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LETTER

Traversing the food-biodiversity nexus towards coexistence by manipulating social–ecological system parameters

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Abstract

Agroecological landscapes have the potential to simultaneously meet food security and biodiversity conservation goals but are hindered by emerging biodiversity conflicts. Here, we opt to view the social–ecological factors that decrease biodiversity impacts or increase tolerance of biodiversity in agroecological landscapes as system parameters for their potential capacity to move a social–ecological system from states of conflict to alternative desired system states devoid of major losses for both food security and biodiversity, that is landscapes of coexistence. We discuss how reframing landscapes as social–ecological systems allows focusing on manageable components, or *coexistence parameters*, that explain biodiversity impacts and are hence capable of dampening conflicts. Approaches from the social, economic, or ecological sciences allow for the formulation of management strategies tailor-made for each system, with a higher chance of success than one-size-fits-all strategies. Conceptually recognizing coexistence parameters may enable easier assessment of a landscape's current state and identification of the required actions needed to transition towards a state of coexistence.

KEYWORDS

conflict reconciliation, conflict resolution, human dominated landscapes, human–nature coexistence, human–wildlife conflict, land-sharing

1 | INTRODUCTION

Agroecological landscapes have the potential to simultaneously meet food security and biodiversity conservation goals. This potential cannot be achieved without ensuring human–wildlife coexistence (Crespin & Simonetti, 2019). Such coexistence entails the elimination and prevention of conflicts which exist at multiple levels of complexity and intensity (from short-term, superficial disputes down to deeper conflicts involving parallel solutions such as from the social, economic, or ecological fields) (Madden & McQuinn, 2014) and stem from the interactions between human activities and wild nature (Young et al., 2010). The most immediate, but no less important, conservation conflicts are those that emerge directly from a biological basis and are predicated on quantitative tradeoffs between conservation interests and food productivity (Crespin & Simonetti, 2019). When these seemingly opposing interests that impact either society or biodiversity are based on clear social–ecological components, conceptualizing the landscape as a system can allow it to be managed by understanding underlying dynamics and processes. This enables the identification and manipulation of parameters that lead to states of human–wildlife (and eventually human–nature) coexistence.

Land solely for nature is increasingly rare (Ellis, Klein Goldewijk, Siebert, Lightman, & Ramankutty, 2010) and projected to be insufficient for conserving the world's species (Svancara et al., 2005). Thus, already transformed land can either be restored to a state resembling nature-dominated landscapes akin to a time before anthropogenic transformation occurred or reframed into multiuse landscapes, allowing for both nature and human activities to integrate, such as in agroecological landscapes. The latter is the land-sharing approach, originally devised from a mathematical model describing tradeoffs between food production and wildlife abundances where low intensity farming enables wildlife to occupy the same land (Green, Cornell, Scharleman, & Balmford, 2005). A framework has been introduced to analyze and navigate this food-biodiversity nexus, the "social–ecological systems model of the food security-biodiversity nexus" (Fischer et al., 2017). The food-biodiversity nexus describes a simple model based on two axes (biodiversity and food security) and the resulting four quadrants which illustrate alternative system states that emerge depending on the tradeoff between food security and biodiversity in a landscape: degraded lands, intensive agricultural landscapes, fortress conservation, and agroecological landscapes (Figure 1). The food-biodiversity nexus assumes that both axes are orthogonal, which is not necessarily so since food security might be enhanced by biodiversity and vice versa, but as a conceptual model it describes the general tradeoff as zero-sum optimization. Among these available system states, only the agroecological landscape optimizes both food security and biodiversity on the same land, that is the land-sharing approach. Land-sharing requires abdicating complete human domination of a landscape and establishing a degree of syntopy between wildlife and domesticated plants or animals meant to be reared as food for human society. This scenario is primed for the emergence of conflicts.

Human–nature coexistence is required to fully transition towards land-sharing (Crespin & Simonetti, 2019), and thus it is also necessary to navigate the nexus from any alternative system state to an agroecological context. We propose navigating the nexus by searching for parameters that determine the impacts driven and felt by opposing interests in a social–ecological system. Specifically, we view these *coexistence parameters* as the tangible and perceived variables that dictate coexistence in a system and thus are subject to management. Our aim is to demonstrate how these coexistence parameters can be identified and used to navigate the nexus towards land-sharing.

