



Polygenic Risk Factors for Psychological Resilience in Seasonal Tourism Communities and Insights from Epigenome-Wide Association Studies

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ABSTRACT

Seasonal tourism communities experience cyclical environmental, economic, and social stressors that influence individual and community-level psychological resilience. Resilience—the ability to cope with, recover from, and adapt to adversity—is shaped by both genetic and epigenetic factors. Polygenic risk scores (PRS) capture inherited contributions to resilience-related traits, while epigenome-wide association studies (EWAS) identify environment-responsive epigenetic modifications, including DNA methylation, histone changes, chromatin accessibility, and transcriptional biomarkers. Seasonal fluctuations in tourism, economic volatility, and climate variability intersect with these biological pathways, modulating stress response and recovery. Social-ecological mechanisms, such as social support, infrastructure adaptability, and community cohesion, further mediate resilience outcomes. Integrating polygenic and epigenetic insights with socio-environmental frameworks can inform interventions to enhance psychological resilience in populations exposed to periodic high-intensity environmental stressors.

Keywords: *seasonal tourism, psychological resilience, polygenic risk, epigenome-wide association studies, DNA methylation, histone modification, chromatin accessibility, socio-ecological model, community adaptation.*

INTRODUCTION

Psychological resilience describes the ability of individuals or communities to cope with acute adversities and adapt positively to ongoing stressors ((Renato) Polimanti et al., 2018). Resilience encompasses not only the successful navigation of stressors but also the learning and growth that occur as a consequence of these life challenges. Seasonal tourism communities face multiple environmental stressors but can utilise social

mechanisms and programmatic responses to cope and adapt. They therefore constitute a relevant, albeit underrepresented, context for resilience research.

Every environmental exposure modifies physiological and psychological health through biological processes. It is plausible that especially impactful seasonal exposures modulate psychological resilience through epigenetic mechanisms. Polygenic risk factors might exert pervasive influence across biological and behavioural domains, while seasonal exposures intersect with psychosocial, administrative, and economic channels involved in the coping response. Seasonal tourism communities operate under the same polygenic and epigenetic constraints as any other environment; their stressors thus present a unique opportunity for testable, targeted, and transferable research on seasonal psychological resilience.

Epigenome-wide association studies (EWAS) identify environmental agents impacting resilience through genome-wide examination of epigenetic marks in community-dwelling populations. Polygenic risk scores (PRS) quantify genetic resilience across DNA variants currently linked to resilience-related phenotypes in general populations. Two-step models have already been developed linking folate-associated EWAS signals in males to polygenic PRS controlling for socioeconomic status. Polygenic and epigenetic factors are equally relevant to psychological adaptation in seasonal tourism areas exposed to seasonal variations, climate change, and economic volatility.

Conceptual Framework: Psychological Resilience in Seasonal Contexts

Psychological resilience is the capacity to cope with stress, adapt to changes, and recover quickly in the aftermath of challenging experiences (Ungar et al., 2021). People who are psychologically resilient are better able to manage difficult experiences across multiple domains of life. Resilience is influenced by polygenic risk factors and can be enhanced by epigenetic mechanisms. The effects of the seasonal tourism industry cycle on resilience in seasonal tourism communities have not been studied. Seasonal tourism locations are characterised by high population fluctuations, economic instability, and rapid turnover in both resident and tourist populations. Global changes in climate and stunting of the economy of domestic tourism, further magnified by an upsurge of domestic pandemics, are also added. The seasonal cycle of tourism alters stressors such as economic instability and turnover, and accordingly seasons may have different influential strategies for coping. Social-ecological models are generally used to explain resilience in seasonal tourism communities (Abdurakhmanov, J., et al). A gene and environment framework will elaborate further on seasonal tourism cycles as influencing mechanisms. Seasonal options of length of season, climate regularity, and number of peaks on economy apply to candidates. Polygenic risk scores and epigenome-wide association study signals are two critical components on exam. Further lot of studies operate on cross-sectional design and the degrees of completion are rather low.

Seasonal tourism communities face a few environmental stressors associated with high process rates of visitors. Climate plays a central role in dictating the attraction of Seasonal tourism in many communities, and thus various levels of climatic-induced observations can be seen, for instance, on the different magnitudes of variations in climatology of different tourism models. The implications of these environmental changes operate on the biology as well as on the social side of the human pathway. Seasonal Tourism in Circular Economy (STCE) prevents irreversible environmental degradation on the ecological aspect is one of the highlighted targets. The societal part of the biocycles is interconnected with the health and mental well-being. They can also be regarded as the environmental-pollution levels su-has Large-scale human migrations into high-energy-using economy clusters and cycles operate their cycles operate on this economic-mechanism socio-political along year. Consider a rather high visiting cross-section rate on past years back a couple or for per several locations but comparatively sharp decline on approach from other time span this insight applies a relatively high degree of maintain riskiness on financial demotives. The higher the visiting-rate goes also close backed up option consideration back out fluctuating high-residue accumulation on other locations bring attention and even larger risk-multiplier on the timeline.

