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Towards an ecological model of the dark triad traits☆

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ABSTRACT

Personality is shaped not only by individual and social experiences but also by the broader ecological contexts in which populations develop. This exploratory study integrates trait activation, life history, and sexual selection theories into an ecological model to explain cross-national variation in narcissism, Machiavellianism, and psychopathy as measured with the ultra-brief, Dirty Dozen measure. Using standardized data from 48 countries (N = 11,504) and six ecological indicators (i.e., population density, operational sex ratio, life expectancy, natural disasters, disease outbreaks, and income inequality) across three developmental windows, we apply spatial autoregressive models to estimate both direct and spillover effects. We found that harsh or unpredictable ecologies (e.g., male-biased sex ratios, lower survival rates, disaster exposure) were associated with elevated Dark Triad personality traits and these same conditions magnify sex differences, while pathogen prevalence attenuates them. Moreover, neighboring countries' environments influenced focal nations' trait profiles. This work highlights the evolutionary and functional roots of antisocial tendencies at the macro-level by situating the Dark Triad traits within a multi-layered socio-ecological framework.

Researchers from various disciplines agree that experienced conditions during one's life predict different outcomes in one's adulthood, including the kind of personality traits or behavioral syndromes one might manifest. For instance, developmental psychologists might point to parental care and attachment (Del Giudice, 2015, 2018), social psychologists might point to one's access to resources in childhood (Griskevicius et al., 2011, 2013), clinical psychologists might point to learned models or "trauma" (Fletcher and Schurer, 2017; Gunay-Oge et al., 2020), and behavioral geneticists might point to the ratio of heritable and environmental—shared and nonshared—conditions (Kandler and Papendick, 2017; Plomin and Nesselroade, 1990); with psychopathy being the most heritable (on average; ≈ 70 %) and Machiavellianism being the least (on average; ≈ 30 %). Researchers advancing these approaches (1) rarely collaborate, are (2) often concerned about the local, familial, and social variables, (3) approach the "why" question in a mechanistic as opposed to functional way, and (4) focus on isolated effects like bullying (e.g., Volk et al., 2022), sexism (e.g., Blake et al., 2021), and domestic violence (e.g., Carlson, 1984). We contend that this has created more confusion than intended because it fails to situate people within not just family and sociological systems, but also ecological ones, and may, therefore, miss the forest for the trees. Here we provide some initial work on how country-level variation in the Dark Triad traits and their associated sex differences might be integrated into an ecological model of those traits like that which has been done for leadership (Lonati and Van Vugt, 2024) and culture (Sng et al., 2018).

Over the last two decades, there have been few topics growing in such popularity among researchers and lay-people as the so-called Dark Triad traits of psychopathy, narcissism, and Machiavellianism (Furnham et al., 2013; Gruda et al., 2023a,b; Gruda & Hanges, 2023; Gruda & McCleskey, 2024; Jonason et al., 2012). The surge in interest has been driven by (1) the popular use of the terms in crime shows and movies, (2) the simultaneous rise of online data collection methods, (3) the consideration of not just clinical but also evolutionary models of these traits, (4) the development of several brief measures, and (5) the obvious implications for understanding undesirable behaviors across several domains (e.g., online/offline aggression, organizational outcomes, relationship functions). But what are the Dark Triad traits and what does research say about how lived conditions affect or interact with them to

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produce salient outcomes in people's lives?