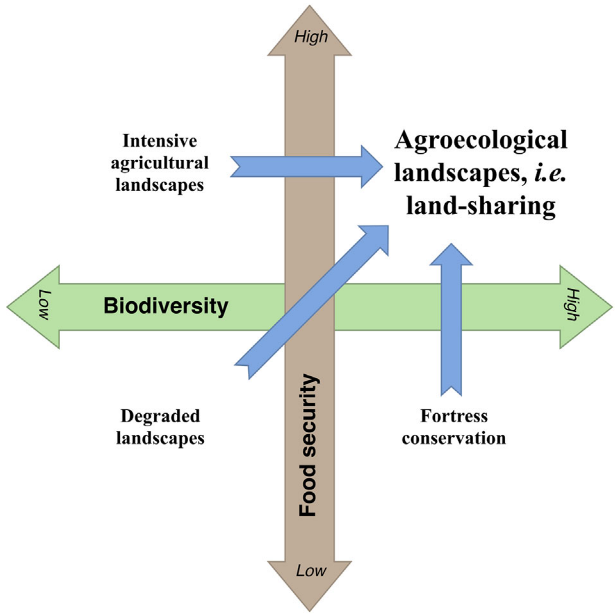

FIGURE 1 The social–ecological systems model of the food-biodiversity nexus presents four quadrants depicting alternative system states emerging as tradeoffs between food security and biodiversity in a landscape, wherein only agroecological landscapes optimize both food security and biodiversity by sharing land. This model is a jumping-off point for conceptual viewing of landscapes as systems and allows abstract identification of possible parameters to nudge a system towards land-sharing. Adapted from Fischer et al. (2017)

2 | CONCEPTUAL IDENTIFICATION OF COEXISTENCE PARAMETERS

Social–ecological systems are interlinked societal and environmental components whose dynamics are shaped by drivers at multiple spatial and temporal scales, which may exist in alternative system states (Fischer et al., 2015). Agroecological landscapes can be understood as social–ecological systems when their major social and ecological components are identified. However, not all the components in a system directly interact in the formation of biodiversity *impacts*: the situations where people negatively impact biodiversity or biodiversity negatively affects human wellbeing (Young et al., 2010). Furthermore, biodiversity impacts may turn into conservation *conflicts* once an affected party finds they need to eliminate a biodiversity impact, giving rise to opposing interests between societal and conservation goals (White et al., 2009). Conflicts, by definition, impede coexistence and if left alone often result in retaliation against the involved wildlife or aspect of biodiversity. Therefore, to determine which social and ecological factors interact in the development and maintenance of a conflict we must first understand how the underlying biodiversity impact emerges. Innovative and participatory approaches will be necessary to properly understand biodiversity impacts—such "social–ecological experiments" (Gaba & Bretagnolle, 2020) should focus on manipulating the social and ecological processes that shape the system and allow situations to arise that give way to opportunities for impacts to occur. Once the formation of biodiversity impacts is sufficiently understood and the factors that directly explain the impact are identified, we may determine which social–ecological factors can be subjected to management strategies so as to minimize or eliminate the impact and quell the conflict. Reframing agroecological landscapes as social–ecological systems allows us to conceptualize social and ecological factors as system components and focus specifically on those manageable components that explain biodiversity impacts and are hence capable of dampening conflicts. Since managing social–ecological components can in theory eliminate the source of conflicts and shift a system from a state of conflict towards one of coexistence, we can say to have identified the coexistence parameters for that system (Figure 2). Much like how ecosystems are subject to regime shifts (Horan, Fenichel, Drury, & Lodge, 2011), we can imagine social–ecological systems to hold thresholds or tipping points between states of conflict or coexistence. The specific social–ecological components that explain biodiversity impacts and consequently the emergence of conflicts also define the conditions the system requires for coexistence, hence the reason we consider them to be coexistence parameters.

