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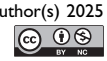

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Proposing critical realism and second-generation environmental justice for advancing sacrifice zone analysis

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Abstract
This article addresses the complex social-ecological challenges faced by sacrifice zones—territories subjected to severe environmental degradation and social injustices. Traditional environmental justice research, with its emphasis on distributive justice, often fails to capture the intricate dynamics of these often not-recognized areas. In light of these limitations, this article proposes a second-generation environmental justice approach, employing a critical realist paradigm, to identify sacrifice zones and explore their deeper causal mechanisms. This approach, which transcends the distributional focus of traditional research, reveals mechanisms commonly observed in these zones. These mechanisms enable and sustain environmental degradation and social injustices through dynamics such as economic exploitation, policy failures, and power imbalances. Intertwined within social-ecological systems, these dynamics create cycles of poverty, health disparities, and ecological harm. Moreover, the article offers a methodological reflection on the theoretical proposal and planning practices toward environmental justice. It concludes with recommendations for future research, emphasizing the importance of systemic change and inclusive policy-making to achieve environmental justice and sustainability.

Keywords
sacrifice zones, critical realism, environmental justice, social-ecological systems, causal mechanisms

Introduction

Communities and ecosystems worldwide increasingly face complex social-ecological challenges, exacerbated by the climate crisis and the increasing toxification of the planet (Boyd and Orellana, 2022). These challenges, which primarily stem from industrial expansion and its logistics, extractive activities, unsustainable energy production, inadequate waste management, and military operations, disproportionately affect localized human communities, known as sacrifice zones (Danielle Mitterrand Fdn, 2019; Juskus, 2023; Perkins, 2024). In these zones, environmental injustices manifest as dense geographical disparities, where communities at risk suffer profound social-ecological hardships due to persistent exposure to pollution and hazardous substances,

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leading to severe impacts on fundamental human rights to life, health, food, water, and sanitation (Roberts and Toffolon-Weiss, 2001; Knox, 2018).

Traditional environmental justice research, primarily focusing on distributive justice, assesses the proximity to environmental hazards and the socioeconomic traits of impacted populations (Walker, 2010; Pellow, 2018). This so-called first-generation approach is increasingly criticized for its narrow focus, which tends to reduce environmental injustices to mere spatial dynamics, failing to capture the nuanced realities of social-ecological conflicts or address broader systematic issues. Consequently, there is growing advocacy for a second-generation environmental justice approach, which expands the focus to include procedural fairness, recognition of community diversity, and broader social justice implications. This approach aims to provide deeper insights and foster more effective analyses (Pellow, 2018).

Aligned with the need for enhanced analytical frameworks, this article proposes adopting a critical realist paradigm to implement second-generation environmental justice research of sacrifice zones. Critical realism has the potential to offer a structured way to examine the underlying mechanisms and power dynamics shaping these zones, transcending traditional proximity-based methods (Sayer, 2015; Fletcher, 2017). This approach not only enhances the structured study of these zones but also deepens geographical inquiries into their complex dynamics. The subsequent sections explore the theoretical foundations and apply these principles to dissect the multifaceted nature of sacrifice zones. We begin by conceptualizing sacrifice zones, followed by an examination of environmental justice approaches. Critical realism as a structural approach and its dimensions of the real, actual, and empirical are then reviewed. The 'Theoretical foundations' section presents the proposed analytical framework for implementing second-generation environmental justice research in sacrifice zones. It addresses the criteria for identifying sacrifice zones, the layered reality of critical realism, and the analytical facets of the mechanisms of sacrifice, detailing the common mechanisms found in these zones and the arguments behind them. The 'Analytical framework' section discusses methodological approaches to studying sacrifice zones, while the 'Methodological reflection' section focuses on environmental justice perspectives in planning. The article concludes with a summary of theoretical insights, their relevance, limitations, and recommendations for future research.

Theoretical foundations

To understand the dynamics of sacrifice zones, we explore three key theoretical foundations: the concept of sacrifice zones, the framework of environmental justice, and the structural approach of critical realism.

Conceptualizing sacrifice zones

Sacrifice zones are territories subjected to severe environmental degradation and social injustices. According to Juskus (2023), they function as a critical concept for identifying and resisting imposed social-ecological burdens and as a relational tool connecting disparate yet interconnected instances of environmental degradation. These zones are social-ecological systems in acute states of social-ecological traps, characterized by persistent harmful economic activities and environmental violence (Moeller, 2005; Holifield and Day, 2017; Danielle Mitterrand Fdn, 2019).

The urgency to address and improve the understanding of sacrifice zones relies on four main characteristics: intersectional social-ecological conflicts, social determinants of health, human rights, and lack of formal recognition. First, sacrifice zones commonly host communities facing multiple and intersectional conflicts resulting from a wide range of social

injustices and environmental degradation (Shade, 2015; Ryder, 2017; Solomonian and Ruggiero, 2021; Amorim-Maia et al., 2022; Colucci, Vecellio, and Allen, 2023; Ngcamu, 2023). Second, given that life circumstances encompassing people's birth, growth, living, working, and aging are recognized as the primary social determinants of health, sacrifice zones directly impact people's health (Curtis and Jones, 1998; Solar and Irwin, 2010; Pearce et al., 2011; Fuenzalida, Cobs-Muñoz, and Guerrero, 2013). Third, environmental injustices in these territories severely impact fundamental human rights to life, health, food, water, and sanitation (Roberts and Toffolon-Weiss, 2001; Knox, 2018; Cangelosi, 2019). Fourth, these territories often lack formal recognition, making them very difficult to address as such (Boyd and Orellana, 2022; Juskus, 2023).

These characteristics mean that the circumstances of these territories and their communities primarily affect social determinants of health and human rights, leading to a spectrum of social-ecological conflicts extending beyond asymmetrical distributions of benefits and harms in often invisibilized regions. Notable examples of sacrifice zones include the so-called 'Cancer Alley' in Louisiana, USA, where petrochemical production has increased cancer risk (James, Jia, and Kedia, 2012), and Taranto, Italy, where steel plant pollution has resulted in high mortality rates (Leogrande et al., 2019). Other examples include urgent cases of industrial pollution in Quintero-Puchuncaví, Chile, and Tulkarm, Palestine (Qato and Nagra, 2013), along with many other territories facing similar risks.

Environmental justice

Environmental justice advocates for equitable environmental conditions across all demographics, especially towards communities that have been historically overburdened, under-resourced, and marginalized. Emerging from civil rights activism, environmental justice has evolved into a fundamental framework within environmental discourses, emphasizing the local relationships between social inequities and environmental degradation (Bullard, 2000; Pellow, 2000; Anguelovski and Martínez-Alier, 2014; Martinez-Alier et al., 2014). This approach supports every individual's right to a healthy, unpolluted environment, transcending race, class, gender, ethnicity, nationality, citizenship, or any other social factors (Pellow, 2018).