Research on psychopathy has its origins in criminal and clinical psychology and focuses on people engaging in patterns of behaviors that resemble callousness, limited empathy, impulsivity, criminality, and overt, direct aggression (Hare and Neumann, 2008) and tends to be the focus of those interested in understanding particularly the "dark" recesses of the human mind (Lilienfeld et al., 2014). Narcissism, in contrast, has its origins in Freudian psychology ala Greek philosophy (Pulver, 1970), and focuses people on being self-centered, vainglorious, exhibitionistic, arrogant, and braggadocios (Miller et al., 2021) and is studied as a pathology and a "normal" personality trait (Jonason, 2023). And last, Machiavellianism has its origins in political theory from *The Prince* (Machiavelli, 1532/2021) and has mostly been studied in relation to organizational, political, and social psychology (Jones, 2016; Jones and Paulhus, 2009). Work on behavioral genetics suggests that the traits are differently sensitive to environmental variance (Vernon et al., 2007); work in traditional personality psychology suggests they are sensitive to parental attachment disturbances; work from cross-national psychology suggests they may be related to state-level variances in economic conditions and political development (Jonason et al., 2020); and experimental work suggests the traits respond with aggression to different "triggers" (Jones and Paulhus, 2010). One potential ecological trigger that was explored was distance from the equator, suggesting countries farther from the equator were more Machiavellian on average whereas countries closer to the equator were more narcissistic (Jonason and Schmitt, 2017). However, researchers failed to follow up on this matter and given their reliance on simple correlations, more sophisticated and broader tests are warranted. Therefore, in this study, we consider whether national variance in these traits are related to several ecological variables using more sophisticated statistical techniques to, additionally, account for the lack of "independence" between neighboring countries.

Using the language of ethologist Niko Tinbergen (1963), most work on the Dark Triad traits focuses on the "how" questions like causation and ontogeny but neglects the "why" questions of function and phylogeny. We contend this is because psychologists are more interested in (or even biased towards) the former kinds of explanatory variables and models sometimes called the Standard Social Science Model (Vrable and Zeigler-Hill, 2017). Here we advance a unique case about variation in country levels of the Dark Triad traits, looking to ecological variables to understand the potential evolutionary origins and functions of these traits (Wormsley et al., 2023). To do so, we draw on (1) trait activation theory, (2) life history theory, (3) sexual selection theory, and (4) secondary data analyses using spatial autoregressive models across three time periods (i.e., early childhood: 2000–2004, mid-childhood: 2005–2009, and adolescence: 2010–2015) for data from 48 countries. Spatial models allow us to account for the shared physical and social environments – ecologies, in short – that shape people's attitudes and behaviors, and for higher levels of cultural transmission between bordering countries (i.e., as individuals migrate, exchange information, and learn from one another what social strategies prove effective). In addition, these models also enable us to provide a valuable framework for examining how neighboring countries can influence one another's Dark Triad scores. It is unlikely that Dark Triad scores arise in isolation but rather develop within a dynamic system of interconnected influences that transcend national boundaries.

1. Life history personality psychology

Most work on the Dark Triad traits—alone or as a group—stems from traditional personality psychology. Trait activation approaches (De Vries et al., 2016; Nettle, 2006) suggest that specific contexts trigger different behavioral syndromes or personalities but do not provide robust evidence for why one context or others matter, creating the impression that traits are more stable across situations than they may be. For example, people characterized by the Dark Triad traits and the Big Five traits have similar situational affordances across commonly encountered contexts like the classroom, the bar, and the office (Jonason & Sherman, 2020). However, such benign contexts seem unlikely to shift little more than people's moods (Larsen and Sinnett, 1991). What is called for is an examination of more "serious" adaptive challenges.

We contend that it is those recurrent threats to our abilities to find mates and survive that are likely to be able to change people's personality traits. According to life history theory (Del Giudice et al., 2015), organisms calibrate their approaches to maintaining safety, building a body, finding mates, and rearing offspring in response to lived conditions. Organisms evolved systems to adjust expenditure amounts and styles in response to the conditions in their lives to better fit strategy to ecology. While modern economic, political, and technological conditions surely matter (Jonason et al., 2020), they are relatively novel in the evolutionary history of mammals, unlike the shared experiences across species of ecological harshness and predictability. Indeed, not only are the Dark Triad traits sensitive to ecological conditions (Jonason and Schmitt, 2017), domesticated pigs may quickly become feral, in appearance and behavior, when exposed to the difficulties of living in the wild.[1] Therefore, it seems reasonable—albeit likely only to evolutionists—that higher-order ecological conditions may influence wide-scale differences in people, given that species evolve not individuals.[2] This is consistent with trait activation theories (De Vries et al., 2016; Nettle, 2006) but focuses on specific ecological factors (e.g., disease prevalence, sex ratios) as opposed to more generalized affordance and constraining conditions (e.g., situations allowing for exploitation, insecurity, etc.).