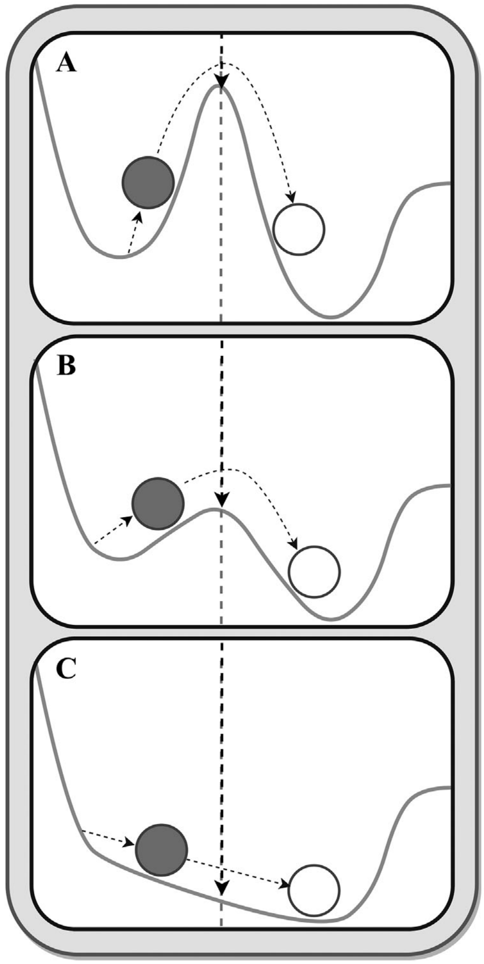

FIGURE 2 Parameters define a state of conflict or coexistence in agroecological landscapes conceptualized as social–ecological systems, and those that can be manipulated should enable management to move the system to a desired state. Coexistence parameters (grey solid line) define equilibrium points and where the system can move. Social–ecological systems can either be in a state of conflict (dark grey circle) or coexistence (hollow circle). Changes in parameter values (black dotted lines) allow equilibrium points to move, and system states to follow suit. (a) Human-dominated landscapes in conflict require large investments of time, resources and effort to resolve conflicts. (b) Identifying and managing parameters that define the system state decrease the investment needed for the state shift. (c) An ideal scenario where all parameters have been identified and dealt with will allow the system to reach coexistence on its own without further investments. The same factors do not always define the same state of coexistence in every landscape, thus coexistence parameters should be system specific

2.1 | From social–ecological drivers to coexistence parameters

To illustrate how coexistence parameters might be identified, first we must recognize possible ecological drivers of biodiversity impacts and social drivers of tolerance to these impacts. Social and ecological systems on their own exist within levels, such as ecosystems, communities, populations, and individuals or society, institutions, groups, and again individuals. Therefore, when aspects from the social and ecological realms interact within social–ecological systems, the resulting impacts can be felt at specific levels (Lischka et al., 2018). Defining the hierarchical level at which social–ecological drivers operate to generate biodiversity impacts is crucial to identifying possible coexistence parameters.

The most prominent biodiversity impacts result in human–wildlife conflicts, such as when carnivores kill livestock or herbivores steal crops for consumption, hurting farmers' livelihoods in the process and in many cases leading to persecution of wildlife (Baker, Boitani, Harris, Saunders, & White, 2008). When biodiversity impacts occur at the individual level, operational social–ecological drivers may stem from factors that affect animal behavior and human tolerance towards the impact (Lischka et al., 2018). However, impacts might occur at broader scales or higher levels, such as when crop raiding, by large elephant herds, primate groups, or flocks of birds, impacts entire human communities. Therefore, it follows that if the level at which biodiversity impacts occur broaden, so too must the social and ecological factors that drive them.

Ecological drivers that influence animal behavior have traditionally been the subject of studies in ecology. Shifts in resource availability affect the probability of attacks on livestock, crops, or people. Decrease in wild prey biomass increases the number of sheep and cattle killed by big cats (Khorozyan, Ghoddousi, Soofi, & Waltert, 2015), and the lowering of prey density during wet seasons increases lion, cheetah and leopard attacks on cattle, goats and sheep (Bagchi & Mishra, 2006; Kolowski & Holecamp, 2006; Mishra, 1997; Patterson, Kasiki, Selempo, & Kays, 2004). The physical characteristics of the habitat and structures surrounding livestock can also alter livestock vulnerability (Kolowski & Holecamp, 2006), since stealthy predators might prefer attacking unaware prey under the presence of cover or when closer to reserves or habitat fragments (Michalski, Boulhosa, Faria, & Peres, 2006; Schiess-Meier, Ramsauer, Gabanapelo, & König, 2007; Van Bommel, Bij de Vaate, De Boer, & De Iongh, 2007). Landscape level thresholds for natural habitat can prevent impacts from taking place, evidenced through a deforestation threshold of 30–40% to avoid human–elephant conflicts (Chartier, Zimmerman, & Ladle, 2011). Weather patterns that affect natural food availability such as those relating to draught have also been associated with primate crop raiding (Naughton-Treves, Treves, Chapman, & Wrangham, 1998), while some highly palatable crops are sought after year round with no regard to other food sources, in which case increasing distance from the forest boundary used by primates can be the best option (Hill, 1997; Naughton-Treves et al., 1998).

