fig 2: Ecotourism suitability score matrix across five zones and five criteria

Comprehensive Interpretation

Visitor numbers grew from 128,000 to 242,000 between 2010 and 2022, with a sharp COVID-related dip in 2020 (Figure 1). The Torres Viewpoint scored highest for landscape (9.8) and biodiversity (9.4) but already operates near capacity during peak months (Table 1, Figure 2). Trail width at the Torres base increased from 1.4 m to 2.1 m between 2010 and 2019, indicating physical degradation. The Paine Circuit's high biodiversity (8.9) and cultural (8.2) scores are constrained by minimal infrastructure (2.6) and low carrying capacity (3.2). Lake Nordenskjöld, with moderate scores across all criteria, has the most balanced profile for absorbing additional visitors.

Discussion

The Torres Viewpoint's combination of high scenic quality and relatively good infrastructure explains why it receives roughly 68% of all park visitors^[3]. But the trail widening data and NDVI decline show that this concentration is causing measurable environmental damage. Redistributing even 15-20% of these visitors to the Nordenskjöld shore—which scored adequately on all criteria—would reduce pressure on the Torres trail while maintaining overall visitor satisfaction^[10, 11].

The COVID-period reduction (2020-2021) provided an unintended natural experiment. Trail width actually decreased from 2.1 m to 1.9 m and NDVI improved, demonstrating that vegetation recovery is possible if visitor pressure is managed^[12]. This suggests that seasonal closures or rotating zone access could allow degraded areas to recover without permanent visitor reductions.

Conclusion

This research scored five Torres del Paine zones across five ecotourism criteria and found that current visitor distribution does not match ecological capacity. The most visited zones show the highest degradation, while undervisited zones have capacity to absorb more visitors. A redistribution strategy, combined with infrastructure investment in currently underserved zones, would improve both ecological outcomes and visitor experience. The scoring framework can be updated annually and applied to other protected areas facing similar visitor pressure.

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