Genetic and Epigenetic Underpinnings: An Overview

Psychological resilience is viewed as a dynamic process, encompassing three dynamic constructs: coping, recovery, and adaptation (Smart et al., 2015). In seasonal tourism communities, the cumulative disruptions caused by anticipated high-volume periods engender significant recovery gaps. Although relief typically follows peak periods, conditions may become progressively more severe, rendering recovery infeasible. Recovery primarily involves restoration and maintenance of normal functioning, with preparatory actions also adopted. Community-level protective measures can lessen or postpone adverse effects arising from peak periods of tourism activity. Seasonal environments present opportunities for development, addressing physiological needs, accruing social capital, and diminishing social isolation. Community-linked psychosocial coping mechanisms, such as social support, accessible services, and adaptable infrastructure, are thus stimulated. Normalised economic and workforce cycles engender further psychosocial protection; non-tourism-related hazards concurrently exert broader influence without irrevocably disrupting momentum. Temporal patterns modulate the ecology of coping and resilience [table 1].

Table 1: Synthesis Across Your Three Studies

Focus Area	Population / Context	Stressors	Genetic / Epigenetic Mechanism	Key Outcome
Tourism Employee Stress (G×E)	Adult workers	Irregular schedules, customer interaction	Candidate genes (BDNF, NR3C1), HPA axis, neurotransmitters	Psychosocial stress, HPA dysregulation
Tourism-Induced Urbanization (TIU)	Adolescents	Social disruption, lifestyle alteration, sleep disruption	HPA axis, BDNF, inflammatory epigenetics	Depression, anxiety, long-term mental health effects
Seasonal Tourism Resilience	Community populations	Seasonal flux, economic instability, climate variability	Polygenic risk scores, DNA methylation, histone modification	Psychological resilience, coping, recovery, adaptation

Polygenic architecture consists of thousands to millions of common single-nucleotide variants (SNVs) that influence resilience-related phenotypes; polygenic-risk studies subsequently provide hazard estimates—risk scores—that guide the design of targeted and cost-effective interventions. Four epigenetic mechanisms underpin physiological reactivity, the stress-response system, and resilience: (i) DNA-methylation signatures, or chemical modifications to the genome that affect gene-expression levels, are readily accessible, with direct access to data from biobanks such as the UK Biobank and the Lifebrian Consortium; (ii) histone-modification markers provide information on dynamic chromatin changes; (iii) chromatin-accessibility maps depict overall accessibility, function as a control for the aforementioned markers, and are accessible in general population studies; and (iv) transcriptional biomarker systems signal active or inactive states of specific brain regions. Substantial heritability (G×E frameworks treat traits as wholly attributable and promote the study of attenuation) and high modulation by environmental variables (e.g., seasonal/temporal effects) at sensitive developmental stages in polygenic and epigenetic frameworks collectively motivate their integration into socio-ecological models (Ziyayev, A. A., et al).

Epigenome-Wide Association Studies and Resilience-Related Signals

Seasonal tourism communities undergo considerable shifts in their characteristics during off-peak and peak seasons, which makes these communities temporary and candidates for psychological resilience studies. Environmental conditions and temporary tourist influxes exert unique seasonal stressors during peak seasons. There is widespread agreement that seasonally stressed individuals develop resilience; however, the concept of resilience has many different meanings, leading to a research gap at a theoretical level. Within-season indicators of resilience remain undocumented, as literature focuses instead on long-term totals, averages, and means. Most importantly, statistical multi-clearance approaches can identify survey items reflecting resilience-related constructs from open-source databases. As such, it is now possible to uncover seasonal risk and resilience elements specific to winter recreation communities (Uddin et al., 2011).

Isolated and repeatable datasets are fundamental when dealing with polygenic risk scores (PRS) based on genome-wide association study (GWAS) summary statistics. Publicly available resources provide these types of data for resilience-related conditions, including bipolar disorder, major depressive disorder, post-traumatic stress disorder, and alcohol use disorder (Penner-Goeke et al., 2023). As a starting point, these systematic data can identify key signal genes from environmental epigenome-wide association studies (EWAS) relating to seasonal-fashion stress. An individual's biological status can only be stably maintained by reserve reactions to either a specific event or a class of seasonal-geophysical phenomena, rather than by behavioural adjustments to the peripherally detected involvement of those seasonal-geophysical figures, their variation rate, their extremeness, and the accumulating multi-sequencing of seasonal phenomena described by Fourier transformation (Arnau-Soler et al., 2019).

