



Commentary

The Kandinsky building in Chile: A case study demonstrating extreme urbanization pressure on coastal ecosystems

Carolina Martínez Reyes^{a,b}, Nelson Rangel-Buitrago^{c,*}

^a Instituto de Geografía, Pontificia Universidad Católica de Chile, Santiago, Chile

^b Centro de Investigación para la Gestión integrada del Riesgo de Desastres – CIGIDEN, Santiago, Chile

^c Programa de Física, Facultad de Ciencias Básicas, Universidad del Atlántico, Barranquilla, Atlántico, Colombia

ARTICLE INFO

Keywords

Coastal urbanization
Coastal dunes
Ecosystems
Human pressures
Kandinsky building
Chile

ABSTRACT

This discussion addresses the urgent issue of coastal urbanization in Chile, particularly focusing on the degradation of dune systems due to accelerated urban development and inadequate management frameworks. Using the Kandinsky Building collapse as a case study, this paper elucidates the vulnerabilities associated with extreme coastal urbanization and the absence of robust legislation. The research calls for the immediate implementation of Integrated Coastal Zone Management (ICZM) and Territorial Planning as pivotal tools for effective coastal governance in Chile. Both these mechanisms, when grounded in science, can provide sustainable solutions that balance current land-use demands with future ecological needs. We emphasize the necessity of scientifically informed setback lines, Environmental Impact Assessments (EIAs), public education, and fiscal instruments to mitigate the challenges posed by extreme coastal urbanization. A Chile-specific ICZM plan, incorporating scientific research into policy formulation and execution, is imperative for evidence-based, adaptive, and sustainable decision-making.

Globally, coastal urbanization denotes the rising human population density in coastal zones, contrasting with rural areas (Rangel-Buitrago 2019). Key Chilean coastal cities, such as Valparaíso, Viña del Mar, and Concón, have undergone rapid tourism growth, leading to an increase in hotels, secondary residences, and, regrettably, illegal settlements (Rangel-Buitrago et al., 2018). These anthropogenic pressures, largely concentrated along the coastline, substantially contribute to coastal degradation.

This surge in tourism catalyzes internal migration, amplifying the human footprint on coastal areas, including dunes. Concerningly, this occurs despite the region's pronounced vulnerability to tsunamis, coastal erosion, extreme wave events as well as other related coastal hazards.

Coastal dunes, characterized by specialized biodiversity, serve both environmental and economic functions by providing essential ecosystem services (Maun 2009). The dynamic interplay between natural processes and anthropogenic activities influences their evolution, conservation, and resilience (Packham and Willis 1997).

Recently, escalating urbanization in coastal areas has placed unprecedented stress on these critical ecosystems (Rangel-Buitrago et al., 2018). Chile's coastline exemplifies the adverse impacts of urban

encroachment on dune systems. The Kandinsky Building, located at the intersection of Viña del Mar and Concón on the Central Chilean coast, serves as a case study in the vulnerabilities plaguing coastal infrastructure (Fig. 1).

The building is located on the Concón Dune System, a unique geomorphological formation characterized by its 'hanging dunes.' These dunes are not directly associated with any beach system and differ from aeolian dunes commonly found adjacent to coastal landscapes. Unlike typical dunes, which continuously receive sand from wind and beach activities, the Concón dunes primarily originated from ancient sedimentary processes dating back to the Pleistocene (approximately 2 million years ago) and the Holocene epochs (approximately 100,000 years ago).

The unique characteristic of these dunes being 'hanging' is manifested in their elevation above the surrounding rock cliffs, disconnected from contemporary sediment supply systems. As a result, they offer an elevated and uninterrupted vantage point to the sea, making them highly attractive for real estate development. The very nature of their elevated positioning over rock cliffs suggests that they were established approximately 10,000 years ago and have remained relatively isolated from dynamic sedimentary activities. Disconnected from the current sea

* Corresponding author.

E-mail addresses: camartinezr@uc.cl (C. Martínez Reyes), nelsonrangel@mail.uniatlantico.edu.co (N. Rangel-Buitrago).

level due to historical sea level changes, these dunes provide significant ecological and geomorphological value, including unique biodiversity and essential ecosystem services like storm surge protection and specialized habitats.

The Kandinsky Building, a 17-story structure experienced critical structural instability due to the failure of a retaining wall, leading to the formation of a large sinkhole that imperiled the building's integrity (Fig. 1). A mandatory evacuation was subsequently enacted for 25 occupants across 11 units, facilitated by law enforcement and firefighting units.