Traditionally, environmental justice research focused on distributive justice, using spatial analyses to document, model, and address disproportionate environmental burdens on marginalized groups, primarily along racial and socioeconomic lines. This so-called first-generation approach often disregards broader systemic factors perpetuating environmental disparities, focusing on physical proximity to pollution sources and their direct impacts on health (Schlosberg, 2007; Walker, 2010).

Recent scholarship has expanded the scope, transitioning to what is termed second-generation environmental justice, advocating for a deeper exploration of the processes and power dynamics that sustain environmental injustices, particularly against historically marginalized groups (Pulido, 1996; Holifield et al., 2018). This includes equitable distribution of environmental burdens and benefits, procedural fairness, recognition, restorative, and intergenerational stewardship (Holifield et al., 2018; Johnson, Campbell, and Svendsen, 2020; Klepp and Fünfgeld, 2022). This broader perspective seeks to unveil the underlying societal structures influencing environmental policy and decision-making processes (Schlosberg, 2007; Holifield, Porter and Walker, 2010; Walker, 2010; Agyeman et al., 2016). Notably, Pellow (2018) introduces the concept of critical environmental justice, urging a comprehensive examination of power dynamics and systemic barriers impeding true environmental equity.

Critical realism as a structural approach

The evolution of environmental justice aligns with critical realism, particularly in addressing the complexities of social-ecological systems, such as sacrifice zones. Critical realism, initially developed by Roy Bhaskar (Archer et al., 2013), was mainly intended to address limitations in empiricism, which relies on observable regularities, and constructivism, which views social realities as entirely constructed (Gorski, 2013; Sayer, 2015). Critical realism is a guiding research philosophy adept at elucidating the complexities of environmental injustices occurring in social-ecological systems, such as sacrifice zones. It merges a realist ontology with a relativist epistemology, postulating that while a factual reality exists independently, our understanding of it is shaped by societal constructs and subjective perceptions (Bhaskar, 2009; Sayer, 2015).

In environmental justice studies, critical realism offers an approach to move beyond first-generation environmental justice to a second-generation approach that seeks to uncover the causal mechanisms underlying these injustices. This shift is transformative, as it enables the investigation of structural issues such as socio-economic policies or systemic discrimination that influence environmental harm in vulnerable communities (Gorski, 2013; Sayer, 2015). By employing critical realism, researchers can engage with complex social-ecological systems, allowing for a deeper understanding of the factors that lead to environmental inequities. This approach enables the analysis of sacrifice zones not just as physical spaces of social and environmental degradation but as manifestations of broader systemic forces, thus strengthening the foundation for transformative environmental justice.

Central to critical realism is its layered ontology, which distinguishes between the *real*, the *actual*, and the *empirical* dimension (Mills, Durepos and Wiebe, 2010; Gorski, 2013). The real dimension encompasses underlying structures and causal mechanisms that have the potential to influence events and processes independent of human awareness and, while not always observable, generate perceptible phenomena. The actual dimension involves events and processes as they occur as a result of underlying structures and/or causal mechanisms, regardless of human observation or conscious perception. The empirical dimension captures these events as experienced and interpreted by people, including data and information gathered through sensory experiences and scientific instruments (Sayer, 2015; Price and Lotz-Sisitka, 2016; Fryer, 2020).

For instance, emissions from an industrial facility can be predicted to degrade air quality (part of the real dimension). The release of pollutants might occur regardless of whether it is observed. Still, the extent of environmental and health impacts (part of the actual dimension) might vary across communities due to differences in exposure and resilience. Residents' personal experiences and responses to pollution (part of the empirical dimension) are influenced by local knowledge and cultural interpretations. The former refers to the context-specific insights and practices developed by communities through direct interactions with their environment, encompassing cultural, experiential, and place-based understandings that often complement or challenge formal scientific perspectives (Geertz, 1983; Corburn, 2003). This approach enables the analysis of scenarios where single causes lead to multiple outcomes, and diverse causes produce similar results (Sayer, 2015). For example, an industrial facility may boost economic conditions while harming the environment. Conversely, industrial emissions and agricultural runoff can both contaminate water bodies, resulting in similar public health crises.

This analytical strength helps identify key structural relationships, distinguishing necessary from contingent relations—inevitable outcomes given specific conditions versus

potential outcomes influenced by varying factors. Critical realism also differentiates between transitive (susceptible to change) and intransitive dimensions (nearly immutable), highlighting the scope and limits of potential interventions (Mukute, 2016). Works by Cox (2021) and Sayer (2015) exhibit how these structures influence actions based on temporal and spatial contexts. Uncovering underlying causal mechanisms offers insights into context-specific outcomes that are unpredictable by empirical regularities alone. Fleetwood (2005) discusses how emergent properties in these systems lead to novel phenomena and outcomes, challenging deterministic explanations and requiring a methodological stance accommodating complexity and unpredictability along human agency. As detailed by Fletcher (2017), social structures, though enduring, are subject to transformation through conscious and unconscious human actions. This interplay between structure and agency is vital for understanding and addressing the dynamics of sacrifice zones, emphasizing the potential for societal change across environmental, social, and economic dimensions.

Aligned with critical realism, agency in environmental justice frameworks operates as a counterforce within structural constraints, particularly in sacrifice zones where communities endure extensive environmental harm. Within these marginalized spaces, individuals and groups often navigate their environments through shared understandings and collective actions, reinforcing community identity and resilience. This interplay reveals how agency emerges not just as resistance but also as an affirmation of identity within challenging conditions (Popay et al., 2003). In practice, agency in sacrifice zones frequently takes the form of community-driven activism and participatory efforts, where residents leverage grassroots organizing and citizen science to generate their own data and narratives. These initiatives empower communities to challenge dominant structures, redefine environmental narratives, and advocate for meaningful change (Juskus, 2023). Thus, environmental justice struggles become dynamic arenas where agency is about contesting power and creating sustainable, life-affirming practices within adverse settings, showcasing how individuals actively work to transform their environments (Pellow, 2018).

Analytical framework

Critical realism is a research philosophy that offers a distinct layered perspective to inform and structure investigations. However, as a research paradigm, it requires additional theories, methods, and concepts to conduct actual research and address complex realities. By employing a critical realism lens, researchers can better attempt to uncover the multi-layered causalities in sacrifice zones.

Roy Bhaskar's foreword by Edwards, O'Mahoney and Vincent (2014) refreshed the concept of anti-reductionism and laminated systems, emphasizing the importance of understanding reality through different ontological levels. This approach parallels the scales of analysis in human geography and social-ecological systems. Consequently, a shift is required from focusing solely on local proximities to considering more complex, scaled spatial relations and flows to better understand social-ecological conflicts in sacrifice zones. These zones exemplify intense human-environment interactions driven by power dynamics, resulting in severe repercussions for both human and non-human communities. As Walker (2010) suggests, it is essential to explore the multiple ways in which well-being, vulnerability, and the environment are spatially intertwined. This perspective acknowledges the interconnectedness of human activities and ecosystems in the Anthropocene, where local events can escalate into global challenges and localities are continuously shaped by global dynamics (Honeybun-Arnolda, Mahony and Chilvers, 2024).