Polygenic Risk Scores: Construction, Interpretation, and Limitations

Polygenic risk scores (PRS) are calculated to quantify an individual's genetic predisposition to particular traits or diseases. They are based on summary statistics from genome-wide association studies (GWAS) that identify single-nucleotide polymorphisms (SNPs) associated with a given phenotype. At present, no polygenic risk score is available for psychological resilience in seasonal tourism communities. Insights from existing literature on the construction and practical limitations of PRS from GWAS data therefore provide valuable context for the identification of genetic variants associated with resilience and their integration into an exploratory PRS.

PRS are derived from summary statistics of existing GWAS for a trait, with the assumption that variants associated with that trait in a sufficiently powered analysis of the trait in a relevant population capture individual genetic susceptibility to the trait in other samples. The procedure generally involves a series of sequential steps that include (1) obtaining summary statistics from an existing GWAS, (2) selecting and clumping the most relevant SNPs to ensure independence and obtain a single nominal P value, (3) determining the most appropriate P-value threshold, (4) constructing the PRS, and (5) ensuring that both the GWAS target and the PRS target are sufficiently genetically similar to avoid transferability issues resulting from population stratification. While the performance of PRSs derived from GWAS is inherently limited by the power and population structure of the original studies, several issues merit careful consideration during the derivation process.

The principal purpose of PRSs is to enhance clinical or public-health strategies by improving discrimination of individual susceptibility (M. Lewis & Vassos, 2020). Resilience in seasonal tourism communities comprises various psychological, biological, occupational, and social factors. Although numerous studies have highlighted the interplay between alleles and environmental stress exposure, such frameworks have not been formalized into gene-environment ($G \times E$) interaction models for resilience in seasonal tourism communities.

Seasonal Tourism Communities: Environmental Stressors and Mechanisms of Coping

Tourism is often commendable as an enabling sector for the economies and societies of communities. However tourism comes with many challenges as tourism also brings environmental changes to communities (physical, economic, demographic, cultural). Research indications (A. Turner et al., 2023) show this provides novel seasonal stressors for such tourist-resident communities and adversely affects tourism (Polimanti et al., 2018). The unique scheduling of the full tourism year impacts visitor volume, environmental changes, population dynamics, and governance. This compels communities to exert even more effort into maintaining a delicate yet vital equilibrium between coping with tourism environmental stressors, fostering resident quality of life, and retaining tourism sustainability than communities not under tourist influence (Chow et al., 2022). Accordingly, the most pressing task today is to find-a-better-way out, balancing adaptation and survival in every potential aspect and to mitigate the capability influences imposed by multiple exogenous determinants whilst safeguarding existing mechanisms. Continued scientific exploration is essential, and polygenic and epigenetic constituents cooperate in system-level exploration ((Renato) Polimanti et al., 2018). The unique trigger by tourism during each season offers a suited large-nature framework conducive for progressing the gen-coping mechanism endeavor.

Integrative Models: Gene-Environment Interactions in Resilience

Seasonal tourism communities represent interesting and challenging research settings, where both genetic predispositions and environmental exposures vary through the year. Presented models (Arnau-Soler et al., 2019) of gene-environment interactions (G×E) elaborate on environmental factors that could modify heritable influences on resilience relevant to seasonal tourism communities, together with plausible mechanisms linking them to adaptation-related behaviours. Seasonal differences in length, regularity of climate variations, and intensity of tourism demand emerge as candidate modifiers for polygenic risk scores (PRS), while epigenome-wide association study (EWAS) signals could derive from social, biological, or other pathways.

This seasonal perspective leverages unique environmental stressors. Seasonal tourism communities often endure marked seasonality; frequent and sometimes substantial economic fluctuations are common; resident-worker turnover can reach extraordinarily high levels, especially in tourist areas relying extensively on low-skilled jobs; and the full range of urban challenges—including excessive crowding, noise, and pollution—can beset these locations when tourism peaks (Gonda et al., 2018). This environment tallies with biological pathways centred on psychostimulants, and with psychosocial mechanisms emphasising social support, infrastructure provision, and access to services.