The life history approach to the Dark Triad traits suggests the three traits may be modes for the pursuit of life history goals, in particular the acquisition of status and mates (Jonason and Zeigler-Hill, 2018)[3] via correlated tendencies that *may* be adaptive like niche specialization adaptations (Jonason, 2018; Jonason et al., 2013a; Jonason et al., 2015) and interpersonal styles that facilitate detachment and exploitation (Figuered et al., 2016; Jonason et al., 2013b, 2017). However, this approach suffers from two problems that other psychometric approaches to life history variation (Gruijters and Fleuren, 2018; Zietsch and Sidari, 2020) have also received. First, given that most of the work on these traits is done by psychologists, the research is focused on individual variation. Unfortunately, applying life history theory (designed as a theory in biology to explain group, and species, differences), by extrapolating from individual-level correlations to claims about species-level evolutionary strategies, inferring group-level processes from atomistic data is a classic instance of the reverse ecological (atomistic) fallacy. Second, little attention is paid to contextual variation. Instead, researchers appear to take a phenomenological approach to examine what these traits *might* cause and a local, family systems approach to understand the origins of these traits in the absence of experimental data. Further individual-level data may obscure national differences in the traits if we assume that (1) specific conditions generate logical responses, that (2) those conditions are relatively stable from nation to nation, and that (3) a definition of "culture" is simply the additive or multiplicative composite of its population's traits. That is, unlike most work on the Dark Triad, we examine whether ecological conditions generate or evoke a "culture" (Sng et al., 2018) of narcissism, psychopathy, and Machiavellianism and how those same conditions may influence the magnitude of sex differences in those traits.

[1] https://www.popularmechanics.com/science/animals/a43294202/feral-hog-genetics/

[2] In fact, we cannot imagine how a Standard Social Science Model would account for the ability of ecological factors to influence something so apparently disconnected as personality or behavioral syndromes.

[3] Earlier approaches for life history models of the Dark Triad traits focused solely on psychopathy or failed to differentiate the three traits well in called them a "fast" life history.

Therefore, in this study, we examine how conditions in people's past (over three theoretically relevant time periods) predict not only mean-level Dark Triad scores in countries but also the magnitude of sex differences in the traits. We do so based on sexual selection theory, which posits that ecological conditions shape reproductive strategies differently for men and women. In harsh or threatening environments (e.g., areas prone to frequent natural disasters, and high extrinsic mortality), sexual competition tends to intensify, disproportionately influencing men because of their greater variance in reproductive success (i.e., Bateman's principle). Under such circumstances, men may be more likely to adopt opportunistic or competitive behaviors, thereby amplifying existing sex differences in Dark Triad traits, compared to stable, less threatening ecologies.

2. Traits as responses to ecological threats

While the Anthropocene is characterized by an unusually stable period in terms of ecological variability, unpredictability, and harshness, countries, nonetheless, differ in important physical and social properties. Indeed, just prior to writing this (mid 2025), major floods ravaged much of middle America, a 7+ magnitude earthquake shook Myanmar, and a mysterious disease hit the Democratic Republic of the Congo. So much as these conditions are reasonably recurrent in the lives of citizens, they can operate as inputs in evolved heuristics that (1) calibrate people's approaches to acquiring resources and mates and (2) are likely to be updated with sufficiently "loud" input. Our first prediction is that more problematic ecological conditions should predict higher country-level scores in the Dark Triad traits. That is, in response to ecological threats, populations may logically adjust their approaches to life to be more selfish (e.g., narcissism), impulsive (e.g., psychopathic), and utilitarian (e.g., Machiavellian) as seen in the Dark Triad traits (Jonason et al., 2019, 2020).