Social aspects that drive tolerance are equally important in determining whether biodiversity impacts become conflicts (Dickman, 2010). These can range from well-understood impacts, such as those directly responsible for loss of economic solvency, to deeper rooted identity-based factors involving cultural values (Madden & McQuinn, 2014). Government helmed top-down management strategies can be perceived as disempowerment by local communities, further decreasing tolerance towards wildlife (Dorresteijn, Milcu, Leventon, Hanspach, & Fischer, 2016). High economic solvency can offset the loss of livestock or crops, since wealthier landowners may be less impacted by the same amount of livestock or crops lost than smaller landowners. Thus, while most stakeholders could accept compensation as a strategy to manage conflicts, it may not increase their tolerance (Naughton-Treves, Grossberg, & Treves, 2003). This is because these top-down strategies do not address the hidden root causes of many conflicts: the psychological trauma, cessation of daily normalcy, and unrealized food security (Barua, Bhagwat, & Jadhav, 2013). These root causes are hidden because nonmaterial costs incurred by local communities due to conservation actions or successes are not easily measured, yet must be taken into account if resolutions are to be achieved (Thondhlana et al., 2020). Monetary or physical losses may not even need to be present for conflicts to emerge, since the mere perception of a biodiversity impact can trigger feelings of threat (Dickman, 2010) and the perceived risk of losses to wildlife is usually higher than in reality (Hill, 2004). Cultural or religious values can also be broader level social drivers of tolerance (Zinn, Manfredo, & Vaske, 2000), further complicating matters.

Landscapes where carnivores and livestock, or herbivores and crops, co-occur are at risk of generating biodiversity impacts. However, determining what factors predict these impacts might allow for modifications to management regimes that lower livestock vulnerability to predation or probability of crops being raided. Once identified, these clear and manageable impact drivers can act within the food-biodiversity nexus as coexistence parameters in food production systems.

We propose that for a landscape pertaining to a particular social–ecological system, if an identifiable factor drives the source of biodiversity impacts or societal tolerance and can be manipulated sufficiently well to allow for the formulation of management strategies, then we can interpret them as coexistence parameters in that particular system for the purpose of transitioning the system towards coexistence and a true agroecological landscape.

2.2 | Usefulness of the coexistence parameter concept

Here, we opt to view the social and ecological factors that decrease biodiversity impacts or increase tolerance as system parameters. This is due to their potential capacity to move a social–ecological system from states of conflict to alternative desired system states devoid of major losses for both food security and biodiversity, *i.e.* coexistence. However, social–ecological systems are complex, with multiple components stemming from both people and nature, shaped by intrinsic and extrinsic societal and ecological variables (Fischer et al., 2015). These systems are interlinked across scales, they do not exist alone (Ostrom, 2009). Hence, multiple variables are expected to require managing to transition from one system state to another. The same can be said of those social–ecological systems working towards land-sharing scenarios and seeking to transition towards agroecological landscapes, since emergent conflicts may not solely depend on one variable, dampening the opportunities for coexistence when either food security, biodiversity conservation, or both are threatened. In fact, management interventions