Methodological Considerations for Studies in Seasonal Populations

In frequentist designs, the appropriate sample size can be computed prior to collecting the data, making it easy to determine the feasibility of studying a given research question. However, in Bayesian settings, such pre-study analyses are often intractable; instead, Benchott et al. proposed a strategy to ensure adequate statistical power based on the investigation of preliminary studies. Second, a large literature has focused on the additional challenges posed by time-varying covariates, a problem that can be exacerbated by a seasonal structure. In particular, the standard approach relies on aggregating time-varying covariates across time, but this may ignore vital information. Recently, Fernández et al. have proposed an alternative modelling strategy to take into account time-varying covariates in conjunction with a seasonal structure. The social cycle cycles refer to periods of social tranquillity and social disorder typically lasting 40 years; Algazi et al. present a theoretical framework to incorporate such cycles into a macroeconomic model. In the domain of tourism science, Barrett and Tiwari emphasise how conditions that favour the development of accommodation-led resorts tend to occur every 20 years. Complementary to these long cycles, a 6-year cycle is also often observed, and this is interpreted using Akcay et al.'s concepts of tourism and information

barrage; the rhythm of both information and accommodation availability during these cycles resonates strongly with tourism activity.

Implications for Policy, Community Interventions, and Public Health

Communities dependent on seasonal tourism face unique physical, economic, and psychosocial stressors, which can intensify mental health difficulties. Integrating genetic and epigenetic knowledge with social-ecological models can enhance the understanding of psychological resilience mechanisms and inform localized interventions that respect existing community assets, challenges, and rights. Genetic and epigenetic processes modify resilience-related signals over the life course (Farré et al., 2024) and constitute important but not exclusive determinants of individual differences, underscoring the relevance of incorporating social-ecological perspectives (Marques Filipe et al., 2021). Comprehension of the local seasonal context remains essential to addressing the origins, progression, and consequences of stressors such as economic volatility, space competition, and fluctuations in workforce availability.

Findings can be applied to develop stratification procedures that identify community members requiring specialized assistance, deploy flexible outreach activities (e.g., physical and mental health evaluations, counselling, relationship restructuring) to coincide with periods of heightened exposure, strengthen connections between stakeholders to bolster community resources, and communicate findings in community-defined formats that promote rather than undermine potential solutions. Respecting local sovereignty and honouring established commitments is vital in maintaining credibility and trustworthiness.

Engagement with communities dependent on seasonal tourism not only pinpoints the genetic and epigenetic factors shaping stressor-induced challenges but also clarifies the interrelationship between those factors and distinct environmental variables. Specific guidelines governing the timing, nature, and scope of inquiry remain available to ensure ethical compliance throughout the research process.

Academically rigorous exploration of seasonal-tourism contexts remains crucial. The study of polygenic and epigenetic influences offers a productive starting point, yet considerable methodological, conceptual, and translational challenges persist. Addressing these gaps necessitates multi-disciplinary cooperation across diverse fields including genetics, epigenetics, molecular biology, social-ecological systems, community-based participatory action research, policy analysis, communication, and outreach. The timely development of openly accessible, harmonized datasets centred on general methodological interests would further support knowledge advancement and enhance the prospect of widespread engagement.

Gaps in Knowledge and Directions for Future Research

Disease incidence and demographic characteristics suffuse the study of resilience with polygenic or epigenetic significance. Few or no indicators of seasonal tourism, nevertheless, underline the necessity of continued research amid existing knowledge gaps. Three methodological, theoretical, and translational questions are paramount for co-exploration of polygenic risk and epigenome-wide association factors (Azimova, S., et al).

The first approach, relevant to prospective studies exploring gene-environment interactions, concerns building on-practice guidelines for polygenic risk scoring. Such guidelines pool recommendations from a dozen labs aligned with the International Precision Medicine Consortium. Multidisciplinary inquiries favour the second, given the ecological notion of seasonal tourism resilience as a boundary condition. Genetics provides fertile terrain for comparative exchange with the wider international community. Scalable learning models that do vary across the travel of tourism familiarisation yet do scale into widely experienced place-based and social contexts illuminate the third. These models call for deliberate annotation, replication, and open-sharing of collection projects dovetailing well-annotated projection data with scoring templates and intervention signals.

Conclusion

Identifying polygenic risk factors for psychological resilience within seasonal tourism communities presents unique challenges for the integration of genetic, epigenetic, and environmental perspectives. Nationally representative data indicate that sections of the tourism sector have recovered closest to pre-pandemic operating conditions; therefore, it remains valuable to investigate whether the findings presented in this proposal can be extended to other populations engaged in tourism in seasonal climates. To facilitate this goal, preliminary evidence from epigenome-wide association studies and polygenic risk scores is shared regarding psychological resilience. Examination of gene–environment interactions and modifiable protective pathways is also encouraged. Proposed programs for continued research emphasize community-level and publicly available studies that combine epigenomic and genotypic data, both within the seasonal tourism context and more broadly across Canada and beyond.

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