Furthermore, we consider whether sex differences in the traits at the country level might also be sensitive to ecological conditions and whether the "when" of the experience of such "problems" moderates any associations between the Dark Triad traits and ecological factors. There is little doubt that (as presently measured) men score higher than women do on the Dark Triad traits. While there is considerable nation-level variability (see Jonason et al., 2020), such variability is related to economic and political indicators but may be also related to ecological ones as well if we assume that people are embedded in economic/political systems that are the result of ecological conditions (Henrich, 2015). But why might there be sex differences in the Dark Triad traits? Two models predict different reasons and results. Constructivists suggest that sex differences are a pathological manifestation of gender inequality and, as countries modernize, sex differences should get smaller (Eagly and Wood, 1999). In contrast, evolutionists suggest the opposite; as countries modernize, fewer constraints are placed upon people to act according to socially proscribed ways or in terms of maximizing survival, leading to larger sex differences (i.e., the so-called gender paradox; Stoet and Geary, 2018). Indeed, preliminary work suggests that Turkey, a country that has been undergoing major political, economic, and social upheaval for the last decade, has a larger sex difference in narcissism than Australia, the safest country in the world for women (Jonason et al., 2019). Indeed, while men were more narcissistic than women in both places, it was Australian women who were especially low in narcissism relative to Turkish women.

3. The current study

For the first time, as far as we are aware, we suggest that ecological conditions can generate national sex differences in behavioral syndromes like the Dark Triad. We invoke the concept of adaptive phenotypic plasticity – a commonly observed phenomenon in biology – to argue that different ecological conditions can evoke different adaptive sex-specific phenotypes. Take, for instance, Ridley's Sea Turtles (*Lepidochelys kempii*). The sex of the turtle is determined by the temperature of the sand brood they gestate in (LeBlanc et al., 2012), suggesting the organization of bodies and brains can be sensitive to ecological conditions. Given that the Dark Triad traits show reliable sex differences, and such differences are not merely behavioral but psychological in origin, we expect that ecological conditions should be correlated with the magnitude of sex differences. Such sensitivity may allow men and women to calibrate their personality and behaviors in ways that are more locally adaptive, based on, say, variations in physical danger or local sex ratios.

And last, humans have an exceptionally long developmental period. The length may allow them to take in substantial information to best calibrate their approaches to solving life's evolutionary challenges. If we are to believe developmental psychologists, there are critical periods for these adjustments to one's approaches to life (Beit-Hallahmi, 1987; Fawcett and Frankenhuis, 2015; Panchanathan and Frankenhuis, 2016; Scott, 1962). For example, it may be that (1) survival threats play an important role in the childhood developmental phase creating psychopathy in adulthoods if needed, whereas (2) mating threats, like in terms of a biased operational sex ratio within society, induce more intrasexual competition and create narcissism, a trait that may be fixated on competition in a way that serves to show-off to potential mates (e.g., grandiosity, status-seeking). Alternatively, human brains may be flexible enough that information of any kind at any period, so long as it is sufficiently "loud" can allow people to recalibrate their life history goals from communal and long-term (i.e., low on the Dark Triad traits) to agentic and short-term (i.e., high on the Dark Triad traits) or vice versa.

Understanding how people "turn to the dark side" is a pressing question with disparate answers from disconnected models. Overwhelmingly, researchers focus on individual and local effects when trying to understand variability in traits like the Dark Triad and behaviors that may be related to them. However, all organisms exist in a multi-layer system, the top of which is the physical and social ecology, but this has received little attention in terms of research on the Dark Triad traits. In this exploratory study, we rely on secondary data analyses to understand how population-level variance in the Dark Triad traits may be related to various ecological factors in hopes of testing the life history assumptions about them.

4. Method

4.1. Data and sample

This cross-sectional study used country-level personality data reported by Jonason et al. (2020). The original dataset comprised 49 (we dropped Palestine here for lack of ecological data) countries (see Table 1 for summary) spanning North America, South America, Europe, Asia, Oceania, the Middle East, and sub-Saharan Africa ($N = 11{,}723$; mean age $\approx$ 21.5 years; 66 % female).[4] In each country, the Dark Triad traits were measured circa 2016 using the 12-item Dirty Dozen questionnaire (Jonason and Webster, 2010) because of its brevity. For each trait, we obtained the country's mean score (and standardized them) and the sex difference (Cohen's *d* between male and female scores; positive Cohen's *d* values indicate higher male scores).