The framework here detailed guides researchers through a systematic process of identifying, analyzing, and addressing sacrifice zones. To facilitate this, we propose a clear, actionable, and adaptable guide for implementing second-generation environmental justice research on sacrifice zones, effectively bridging the gap between theoretical insights and real-world applications. The first step focuses on identifying these zones based on human rights violations and environmental degradation, setting the foundation for further analysis and intervention. The second step employs critical realism principles to analyze the underlying mechanisms perpetuating these zones.

(1) Criteria for identifying sacrifice zones

Activists and NGOs often highlight sacrifice zones to expose areas suffering from severe degradation (Valenzuela-Fuentes, Alarcón-Barrueto, and Torres-Salinas, 2021). However, governments and private companies frequently avoid recognizing these zones to evade liability and responsibility (Gayo et al., 2022). Tools such as the CDC/ATSDR Environmental Justice Index (Freelander et al., 2023) represent significant advances in identifying and prioritizing areas facing cumulative environmental and social burdens. However, since sacrifice zones, in particular, remain relatively underexplored in environmental justice research, there is limited evidence on the effectiveness of such indexes in specifically identifying these high-risk areas. The need for future adaptations of such tools to provide valuable insights into sacrifice zones is pressing. However, current limitations—including broad geographic scales, access to reliable data, equal weighting of variables, and a focus on generalized cumulative burdens—may present challenges in accurately distinguishing the intense and localized impacts that define sacrifice zones.

Therefore, identifying these zones is crucial for studying, understanding, and potentially formalizing them. In this first phase, we propose an approach grounded in the principles of environmental justice, focusing on recognition and distribution. This approach initially identifies territories flagged by grassroots movements and community activists where human rights violations indicate underlying environmental and social injustices. Following this identification, it assesses the extent of social and environmental degradation and its direct sources, helping to highlight areas in need of formal recognition and deeper study.

(a) Human rights: Identifying sacrifice zones involves recognizing areas where human rights violations are prevalent due to severe environmental injustices (Boyd and Orellana, 2022). Grassroots movements and NGOs play a leading role in consistently highlighting these territories, providing a crucial starting point for formal recognition (Valenzuela-Fuentes, Alarcón-Barrueto, and Torres-Salinas, 2021; Juskus, 2023). Human rights principles, such as those codified in the United Nations' right to a healthy environment (Knox, 2018) and the World Health Organization's guidelines on environmental health risks (Solar and Irwin, 2010), focus on the local realities of affected communities in sacrifice zones. These rights, particularly those related to life, health, food, water, and a clean environment, align with international standards and provide a robust framework for identifying these zones. The rights to life and health include protection from environmental hazards that directly impact human health and longevity. Ensuring access to safe and sufficient food and water is fundamental, as environmental degradation often compromises these resources, disproportionately affecting historically marginalized communities (Solomonian and Ruggiero, 2021). The right to a clean and sustainable environment supports the well-being of current and future generations and is closely linked to the principles of sustainable development and environmental stewardship (Bennett et al., 2018; Johnson, Campbell, and Svendsen, 2020).

Focusing on these human rights highlights areas to be potentially identified as sacrifice zones by integrating multiple forms of evidence. To substantiate the severe impacts on health, environment, and socioeconomic realities that characterize these zones, it is essential to gather quantitative data (e.g., epidemiological studies, health records, and environmental monitoring data) and qualitative data (e.g., interviews and focus groups). This combination allows for identification and formalization. Empirical studies confirm the extent of harm, and grassroots discourses highlight the lived experiences of those directly affected, validating instances where rights to health, safety, and a sustainable environment are persistently compromised (Shade, 2015; Juskus, 2023). Relevant social-ecological indicators of human rights violations include:

(i) Health indicators: Increased incidence of respiratory diseases, cancers, neurological disorders, and other health conditions linked to long-term environmental exposure serves as clear evidence of the right to health being undermined (Solar and Irwin, 2010).
(ii) Environmental indicators: Elevated levels of air and water pollution, hazardous waste sites, and deforestation or habitat destruction rates are direct indicators of environmental degradation (Knox, 2018). Environmental monitoring provides objective evidence of pollutants, while community-reported data and qualitative insights capture these pollutants' immediate and observed impact on daily life, underscoring the right to a healthy environment (Valenzuela-Fuentes, Alarcón-Barrueto, and Torres-Salinas, 2021).
(iii) Socioeconomic indicators: High poverty rates, limited access to healthcare, access to education, and other social services can exacerbate communities' vulnerability to environmental hazards, revealing disparities in availability and access to resources that disregard principles of social equity and justice (Amorim-Maia et al., 2022).

(b) Extent and direct sources of environmental degradation: Local polluting activities directly impact residents of sacrifice zones, influencing their health beyond individual risk factors (Roberts and Toffolon-Weiss, 2001; Knox, 2018). Identifying the primary sources and dynamics of pollution and environmental degradation is essential for understanding sacrifice zones' drivers. Common sources include industrial activities, agricultural practices, and urban development, each contributing differently to environmental degradation and health issues. Documenting these sources can better identify territories of influence as sacrifice zones.[1]

(2) Analytical facets of mechanisms of sacrifice

Sacrifice zones, identified according to their context-dependent definition, have causal mechanisms that create, facilitate, and perpetuate the dynamics of sacrifice. These territories endure persistent environmental injustices, and their inequalities and struggles are not identical nor uniformly materialized (Pellow, 2000; Gayo et al., 2022). However, despite their uniqueness, some common mechanisms of environmental injustices can often be recognized. Understanding these mechanisms is crucial for addressing the complex realities within these zones.

To effectively address these complexities, it's essential to analyze the underlying causal mechanisms that promote and perpetuate environmental and social injustices. This phase involves a detailed examination through critical realism's three dimensions—real, actual, and empirical. Identifying sacrifice zones highlights human rights violations and environmental degradation as key factors of social-ecological sacrifice.

To understand the structural mechanisms at play in these zones, we propose following critical realism's ontological levels for a layered analysis through the real, actual, and empirical dimensions. To this end, this subsection explores the common mechanisms found in sacrifice zones across different layers of reality—real, actual, and empirical, as defined by critical realism.