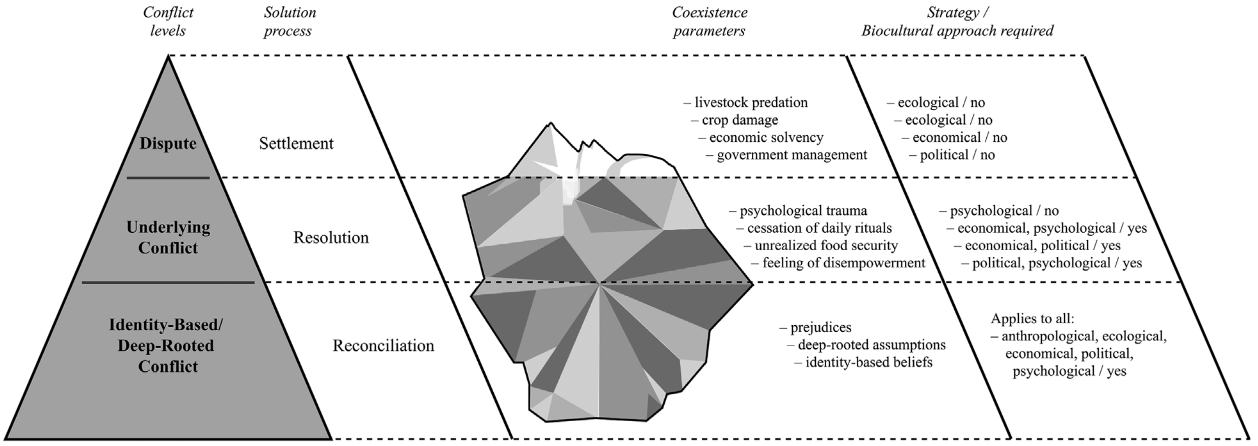

FIGURE 3 Deeper levels of conflicts and their solution processes may require approaches with an increasing number of disciplines and level of integration due to increased complexity, which may necessitate the use of biocultural approaches. The levels of conflict model classifies conflicts and their solution processes in order of increasing complexity and intensity towards the base of the pyramid. We choose to visualize the model through an iceberg metaphor that helps understand how underlying and deep-rooted conflicts remain hidden at first sight. Variables that define whether an agroecological landscape is in human–nature conflict or coexistence act as system parameters and thus can be managed to shift a state towards coexistence. Parameters are simpler at the top and increase in complexity near the bottom. Strategies to manage parameters might require single disciplines at the top but increase in number towards the bottom along with the level of integration needed. Biocultural disciplines might emerge as necessary. Source adapted from Madden and McQuinn (2014) and the Canadian Institute for Conflict Resolution (2000)

employed specifically in carnivore–livestock conflicts have resulted in varied context-dependent successes and failures (Wilkinson et al., 2020). One-size-fits-all approaches have not been found suitable due to widely varying realities between landscapes (König et al., 2020) and even communities (Perry, Moorhouse, Loveridge, & Macdonald, 2020), supporting the need for integrated and participatory research when resolving human–nature conflicts and achieving coexistence.

Conflicts occur at differing levels of complexity (Lederach, 2003; Madden, 2004; Madden & McQuinn, 2014). Best visualized by the levels of conflict model (Canadian Institute for Conflict Resolution, 2000), mere disputes can be settled by managing concrete ecological variables and mitigating biodiversity impacts. However, unsettled disputes can build up emotions and create underlying conflicts that require resolution, and further deep-rooted prejudices require reconciliation tactics. As such, when conflicts deepen, the variables that affect tolerance may become harder to distinguish, separate from each other, or might increase their interactions. Thus, the number of variables that need to be addressed might increase, which ultimately obstructs the identification of coexistence parameters. Indeed, reaching sustainability levels where human–nature coexistence is achieved requires approaches that address a plurality of knowledge and worldviews through inter- and transdisciplinary sciences—*i.e.* biocultural approaches (Hanspach et al., 2020). Therefore, when managing a social–ecological system for conflicts, one should expect a multiplicity of parameters defining the system state. Because of this operational complexity, conceptually recognizing parameters that define a desired system state may enable easier assessment of a landscape's state and identification of the required actions needed to transition towards coexistence.