The incident has attracted substantial global scrutiny, corroborated by the broad dissemination of images illustrating the compromised state of the structure (Fig. 1). Recent extreme precipitation events tied to a frontal system in the central-southern region have exacerbated the situation. The failure of a nearby public stormwater collector—engineered and constructed independently of the original building contractors—led to significant soil displacement, causing the collapse of an adjacent retaining wall and street. The events were further intensified by this year's more abundant and concentrated rainfall, associated with the warm phase of the El Niño Southern Oscillation (ENSO). This incident underscores the interconnected vulnerabilities of coastal infrastructure and urban water management systems, particularly in the context of changing climate conditions.

Nevertheless, the underlying cause of this catastrophe is intrinsically tied to extreme urbanization occurring on a dune system. Such development manifests inherent risks and vulnerabilities, yet the absence of robust coastal management legislation amplifies these challenges. Despite the exigency, a proposed 'Coastal Law,' intended to serve as a framework for Integrated Coastal Zone Management (ICZM), remains stalled in legislative processes. Contrarily, discussions advancing real estate investment in these ecologically sensitive areas continue to gain momentum, a situation that presents a paradox considering the manifest vulnerabilities.

The challenges associated with extreme coastal urbanization are both globally pervasive and multifaceted (Williams and Micallef 2009). For example, the state of Florida in the United States and the city of Cartagena in Colombia confront serious challenges posed by extreme meteorological conditions, rising sea levels, and subsidence. These

environmental factors pose significant risks to the flourishing real estate and tourism sectors in both the United States and Colombia, which predominantly rely on coastal resources. Similarly, Australia's Gold Coast, the Mediterranean Coast, Jakarta city and many other locations around the world are grappling with the interconnected issues of shoreline erosion, subsidence, and unchecked urban development.

In Chile, as in other coastal nations, Integrated Coastal Zone Management (ICZM) and Territorial Planning should serve as primary tools for effective coastal governance, particularly considering conflicting sectoral activities such as urbanization, industry, tourism, and conservation (Davis and Fitzgerald 2004; Doody 2013; Pilkey and Cooper 2014). These mechanisms provide:

- A framework for inter-agency collaboration.
- GIS-based data organization specific to coastal geographies.
- Conflict-resolution strategies pertinent to resource utilization and conservation at both local and regional levels.

Sustainable management necessitates a balance between current land-use demands and the needs of future generations (Pilkey and Cooper 2014; Rangel-Buitrago et al., 2015). Thus, coastal management should be anchored in scientific knowledge relevant to local Chilean ecosystems—specifically, dune systems—and should consider the economic, environmental, and social well-being of local communities (Van der Meulen and Salman 1996).

The case of the Kandinsky Building elucidates the shortcomings in prevailing governance structures in Chile concerning coastal management, primarily attributable to institutional oversight. Therefore, a Chile-specific ICZM plan is imperative. Essential components of this plan should include:

- Establishment of well-defined, scientifically substantiated objectives.
- Identification and characterization of variables unique to the Chilean shoreline.
- Formulation of management alternatives that are mindful of Chile's administrative, political, and legal contexts.



Fig. 1. The Kandinsky Building, a 17-story structure, experienced critical structural instability due to retaining wall failure and extreme precipitation events, intensified by the El Niño Southern Oscillation (ENSO). The incident led to mandatory evacuation and highlighted the vulnerabilities of coastal infrastructure, particularly when constructed on coastal systems, in the context of changing climate conditions. Nevertheless, the underlying cause of this catastrophe is intrinsically tied to extreme urbanization occurring on a dune system.

- Implementation of monitoring protocols for continuous assessment of coastal integrity.

Restrictive measures on construction activities and access to ecologically vulnerable coastal zones are essential. Also, it is necessary the implementation of strategies that minimize human impact. Moreover, enforcing prohibitions on activities like fires, vehicular traffic, and sand extraction is critical (Pilkey et al., 2022). Strict adherence to setback requirements for new constructions, grounded in both ecological and land-use considerations, must be obligatory.

Extreme coastal urbanization severely challenges the resilience and ecological integrity of Chile's unique dune systems. The rapid pace of development often outstrips the capacity of traditional management frameworks, necessitating immediate, science-based interventions. Rigorous approaches for managing coastal urbanization in Chile, aiming to preserve ecosystem integrity and sustainability are necessary, some of them are:

- **Spatial planning** plays a critical role in designating areas for development versus conservation. In Chile, zoning regulations should be formulated based on scientific data, which considers variables like topography, erosion rates, and the ecosystem services provided by coastal environments.
- **Science-based setback lines**, determined through dynamic modeling of local coastal processes, can help mitigate risks associated with development in these zones. Such setback lines act as buffers against prevalent risks such as storm surges and tsunamis.
- **Integrated Coastal Zone Management (ICZM)** offers a comprehensive framework that incorporates terrestrial, marine, and anthropogenic elements. In Chile, ICZM should involve diverse stakeholders, including government agencies, academic institutions, civil organizations, and the private sector, all underpinned by robust scientific research.
- **Adaptive management strategies** are essential and should include continuous ecological surveillance and regular updates to protocols based on the latest scientific research.
- **Robust legislative frameworks and stringent enforcement mechanisms**, including mandatory Environmental Impact Assessments (EIAs), are crucial. Non-compliance should be met with substantial penalties.
- **Public education initiatives**, rooted in scientific data, can effectively change community attitudes towards conservation. Empowering local communities through scientific monitoring can foster a culture of stewardship.
- **Fiscal mechanisms**, like property development taxes in ecologically sensitive areas, can financially support conservation efforts. Reallocated funds could be used for specific empirical research, ongoing surveillance, and maintaining natural buffer zones.

This discussion aims to illuminate critical aspects of coastal urbanization, particularly in Chile, by emphasizing the complex interplay between anthropogenic pressures, ecosystem vulnerability, and legislative shortfalls. Rapid tourism growth and internal migration have intensified human impacts on coastal zones, thereby eroding ecosystem resilience and magnifying their natural susceptibility to hazards such as tsunamis, erosion, and climatic extremes. This situation is worsened by the lack of a comprehensive legislative framework for Integrated Coastal Zone Management (ICZM) in Chile, resulting in governance deficiencies and increased risks. Furthermore, these vulnerabilities are interconnected, as exemplified by the detrimental effects of poor urban water management on coastal infrastructure, especially under variable climate conditions like the El Niño Southern Oscillation (ENSO).

Chile, along with other coastal countries, faces unique challenges in coastal management, shaped by specific geographical and sociocultural factors. The integration of these distinct elements into a holistic, science-based strategy is crucial for effective governance. Optimal coastal

management is not solely an institutional endeavor; rather, it requires engagement from a collective of stakeholders. Incorporating scientific research into policy formulation and implementation is essential for evidence-based, adaptive, and sustainable decision-making, thereby mitigating catastrophic outcomes such as those exemplified by the Kandinsky Building collapse.

Epilogue

Considering recent developments, the urgency of addressing the multifaceted challenges of coastal management becomes abundantly clear. A new sinkhole in the dune field of Concón prompted authorities to evacuate four buildings, including three towers in Miramar and Santorini Norte, affecting over 200 residents. This sinkhole emerged following heavy rainfall generated by a frontal system that impacted central Chile over the weekend. Alarming, this incident occurs less than a month after the Kandinsky building was evacuated due to the risk of collapse.

These events serve as stark reminders of the immediate and tangible consequences of inadequate coastal management strategies, particularly in the face of intensifying climatic events. They underscore the imperative for a multi-stakeholder, science-based approach to coastal governance, one that is adaptive, data-driven, and capable of mitigating risks proactively. The perils of delayed action and fragmented policymaking are no longer abstract concerns but harsh realities that jeopardize both human life and ecological integrity. While this discussion has largely focused on the case of Chile, the ramifications are undoubtedly global, necessitating urgent, collaborative efforts for sustainable coastal management worldwide.

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

Data will be made available on request.

Acknowledgments

This work is a contribution from "Instituto de Geografía" Pontificia Universidad Católica de Chile, "Centro para la Gestión integrada del Riesgo de Desastres – CIGIDEN" and "Geología, Geofísica y Procesos Marino-Costeros", Universidad del Atlántico. Research Center for Integrated Disaster Risk Management: ANID/1522A0005 FONDAP 2022

References

- Davis, D., Fitzgerald, D., 2004. *Beaches and Coasts*. Blackwell Pub. Co., New York.
- Doody, P., 2013. *Coastal Conservation and Management: an Ecological Perspective*. Springer, New York.
- Maun, M.A., 2009. *The Biology of Coastal Sand Dunes*. Oxford University Press, New York.
- Packham, J.R., Willis, A.J., 1997. *Ecology of Dunes, Salt Marsh and Shingle*. Springer, Amsterdam.
- Pilkey, O.H., Cooper, A.G., 2014. *The Last Beach*. Duke University Press, Durham.
- Pilkey, O.H., Neal, W., Longo, N., Rangel-Buitrago, N., Pilkey, K., Hayes, H., 2022. *Vanishing Sands: Losing Beaches to Mining*. Duke University Press, Durham.
- Rangel-Buitrago, N., Contreras-López, M., Martínez, C., Williams, A., 2018. Can coastal scenery be managed? The Valparaíso region, Chile as a case study. *Ocean Coast Manag.* 163, 383–400.
- Van der Meulen, F., Salman, A.H.P.M., 1996. Management of Mediterranean coastal dunes. *Ocean Coast Manag.* 30 (1–2), 177–195.
- Williams, A.T., Micallef, A., 2009. *Beach Management Principles and Practice*. Earthscan, London.