Real dimension of sacrifice

The most common mechanisms to examine in sacrifice zones at this dimension can be represented by economic exploitation, policy failures, political power, and environmental degradation. Foundational elements such as these often operate independently of human awareness but significantly impact events and processes. The real dimension of sacrifice zones encompasses the underlying structural factors that drive their creation and persistence. These factors include (a) economic exploitation, (b) policy failures and governance issues, (c) power dynamics and political control, and (d) environmental degradation and social-ecological traps. By examining these elements, we can better understand how sacrifice zones are formed, maintained, and reinforced, revealing the deep-seated issues contributing to social-ecological degradation. This section explores these factors in detail, highlighting their roles in shaping the harsh realities of sacrifice zones.

(a) Economic exploitation: Economic exploitation in sacrifice zones involves intensive use of resources for profit, often disregarding local communities and environmental health. It includes extractive industries, intensive agriculture, and manufacturing that prioritize financial gain over social and ecological well-being. The development model driving economic exploitation comprises social, economic, and political strategies at various scales, shaping the spatial conditions of these territories and communities (Brandão et al., 2021; Pérez and Marsico, 2021). Addressing sacrifice zones as products of development models allows examining their structural components, revealing the factors contributing to their existence (Hormazabal Poblete et al., 2019).

Extractivism, rooted in colonial times, is a significant promoter of sacrifice zones due to its intensive growth and resource consumption tendencies (Brand, Boos, and Brad, 2017; Irarrazaval, 2021). This model restructures landscapes and social interactions, leading to subjugation, violence, and environmental depletion (Brand, Boos, and Brad, 2017; Chagnon et al., 2022). For extractivism to thrive, certain populations must suffer in sacrifice zones to provide commodities and services. This dynamic is evident in the creation of 'Green Sacrifice Zones' for energy transitions (Hornborg, 2009; Zografos and Robbins, 2020). Concepts like environmental load displacement and unequal ecological exchange highlight these dynamics, showing how environmental burdens and resource depletion are transferred from wealthier to poorer regions, reinforcing economic dependency and environmental degradation (Hornborg, 2009, 2011; Jorgenson, 2016; Givens and Huang, 2021).

For example, the history of Quintero-Puchuncaví reflects the impacts of extractivist practices under neoliberal governance. Since the establishment of the industrial complex in the 1960s, the region has suffered from severe pollution incidents, including a major oil spill in 2014, which released 37,000 liters of crude oil into the bay. This incident underscores the environmental vulnerability imposed by industrial activities and the challenges of governance in addressing long-term ecological damage (Espinoza-Almonacid, 2016). Economic exploitation in these zones often leads to poverty traps, where communities cannot mobilize resources to overcome shocks or chronic low-income situations, resulting in persistent or worsening poverty (Tidball, 2016). Degraded resources hamper livelihoods and resource management, creating a feedback loop reinforcing poverty and

environmental deterioration (Cinner, 2011; Stedman, 2016; Barceló et al., 2024). Examples include the industrial activity in Duisburg-Marxloh in Germany's Ruhr area, resulting in poverty and environmental degradation (Kürpick and Weck, 2000), and the Chaco Region in Argentina, where habitat destruction and indigenous displacement have occurred (Zarrilli, 2020).

(b) Policy failures and governance issues: Despite their unique contexts, sacrifice zones find common ground in public policies—or the lack thereof—that approve and perpetuate, by execution or omission, the sacrifice cycle of social-ecological degradation. This cycle, often facilitated by public policies and institutional actors, primarily stems from extractivism, industrialism, and waste disposal activities. Policy failures in these zones involve inadequate regulation, poor enforcement, or a lack of focus on local communities and the environment (Brondizio, Ostrom, and Young, 2009).

Sacrifice zones are often linked to zoning and land use planning, which involves governmental involvement in transforming an area into a social-ecological sacrifice zone (Lopes de Souza, 2021). For instance, in the Appalachian region of the United States, resource exploitation is justified by portraying affected people as culturally marginal yet virtuous and patriotic (Holifield and Day, 2017). However, sacrifice zones often remain unrecognized officially due to economic and political forces prioritizing profit over community well-being.

Policy failures may manifest in two main dimensions: a multi-scale development model triggering the sacrifice cycle and a governance grid that enables it. Governance involves collective action among societal actors, including the state, for resource allocation and use. It extends beyond government structures to include NGOs, businesses, scientific communities, coalitions, civic groups, and households (Muñoz-Erickson et al., 2016; UNESCO International Bureau of Education, N.D.). In territories under extractive, waste disposal, or industrialized development models, governance often promotes growth at the expense of environmental sacrifice, framing it as necessary for progress (Valenzuela-Fuentes, Alarcón-Barrueto, and Torres-Salinas, 2021; Reinert, 2018). This degradation hampers the ability to learn, mitigate, adapt, and anticipate future occurrences, ultimately affecting environmental health, quality of life, and human rights (Fresque-Baxter and Armitage, 2012). When development models and governance systems enable extractivist, industrial, and disposal activities to overwhelm coping mechanisms, the social-ecological system degrades, transforming territories into sacrifice zones (Berkes, 2017). Thus, policy failures are intricately connected to introducing and perpetuating harmful development models and ineffective governance grids, leading to creating and maintaining sacrifice zones.

(c) Power dynamics and political control: Political power encompasses the influence, control, and decision-making authority wielded by powerful corporations, government bodies, and other entities in sacrifice zones. Sociopolitical arrangements, including policies and institutions, shape these zones and can either perpetuate or challenge their marginalization (see Brock and Dunlap, 2018). Historical processes such as (neo)colonization and globalization have left legacies of resource extraction, discriminatory policies, and social inequalities continuing to influence these areas.

The exercise of political power and power imbalance can lead to a social-ecological rigidity trap dominated by self-reinforcing institutions (Stedman, 2016; Carpenter and Brock, 2008). This trap results in inflexible governance with asymmetrical power dynamics, as seen in sacrifice zones with contentious development models (Stedman, 2016). In these contexts, those in power use established structures to control the interpretation of the sacrifice reality (Sepúlveda and Cobs-Muñoz, 2022). Despite

people inhabiting a world of meaning (Yi-Fu Tuan In Rodaway, 2011), in sacrifice zones, this meaning is often dictated by power-holders. Dominant industries shape narratives and guidelines, influencing perceptions—related to the empirical dimension. These contexts create and reinforce narratives that are difficult to criticize unless alternative critical narratives are recognized. When these alternatives gain traction, they challenge dominant actors, allowing the rise of activist groups and grassroots movements (Kurtz, 2020; Sepúlveda and Cobs-Muñoz, 2022).

Scholars like Harvey (1990; 1996; 2008), Lefebvre (1991), Lopes de Souza (2021), Massey (1994; 2005; 2007), and Said (1979) emphasize the significance of place in power relations, highlighting how it maintains social hierarchies and injustices. Power dynamics that favor certain groups exacerbate inequalities and perpetuate the cycle of resource exploitation and environmental degradation (see Fox, 1999). The resulting environmental damage often extends beyond regional boundaries, affecting transboundary resources like fisheries, rivers, and air quality.