We find it helpful to visualize the levels of conflict and their solution processes through the often-used iceberg metaphor. A captain of a ship at sea trying to remain afloat must not just contend with the ice that is above sea level, but must also remain vigilant of the rest of the ice that makes up the bulk of the perilous iceberg. Likewise, conservationists trying to solve a conflict are captains of a ship (*i.e.*, landscape) carrying both people and wildlife, and only contending with disputes without awareness over possible underlying or deep-rooted conflicts will more often than not lead to failures. This vigilance extends to increased use of inter- and transdisciplinarity and more diverse biocultural approaches. Thus, deeper conflicts may require solutions with increased complexity regarding the number of disciplines and their level of integration (Figure 3). For example, when an underlying conflict is based on perceived damages that do not exist, no matter how much loss to predation is reduced or even eliminated by managing ecological variables, if stakeholder perception remains unchanged (*i.e.*, nonmaterial costs are not addressed), the underlying conflict will not be resolved. In deep-rooted conflicts, prejudice may take hold in belief systems or even form part of a community's identity. Persecution of carnivores that are not large enough to attack livestock and other trophically unrelated groups incapable of the same feat is a common occurrence in many local communities and can even become culturally ingrained (Dickman, 2010). Communities dependent on landscapes with fewer sources of food and shelter for livelihood also tend to become antagonistic towards wild animals because they are more vulnerable: they have more to lose than those who enjoy multiple sources of wealth and income (Sjoberg, Moen, & Rundmo, 2004). Defense against wildlife becomes part of the way of life. These cases show deeper levels of conflict that are more complex than quantitative tradeoffs of food production and biodiversity. Their unique social–ecological context is translated into unique combinations of social–ecological variables that dictate a state of conflict, and thus also the parameters capable of transitioning the system into the target state of coexistence. Therefore, determining what variables must be managed in order to allow human–wildlife syntopy (identifying possible coexistence parameters), no matter whether they must be approached from the social, economic or ecological sciences, might allow for the formulation of management strategies tailor-made for each system with a higher chance of success than one-size-fits-all strategies based on general patterns.

2.3 | Caveats

Here we emphasize that conflict resolution methods require management at the local level. We mean to illustrate how coexistence parameters can be identified to work in the context of the "food-biodiversity nexus" conceptual framework. Thus, we do not intend to offer the complete repertoire of coexistence parameters that a complex social–ecological system immersed in underlying conflicts would truly need to rely on for coexistence. Also, we acknowledge a risk of confusing the concepts of "variables" and "parameters" when referring to social–ecological system attributes as either. It is a matter of perspective: when assessing multiple landscapes, an attribute measured in each one can be a variable (as is normally done), but act as a state defining parameter when viewing each landscape as a system and multiple landscapes as interconnected systems.

3 | CONCLUDING REMARKS

The social–ecological systems model of the food-biodiversity nexus provides distinct system states of which agroecological landscapes represent the land-sharing strategy, a necessary approach to biodiversity conservation in a world devoid of sufficient land for nature. Since sharing land requires reaching human–wildlife coexistence, we sought to exemplify the searching of parameters that when modified can enable coexistence dynamics in these systems. In general, conceptual identification of coexistence parameters for each system with conflicts will reveal unique parameter combinations. Hence, manipulation of just one ecological or social factor component might not be enough to reduce biodiversity impacts or increase tolerance levels, instead requiring tailor-made management of multiple parameters to transition towards coexistence states. As a concept, social–ecological systems provide a means to analyze the food-biodiversity nexus. We hope our reframing of the various possible variables from distinct disciplines that can be managed for coexistence as parameters in systems helps in this endeavor. Abstract thinking approaches problems in a new light, such that interpreting agroecological landscapes as social–ecological systems at the conceptual level enables variables that dictate impacts or tolerance to be regarded as system parameters of coexistence, allowing for more effective transition strategies. A shared landscape, reaching coexistence with nature while we produce our sustenance, is a win-win scenario where we protect biodiversity while maintaining the necessary components for ecosystem services, so we may call them what they should be: landscapes of coexistence.

> Conservation is a state of harmony between men and land. … Harmony with land is like harmony with a friend; you cannot cherish his right hand and chop off his left. That is to say, you cannot love game and hate predators; you cannot conserve the waters and waste the ranges; you cannot build the forest and mine the farm. The land is one organism.
>
> Leopold (c. 1953).

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

AUTHOR CONTRIBUTIONS

Concept, design, and drafting of the manuscript was done by Silvio J. Crespin. Critical review of the manuscript was done by Silvio J. Crespin and Javier A. Simonetti.

ETHICS STATEMENT

The authors declare that human ethics approval was not needed for this study.

DATA ACCESSIBILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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