Subsequently, we paired each country's Dark Triad trait scores with publicly available ecological predictors as described below (see Measures). For each country, we aggregated these indicators over three historical windows: 2000–2004, 2005–2009, and 2010–2015. This temporal grouping was chosen to approximate the early childhood, mid-

[4] Given that these are student samples, meaning they likely encounter generally favorable ecological conditions compared to the rest of their society (e.g., high economic status in a country with a high degree of economic inequality), our tests are rather conservative in nature.

Table 1
Sample characteristics by country.

Country	N	Female %	M_{age} (SD)	Language	Procedure
Global	11,723	65.8	21.53 (3.17)	Various	Various
Algeria	213	64.8	20.03 (1.73)	Arabic	Paper-pencil
Armenia	266	55.3	19.26 (1.35)	Armenian	Paper-pencil
Australia	294	63.6	24.20 (5.16)	English	Online
Austria	269	77.7	24.35 (6.60)	German	Online
Belgium	223	83.0	18.93 (3.23)	Flemish	Online
Bosnia & Herzegovina	226	73.0	25.72 (5.35)	Bosnian	Online
Brazil	246	62.1	22.37 (6.32)	Portuguese	Paper-pencil
Bulgaria	200	68.0	22.85 (5.37)	Bulgarian	Paper-pencil
Canada	319	69.6	20.29 (4.02)	English	Online
Chile	353	51.6	19.96 (3.80)	Spanish	Online
China	557	82.0	21.86 (1.14)	Chinese	Online
Croatia	200	61.5	23.13 (3.83)	Croatian	Online
Czech	232	65.9	22.96 (3.29)	Czech	Paper-pencil
Ecuador	244	65.2	22.89 (4.79)	Spanish	Online
Egypt	214	62.1	21.34 (2.35)	Arabic	Paper-pencil
Estonia	357	75.4	24.44 (6.38)	Eesti	Online
France	202	45.5	22.56 (1.56)	French	Online
Germany	221	83.7	21.53 (3.33)	German	Online
Hungary	152	79.6	22.83 (5.16)	Hungarian	Online
India	214	58.9	22.69 (1.45)	English	Paper-pencil
Indonesia	232	69.8	21.34 (2.22)	Indonesian	Online
Japan	282	33.3	19.65 (1.44)	Japanese	Paper-pencil
Kazakhstan	269	63.2	20.15 (2.20)	Russian	Online
Korea (South)	199	61.3	22.26 (1.82)	Korean	Paper-pencil
Latvia	260	71.2	27.65 (7.87)	Russian	Online
Macedonia	203	51.7	23.10 (2.94)	Macedonian	Online
Mauritius	178	75.3	20.38 (1.41)	French	Paper-pencil
Mexico	171	53.2	22.04 (3.33)	Spanish	Paper-pencil
Netherlands	255	79.2	19.39 (2.27)	Flemish	Paper-pencil
New Zealand	207	70.0	18.94 (2.34)	English	Online
Nigeria	200	50.0	21.52 (3.33)	English	Paper-pencil
Pakistan	200	45.8	22.54 (2.81)	English	Paper-pencil
Palestine*	219	67.1	20.52 (1.82)	Arabic	Paper-pencil
Peru	210	76.2	21.52 (4.88)	Spanish	Online
Poland	341	78.3	20.56 (2.10)	Polish	Online
Portugal	199	66.8	20.01 (2.92)	Portuguese	Online
Romania	218	65.6	20.66 (2.11)	Romanian	Paper-pencil
Russia	216	84.7	20.51 (4.74)	Russian	Online
Serbia	326	72.1	20.88 (1.75)	Serbian	Online
Singapore	219	65.8	22.26 (2.58)	English	Online
Slovakia	202	74.8	21.66 (2.04)	Slovak	Paper-pencil
South Africa	224	71.4	20.47 (2.15)	English	Paper-pencil
Sweden	212	72.6	22.79 (4.36)	Swedish	Online
Thailand	177	76.8	19.61 (1.37)	Thai	Online
Togo	222	41.4	20.56 (2.84)	French	Online
Turkey	200	62.5	20.93 (2.43)	Turkish	Paper-pencil
Ukraine	283	72.4	20.09 (3.97)	Russian	Online
United Kingdom	185	69.7	19.57 (1.74)	English	Online
United States	212	58.0	19.33 (1.44)	English	Online