(d) Environmental degradation and social-ecological traps: Human activities leading to pollution, deforestation, habitat destruction, and ecosystem disruption promote sacrifice zones, harming both human and non-human communities. A key mechanism that reveals environmental degradation is the phenomenon of social-ecological traps. Sacrifice zones, as social-ecological systems, are intricately linked by social, economic, ecological, cultural, political, and technological subsystems engaged in long-lasting social-ecological traps (see Petrosillo, Aretano, and Zurlini, 2015; Tidball, 2016). These traps occur when social and ecological feedbacks mutually reinforce each other, driving the system toward an undesirable locked-in state that may be difficult or impossible to reverse (Cinner, 2011; Boonstra and de Boer, 2014; Tidball, 2016). They hinder adaptation and flexibility, impeding effective responses to environmental challenges (Carpenter and Brock, 2008).

Critical realism helps recognize the complex interdependencies between social and ecological subsystems within sacrifice zones. Finding long-term solutions to social-ecological conflicts is challenging due to the interplay between polluting economic activities and the reliance on ecological resources. This dependency perpetuates a cycle of resource extraction, processing, and environmental degradation. Communities in these zones sustain social-ecological traps by heavily relying on resources without reducing their demand, creating a feedback loop supporting unsustainable practices. Limited resources, skills, and expertise compound vulnerabilities, further entrenching individuals and communities. Human responses to these traps are shaped by underlying social structures and power dynamics, often compelling people to either leave (displacement) or remain under severe social, environmental, economic, and health risks.

Actual dimension of sacrifice

The actual dimension of sacrifice zones examines the sociocultural and contextual factors that shape these areas. This analysis includes the following key elements: local contexts and scalable dynamics, socio-cultural dynamics, intersectional factors, and adaptation strategies and resilience. By exploring these elements, we gain insight into how global and local interactions, historical legacies, social networks, and power imbalances contribute to the ongoing challenges in sacrifice zones (Bernard et al., 2007; Mohai and Saha, 2015; Díaz et al., 2019). Understanding these complexities is essential for addressing the unique characteristics, interactions, and systemic issues faced by marginalized and exploited communities in these areas (Folke, 2007; Schlosberg, 2007).

(a) Local contexts and scalable dynamics: Global environmental issues are intrinsically local ones despite appearing isolated. While

environmental issues operate on a global scale, their impacts are heterogeneous at local scales, whereas major polluters exhibit more homogeneous behaviors across scales. Sacrifice zones are particularly vulnerable to these cross-scale and social-ecologically complex hazards derived from human-driven changes in biophysical processes (Díaz et al., 2019; Gayo et al., 2022).

Scientific evidence shows that the climate crisis accelerates unprecedented multi-scale processes, affecting not only ecological life support systems but also the character of particular places and, with that, their capability to locally exercise resilience (Berkes, 2017; Díaz et al., 2019; Masterson et al., 2019). In fact, Swyngedouw (1997) argues that in constructing scale and power relations, the local and global are deeply intertwined. It is the case that sacrifice zones are commonly seen through a global lens, although these dynamics are rooted and sustained locally. In the Anthropocene, particularly during the Capitalocene (see Moore, 2017), local dynamics quickly escalate to global challenges and local contexts are continuously shaped and influenced by global influences (Martín-López et al., 2020).

The effects of development models and global environmental problems are interconnected, not isolated. In sacrifice zones, inequalities arise from local and global dynamics within the economic and socio-political spectrum (Been, 1994; Roberts, Pellow, and Mohai, 2018). Moreover, Folke (2007) emphasizes that social and ecological systems are interconnected, co-evolving across spatial and temporal scales, with decisions in one place affecting people elsewhere. This interconnection promotes a scenario where provisioning for regional and global needs generates a local cycle of social-ecological failure, forming the foundation of sacrifice zones.

(b) Socio-cultural dynamics: The actual dimension examines the social networks and community relationships within sacrifice zones. These networks can either facilitate or hinder resilience, coping strategies, and community organization in response to environmental degradation and economic exploitation. Collective memory and trauma highlight how historical events (Hirschberger, 2018), such as environmental disasters or socio-economic injustices, leave lasting impacts on communities' psyches. These memories shape community responses and perceptions of future developments.

Socio-cultural dynamics reveal how social inequalities and discriminatory practices contribute to the formation of sacrifice zones. Historical legacies, systemic racism, and marginalization lead to the concentration of harmful activities and inadequate infrastructure in these areas, perpetuating a cycle of social injustice and environmental degradation. Cultural heritage and traditions of communities in sacrifice zones are intrinsically compromised (Valenzuela-Fuentes, Alarcón-Barrueto, and Torres-Salinas, 2021). Culture not only takes place but makes place (Seamon, 2018). In social-ecological systems, cultural practices and local knowledge influence resource management, ecological interactions, and social cohesion, which are crucial for adaptation and resilience (Barceló et al., 2024).

Evidence of environmental (in)justice shows that frontline communities constantly exposed to pollution, such as those in sacrifice zones, are often determined by poverty, race, ethnicity, and gender inequalities. These inequalities are rooted in racism, discrimination, (neo)colonialism, patriarchy, impunity, and political systems that systematically disregard human rights (Schlosberg, 2007; Pearce et al., 2011; Roberts, Pellow, and Mohai, 2018; Boyd and Orellana, 2022). This systematic commodification of social fabric and ecological heritage has created de facto second-class inhabitants and formalized degraded environments. Poor and marginalized communities being more heavily affected by pollution is a clear form of environmental injustice, as evidenced by Boyd and Orellana (2022) in a recent UN Report on non-toxic environments.

(c) Intersectional factors: Understanding the unique experiences of oppression and privilege within sacrifice zones requires recognizing the intersecting social categories of race, ethnicity, class, gender, and age, among other social factors. These intersections significantly impact how different groups face environmental injustices, with historically marginalized communities often bearing the brunt of these impacts. Research shows that climate change and environmental degradation exacerbate existing social vulnerabilities and create new forms of disadvantage, particularly for women, racial and ethnic minorities, low-income groups, and other marginalized populations (Ngcamu, 2023). Women and minorities are often underrepresented in adaptation planning and decision-making processes, typically dominated by technocentric approaches that overlook local needs and knowledge (Amorim-Maia et al., 2022).

To effectively address these complexities, adopting an intersectional lens is crucial. This involves analyzing the structural and systemic drivers of inequities, such as economic exploitation, policy failures, and political power imbalances, which perpetuate environmental and social injustices (Amorim-Maia et al., 2022). Understanding the historical context of racial and gender-based violence and its role in shaping current social inequalities is essential, including the systematic devaluation of marginalized groups and its integration into economic processes (Ngcamu, 2023). Adopting decolonial and place-based planning strategies recognizes traditional, situated, and local knowledge, valuing the lived experiences of marginalized communities and integrating their insights into planning processes (Amorim-Maia et al., 2022; Sultana, 2022). Promoting cross-identity and cross-vulnerability forms of activism and community resilience empowers local communities to lead changes, supporting minority-focused organizations and fostering inclusive participation in decision-making (Ryder, 2017).

(d) Adaptation strategies and resilience: Sacrifice zones provide compelling evidence for the argument made by Moore (2016) that the ongoing global climate crisis encompasses far more than just unfavorable climatic conditions. These territories are at the crossroads of multiple social and environmental conflicts, significantly contributing to and exacerbated by the climate crisis. As such, they experience intensified impacts from polluting activities, making adaptation strategies and resilience critical (Byskov et al., 2021).

Research on social-ecological systems highlights two types of adaptive capacity: objective and subjective. Objective adaptive capacity includes tangible factors such as political support, financial capital, and human resources. In contrast, subjective adaptive capacity involves how individuals and communities perceive and respond to climate change (Fresque-Baxter and Armitage, 2012). In sacrifice zones, conflicts can be perceived differently based on varying interests and perspectives, as evidenced by Hurley (1995) in Gary, IN, USA. Environmental inequalities in these areas are shaped by continuous negotiation and often conflict among multiple groups (Pellow, 2000). Effective climate change adaptation requires understanding these diverse perceptions and experiences. The success of adaptation efforts depends on the underlying values and specific attributes that communities prioritize. Respecting and integrating these diverse perspectives is essential for developing effective and inclusive adaptation strategies (Fresque-Baxter and Armitage, 2012).

Empirical dimension of sacrifice

This dimension aims to capture the lived experiences of people in sacrifice zones through qualitative and quantitative data. It includes data gathered from sensory experiences and scientific instruments, providing a comprehensive view of the impacts.

In critical realism, reality is influenced by theories but not determined by them. This theoretical perspective implies that any attempt to grasp the complexities of reality inherently involves fallibility (Bhaskar, 2009; O'Mahoney and Vincent, 2014). Interpretations from research participants, theorists, or scientists can be more explicit within the empirical dimension. Consequently, it should not be assumed that scientific explanations are consistently more accurate than experiential explanations, as all of them remain fundamentally susceptible to inaccuracies and have the potential to be fallible. As O'Mahoney and Vincent (2014) highlight, the experiences and explanations of phenomena given by the participants might indeed offer more authentic and precise insights to explain reality (see Espinosa, 2021; Otamendi-Urroz et al., 2023).

The subjective realities, perceptions, and interactions of individuals and communities in sacrifice zones are as crucial as established theories. The empirical dimension acknowledges the uniqueness of experiences within these marginalized contexts. Beyond considering the real and actual dimensions and respective mechanisms, human experiences in sacrifice zones are shaped by cultural origins, historical nuances, and daily interactions with the environment and society. This holistic approach recognizes that well-being and resilience are influenced not only by objective factors but also by subjective interpretations and emotions.

A central causal mechanism in this dimension is the concept of sense of place, which includes approaches such as identity, attachment, and dependence on the local environment. These concepts are not isolated fragments of reality but are profoundly influenced by the bonds that individuals and communities share with their environment. Place identity emerges as a cognitive bond between individuals and their physical environment, shaped by conscious and unconscious constructs (Fresque-Baxter and Armitage, 2012). Place attachment, on the other hand, refers to the emotional ties individuals and communities form with their environment, while place dependence revolves around the reliance on a particular location to meet specific goals.

The concept of sense of place acknowledges the deep interconnections between human and natural systems, framing these relationships as dynamic, adaptive, and mutually influential. Social-ecological systems research, for example, emphasizes that human well-being and ecosystem health are inextricably linked, where human actions shape ecological resilience, and ecological changes reciprocally influence social structures and behaviors (Preiser et al., 2018). This interdependence highlights how environmental disruptions—such as pollution or resource depletion—impact the social and economic conditions of communities, affecting their capacity for resilience and adaptive action (Masterson et al., 2017). Additionally, sense of place extends beyond physical attachment, encompassing the emotional and cultural bonds that connect communities to natural landscapes, which in turn influence environmental stewardship and resilience behaviors (Pellow, 2018). For communities in sacrifice zones, these landscapes are viewed as more than utilitarian resources; they are essential to cultural identity and social cohesion, intensifying advocacy for environmental justice and care-driven responses (Amorim-Maia et al., 2022). Recognizing this interconnected, symbiotic relationship underscores how changes in one domain—human or ecological—inevitably affect the other, reinforcing the call for integrated, justice-centered approaches to environmental and social well-being.

Within the broader sense of place, place meaning gains prominence. This concept is intrinsically linked to attachment, as the strength of attachment is rooted in the meanings attributed to a location. This interplay allows the exploration of conflicts between groups equally attached to a place but with divergent symbolic and emotional interpretations

(Masterson et al., 2017). Dependence, on the other hand, hinges on the quality of the place in terms of the physical and social resources it offers and its appeal compared to alternatives (Scannell and Gifford, 2010). This highlights how the attributes and resources of a place impact the behaviors and decisions of individuals and communities within sacrifice zones.

This causal mechanism shapes how communities relate to their surroundings and influences their willingness to engage in environmental conservation and sustainable practices. This analysis aims to capture the experiential realities and personal truths of individuals and communities in zones where their human rights are violated daily. It recognizes their agency and the manifold ways they interact with their surroundings. By delving into these interrelationships, a richer understanding of how individuals and communities navigate their environments and respond to the challenges of sacrifice zones can be achieved, shedding light on their struggles and potential pathways toward meaningful change.

Methodological reflection

Scientific methods serve to provide evidence from which knowledge can eventually—hopefully—emerge. There is thus an inherent connection between methodology and epistemology, and there are two general conceptions of scientific knowledge in critical realism (Zhang, 2023): one that holds that the intransitive real dimension is causally related to the two observable dimensions of the actual and the empirical, which then in turn form the source of an ontology; and a competing view that the real is not only the set of generative structures that cause the observable phenomena but also gives rise to the underlying ontology. In the first variant, the ontology is an ontology of interpretations of the world. In the second variant, ontology describes what exists beyond interpretations of it. Critical realism, as proposed by Bhaskar (2009, 36–37) and adopted in this article, is based on a hybrid of the two outlined models, distinguishing between a so-called philosophical ontology (caused by the real domain) and a scientific ontology (rooted in the experience of the world). This distinction reflects the basic assumption of separation between what exists out there and the world as perceived. In this section, this latter conception of knowledge is elucidated in a methodological context and in the setting of sacrifice zones.