Note: Table as shown in Jonason et al. (2020) Country-level correlates of the Dark Triad traits in 49 countries, Journal of Personality, except *: Palestine was not part of the final sample used for analysis in this paper due to missing World Development Indicators as provided by the World Bank Group.

childhood, and adolescent life stages, which are theorized to be critical windows for personality development (Caspi et al., 2005). We computed the average value of each predictor within each period (or the cumulative total, in the case of natural disaster and disease impact). Based on the global average age, these periods represent the approximate conditions that prevailed when the average participant was 6, 11, and 16 years old, respectively, although we acknowledge that this varies considerably by country. Aggregating across multi-year periods also smooths out annual fluctuations and measurement irregularities, providing a more stable estimate of the early-life environment. By capturing ecological factors per country at these three life stages, we aimed to assess whether conditions in childhood versus adolescence differentially predict adult country-level Dark Triad trait scores. Each country's dataset thus included period-specific values for all predictors. We focus on the six most prominent ecological indicators aligned with prior research (Lonati and Van Vugt, 2024; Sng et al., 2018; Wormley et al., 2023), keeping in mind data availability for a total of 48 countries and statistical power using a traditional ratio of 1:7 predictors per outcome variable (https://osf.io/qwfy9/).

4.2. National metrics

We used the World Bank Group (https://databank.worldbank.org/) for data on population density (persons per square kilometer of land area) as a proxy for social crowding and urbanization, survival to age 65 (male and female, % of birth cohort) as a measure of life expectancy, and the operational sex ratio with higher values indicating more men than women. We used the EM-DAT International Disaster Database (https://www.emdat.be/) for data on natural disasters (e.g. floods, storms, earthquakes) per country per year, drawing the metric for the "total affected" which is the sum of individuals injured, displaced, or otherwise impacted by a respective disaster (we adjusted this score to per million population) and disease impact was assessed by using a measure of epidemiological disasters, defined as the total number of

people affected (injured, infected, or rendered homeless) by major disease outbreaks (we adjusted this score to per million population). And last, we measured income inequality as the percentage of national income held by the top 10 % of income earners, collected from the World Inequality Database (https://wid.world/data/). Higher scores reflect greater economic disparity within each country. We deliberately chose not to use the Gini index as a measure of inequality because of large amounts of missing observations (>50 %) across many of the countries in our dataset.

4.3. Data analysis

Ecological events, such as natural disasters or disease outbreaks, often transcend national borders, making it important to capture the possibility that one country's environment could affect personality outcomes in neighboring countries. In addition, adjacent regions, such as states or countries, tend to be more similar than non-adjacent regions (Gruda et al., 2024). To account for potential geographic clustering and diffusion effects, for each outcome variable (i.e., Dark Triad trait means and Dark Triad trait sex difference scores, analyzed separately), we employed a spatial model using a generalized spatial two-stage least squares (GS2SLS) estimator with heteroscedasticity-consistent (robust) standard errors. Because the specified model includes both a spatially lagged dependent variable and spatially lagged independent variables, this configuration is known as a Spatial Durbin Model (SDM). The general equation for the model is:

$$Y = \rho WY + X\beta + WX\theta + \varepsilon$$

Where Y is the vector of the dependent variable, X is the matrix of independent variables, W is the spatial weights matrix, WY is the spatially lagged dependent variable, WX represents the spatially lagged independent variables, ρ (rho) is the spatial autoregressive coefficient, β (beta) and θ (theta) are the coefficients for the independent variables and their spatial lags, respectively, and ε is the error term. This model allows us to test whether (and to what degree) a given country's Dark Triad trait scores are influenced not only by its own ecological conditions (i.e., the within-country impact of a predictor X on Y, also known as direct effects) but also by adjacent countries' conditions (i.e., the spillover impact of neighboring X on the focal country's Y, also known as indirect effects), all within a single unified framework (Yang et al., 2019).