Critical realism is not in itself a method but a theoretical framework (Yeung, 1997). As such, it guides us to find appropriate methods to address different ontological levels. One such guide—and an important difference between critical realism and positivism—is that critical realism specifically prompts us to investigate also the non-observable. This implies that we cannot apply empirical methods such as those of statistics, geographic information systems, and related fields. Instead, critical realism encourages that we also ask questions at the ontological and conceptual levels. For example, we have argued above that the intangible structures of economic exploitation, policy failures, governance issues, power dynamics, political control, environmental degradation, and social-ecological traps together account for the real dimension and lead to sacrifice zones. It may, therefore, be useful to ask what exactly sacrifice is, how it is constituted, what components it is made up of, and so on. Answering these questions may require the formal representation of the philosophical ontology (see above), for which various design methods can be used, including those based on predicate logic, first-order logic, and second-order logic (Aminu et al., 2020; Fernández-López and Gómez-Pérez, 2002). Based on such models, one could then use formal reasoning techniques to derive formal statements about the real domain and its constituents in combination (Frey and Cox, 2015; Lenko et al., 2019). Another way to approach the real domain in the context of sacrifice zones is to use institutional analysis (Epstein et al., 2015; Thiel and Moser, 2018).

In the case of sacrifice zones, the outlined components of the real dimension are deeply intertwined with the workings and logics of institutions and their interrelationships. Uncovering them would help identify mechanisms that would not be immediately apparent in observing manifested sacrifice, which would be captured by operationalizing phenomena of the latter. Regardless of the methods used, it is important to remember that knowledge located in the real dimension cannot be obtained on the basis of observed sacrifice. This follows from the two-fold ontological view presented above, which separates what exists at the intransitive level from what exists at the transitive level. Transferring knowledge derived from observations on one level to the other would thus lead to a logical fallacy.

Turning to the two observable dimensions of the actual and the empirical, we need to distinguish between two kinds of knowledge. One kind of knowledge concerns sacrifice zones 'as they happen out there' (the actual dimension), while the other kind of knowledge we may want to obtain relates to concrete human experiences of lived sacrifice zones—as in local knowledge. The two are very different in nature and, although related, form different knowledge systems describing different kinds of phenomena. The case of the actual dimension can be studied using established social-empirical and psychometric research methods (Rust and Golombok, 2014; Jerabek, 2015). We have identified local contexts, including scalable dynamics, sociocultural dynamics, intersectional factors, and adaptation strategies, as relevant observable properties of this dimension, and all of these properties can be studied using primary or secondary data such as the census or cadastres. This works because the actual sacrifice zone dimension is characterized by phenomena that are assumed to unfold independently of their observation. It becomes more difficult with the empirical dimension. This dimension does not describe the immediate realizations of sacrifice but their lived, first-hand, and thus cognitively processed reflections. We are thus dealing with a very different kind of dimension, which also requires a different methodological strategy.

The concept of place may be a useful catalyst for understanding lived geographical realities. For example, one might draw on a phenomenological or related kind of strategy to understand, as unbiasedly as possible, how people actually experience a sacrifice zone in action (Tuan, 2006; Seamon and Larsen, 2020; Sepúlveda, Cobs-Muñoz, and Maturana, 2023; Cobs-Muñoz and Slivinskaya, 2023). This would imply that the ontic elements we want to learn about are located in the so-called lifeworlds, that is, in the pre-scientific, often unconscious and taken-for-granted lived reality of everyday life (Zahavi, 2003, 125 *ff.*). Alternatively, one can take a poststructural standpoint and thus adopt a non-fixed ontology of lived experience in a sacrifice zone that recognizes that everything is in constant flux, in an ongoing process of constant rewiring of relationships (Cresswell, 2015). We could, for example, use the concepts and methods of actor-network theory or assemblage theory to understand this process of rewiring (Müller, 2015; DeLanda, 2016; Leszczynski, 2019; Nwankwo, 2024), which in turn would lead to an emergence that gives rise to the concrete, holistic everyday experiences in sacrifice zones. What we have just outlined are established methods in human geography and wider social sciences of how to engage with places. There is also an ongoing development in the neighboring field of geographic information science that aims to make place the object of inquiry (see Purves, Winter, and Kuhn, 2019; Westerholt, 2019; Wagner, Zipf, and Westerholt, 2020; Mocnik, 2022). The goal there is to develop a more formal apparatus for studying place. However, these approaches are still in their initial stages but could provide very interesting avenues for better understanding the empirical dimension of sacrifice zones in the future.

The approaches outlined show how different the methodologies needed for the two different forms of observable phenomena of sacrifice zones are while the actual dimension can rely on traditional social-empirical and psychometric approaches due to its objective character, the complex experiential worlds of life in a sacrifice zone require methods that take holism, multidimensionality, and subjectivity into account.

Planning for environmental justice

Understanding sacrifice zones is important. However, it is also relevant to bear in mind the role of planning in how sacrifice zones manifest. Planning for environmental justice within sacrifice zones necessitates a multifaceted approach that integrates various principles and methodologies to address inequities and promote sustainability (Ntiwane and Coetzee, 2018). These approaches must be tailored to local-specific realities, addressing the intertwined issues of equity, sustainability, and economic development (Campbell, 2016). This section outlines essential steps and considerations for achieving just and sustainable outcomes, including procedural and restorative justice, intergenerational stewardship, and scenario planning.

Klein (2016) underlines the idea of an intellectual justification behind the existence and persistence of sacrifice zones, encapsulated in what the author calls 'sacrifice zone mentality,' targeting either people or places. In the context of environmental planning and policymaking, sacrifice zones often result from the complexities of capitalism, influenced by globalization and formal planning mechanisms (Klein, 2016; Kurtz, 2020). Therefore, principles like prevention, precaution, and non-discrimination emphasize the need to understand sacrifice zones for effective action (Ntiwane and Coetzee, 2018). Resolving this requires addressing power dynamics, policy flaws, and economic exploitation driving these zones while respecting affected communities' experiences and cultural identities (Jokela-Pansini and Militz, 2022).

To ensure fair, inclusive, and transparent decision-making processes, procedural justice is vital. This allows historically marginalized communities to have a voice in the policies that affect them, ensuring their needs and concerns are addressed. Engaging all actors and rights holders, especially those from overburdened communities, fosters diverse perspectives and equitable representation in decision-making processes (Agyeman et al., 2016; Loos et al., 2023). Transparent processes build trust between communities and planners, facilitating better cooperation and policy implementation (Ntiwane and Coetzee, 2018). In Quintero-Puchuncaví, Chile, the formation of grassroots movements, such as 'Mujeres de Zonas de Sacrificio en Resistencia' (in Spanish for Women of Sacrifice Zones in Resistance), highlights local efforts to demand accountability and environmental protection. This group has mobilized to raise awareness and advocate for legal action, leveraging collective power to challenge extractivist policies and promote an alternative vision based on care ethics and community resilience (Bolados-García and Sánchez-Cuevas, 2017)). In Louisiana's Cancer Alley, a stretch of industrialized communities along the Mississippi River in the United States, grassroots organizations like the Louisiana Bucket Brigade and community activists have mobilized to document and protest the environmental injustices affecting their communities. Using tools such as EPA-approved 'grab air' buckets, they gather air quality data to hold industrial plants accountable, a task largely unaddressed by local regulatory agencies. These actions underscore the role of procedural justice by giving voice to marginalized communities and pushing for transparency in pollution reporting (Randolph, 2021).

Restorative justice, on the other hand, focuses on repairing the harm caused by environmental injustices. It acknowledges historical wrongs and seeks to provide compensation or remediation

(Pellow, 2018). Implementing projects that directly benefit affected communities might contribute to restoring their health, environment, and well-being. Facilitating conversations between affected communities and policymakers acknowledges past grievances and co-creates solutions. Following the previous example, recent efforts to address pollution in Quintero-Puchuncaví have focused on limited remediation and health interventions. Local and national policies have introduced health monitoring for residents and minimal emission reduction requirements for industries. However, these responses are often seen as insufficient by the local community, which calls for more comprehensive restoration and accountability measures to repair long-term harm (Valenzuela-Fuentes, Alarcón-Barrueto, and Torres-Salinas, 2021). Along the same line, efforts to address the legacy of industrial pollution in Louisiana include community-led campaigns for stricter regulations and pollution reductions. However, community members argue that merely reducing emissions is insufficient for genuine restorative justice. True restoration, they assert, would involve more extensive reparations and health programs to mitigate decades of exposure to hazardous chemicals, providing long-term relief to affected residents (Roberts and Toffolon-Weiss, 2001; Randolph, 2021).

Intergenerational stewardship emphasizes the responsibility of current generations to manage resources sustainably to ensure the well-being of future generations (Pellow, 2018). This is crucial for long-term environmental justice and sustainability. Practices that preserve natural resources and reduce environmental degradation are essential for maintaining ecosystem health for future generations. Embedding principles of sustainability and stewardship in planning policies ensures that long-term environmental health is prioritized (Pellow, 2018). The Netherlands' Delta Plan for sustainable water management exemplifies intergenerational stewardship by focusing on flood protection, freshwater supply, and environmental conservation for future generations. Spatial planning must consider long-term impacts to ensure sustainability and the well-being of future populations (Campbell, 2016).

Scenario planning offers a strategic method to anticipate and prepare for future challenges and opportunities, particularly in the context of environmental justice Lembi, Wentworth, and Hodbod (2024). By creating detailed narratives about various possible future conditions, planners can develop flexible and robust strategies to address uncertainties and ensure adaptable outcomes (Brinkley and Wagner, 2024). This process involves identifying key drivers, developing narratives, evaluating impacts, and formulating strategies. Identifying key drivers requires considering various environmental, social, and economic factors (Campbell, 2016). Developing diverse and plausible scenarios helps understand potential future conditions (Brinkley and Wagner, 2024). Evaluating the potential effects of these scenarios on different aspects of society and the environment ensures comprehensive and effective planning strategies (Maciejewska and Ulanicka-Raczyńska, 2023). Finally, formulating adaptable strategies based on the scenario analysis is crucial for strategic planning (Ntiwane and Coetzee, 2018).

Conclusions

In this article, we have explored and discussed the intricate dynamics of sacrifice zones through the lenses of critical realism and second-generation environmental justice. By examining these zones across the real, actual, and empirical dimensions, we have provided a comprehensive framework to enhance our understanding of the multifaceted nature of environmental and social injustices embedded in these areas. Our theoretical exploration and discussion build on the work of scholars such as Holifield and Day (2017), Reinert (2018), Lopes de Souza (2021), Valenzuela-Fuentes, Alarcón-Barrueto, and Torres-Salinas (2021), Juskus (2023), and Perkins (2024), asserting that

sacrifice zones are shaped by deep-rooted structural factors such as economic exploitation, policy failures, power dynamics, and environmental degradation.

These structural factors would enable inhabitants of sacrifice zones to experience social, cultural, and economic disadvantages, often lacking the resources and agency to advocate for their own well-being and health (Bernard et al., 2007). Consequently, they face increased vulnerability to adverse health outcomes and social hardships, leading to coerced surrender of ecological settings and compelled societal adaptation. These realities operate within a complex web of social-ecological systems, perpetuating cycles of poverty, health disparities, and environmental harm that affect groups differently. Recognizing this intersectionality of social, cultural, and demographic factors allows for a better understanding and addressing of the lived experiences of marginalized communities in sacrifice zones. This understanding is crucial for developing inclusive and just policies and interventions, ensuring that all voices are heard and all needs are considered. Integrating local knowledge and deep engagement with stakeholders and rights holders can enhance the effectiveness of sustainability initiatives and promote just outcomes in environmental governance (Martín-López et al., 2020; Loos et al., 2023).

Integrating critical realism with second-generation environmental justice principles offers a robust framework for identifying and addressing the driving forces and structural forms of sacrifice zones, as critiqued by Perkins (2024). This approach underscores the argument made by Pellow (2018) about the need for equitable distribution of environmental benefits and burdens while emphasizing procedural fairness, recognition, and restorative justice. This aligns with Grossmann et al. (2022) and Zografos and Robbins (2020), who articulate a shift from sustainability to social-ecological justice and just transitions, highlighting the intertwined nature of social and ecological concerns and the limitations of traditional sustainability frameworks in addressing deep-rooted injustices.

While our work provides significant theoretical insights, it acknowledges its limitations, particularly the reliance on existing literature and theoretical frameworks, which may overlook context-specific nuances. Continuous refinement of methodologies and approaches is necessary to adapt to the evolving challenges and complexities of sacrifice zones. Future research should focus on empirical studies that validate and expand upon the theoretical insights presented in this article. Longitudinal studies tracking the impacts of interventions over time and assessing their effectiveness in fostering environmental justice are needed. Furthermore, exploring the role of emerging technologies and participatory methods in enhancing community resilience and adaptive capacity in sacrifice zones could provide valuable directions for further investigation.

In conclusion, this article provides a detailed theoretical examination of the mechanisms and dynamics that create and sustain sacrifice zones. By employing a critical realist approach, we offer a nuanced understanding of these zones, emphasizing the importance of integrating equity, sustainability, and social justice into environmental planning and policy-making. Addressing the challenges of sacrifice zones requires a commitment to systemic change and a willingness to embrace complexity, ensuring that the voices of the most affected communities are central to pursuing a just and sustainable future. As Boyd and Orellana (2022) assert, sacrifice zones embody the utmost failure of a State's responsibility to uphold the right to a clean, healthy, and sustainable environment. Embracing this holistic framework paves the way for transformative approaches to confront the systemic challenges faced by sacrifice zones, creating a more just and equitable future.

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Note

1. For additional methods related to studying sacrifice zones, please refer to the 'Methodological reflection' section of this article.

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