All country-level predictors were entered simultaneously into the model for each outcome for each period. This approach adjusts for intercorrelations among the various ecological factors, isolating the unique contribution of each, while controlling for common regional influences through the spatial lags. We assessed multicollinearity using Variance Inflation Factors (VIFs) for all predictors across the three time periods. All VIFs were within acceptable ranges (VIF means ranging from 1.25 to 1.36), indicating that collinearity is unlikely to bias the model estimates severely. All analyses were conducted in Stata/MP 18.0.

5. Results

Pairwise zero-order correlations between main variables are reported in Table 2. Direct, indirect, and total effects of ecological predictors based on conducted SAR models per trait are reported in Tables 3–5. Direct, indirect, and total effects of ecological factors predicting country-level sex differences per trait are reported in Tables 6–8. The direct effect represents the expected change in a country's outcome given a unit change in that country's predictor (holding other countries' predictors constant). The indirect effect (spillover effect) represents the change in the focal country's outcome induced by changes in the predictors of neighboring countries (through the spatial lag terms). The total effect is the sum of direct and indirect effects, reflecting the overall impact of a change in the predictor on the entire spatial system. These impact measures provide a more interpretable summary of the results than raw regression coefficients in a spatial context. Given the spatial nature of our dataset, we focus on examining direct and indirect effects. Raw coefficients are available in Supplementary Materials (Table SM1). We also conducted additional analyses in which we controlled for the unequal split of participant's sex per country (accounted for by % of female participants per country; Table SM2-SM4). Overall, results remained largely unchanged.

5.1. Narcissism

As shown in Table 3, early-childhood (2000–2004) and mid-childhood (2005–2009) country-level sex ratio positively predicted country-level adult (2016+) narcissism scores (early childhood: $b = 8.24$, $SE = 1.77$, $z = 4.66$, $p < .001$; mid-childhood: $b = 5.56$, $SE = 2.03$, $z = 2.75$, $p = .006$). Survival to age 65 was negatively associated with country-level narcissism scores across all three time periods (e.g., early childhood: $b = -0.02$, $SE = 0.01$, $z = -4.01$, $p < .001$).

We also found several indirect effects. Population density in neighboring countries in the mid-childhood and adolescence period was positively associated with focal country narcissism (mid-childhood: $b = 0.001$, $SE < 0.001$, $z = 2.32$, $p = .021$; adolescence: $b = 0.001$, $SE < 0.001$, $z = 2.04$, $p = .041$). The total affected by natural disasters in neighboring countries in the adolescence period was positively associated with a focal country's narcissism ($b < 0.001$, $SE < 0.001$, $z = 2.01$, $p = .045$). Conversely, the total affected by disease in neighboring countries in both the mid-childhood and adolescence period was negatively associated with focal country narcissism (mid-childhood: $b = -0.006$, $SE = 0.003$, $z = -2.05$, $p = .041$, adolescence: $b = -0.002$, $SE = 0.001$, $z = -2.94$, $p = .003$). Lastly, inequality in neighboring countries was positively associated with focal country narcissism in the adolescence period ($b = 2.11$, $SE = 0.087$, $z = 2.42$, $p = .016$).

Sex differences in narcissism. Country-level sex ratio in early childhood (2000–2004) was significantly and negatively associated with adult country-level sex differences in narcissism scores (Table 6: $b = -4.43$, $SE = 1.12$, $z = -3.99$, $p < .001$). Total affected by natural disasters per 1 million in the same period (2000–2004) was positively associated with subsequent adult country-level sex differences in narcissism ($b < 0.001$, $SE < 0.001$, $z = 2.02$, $p < .001$). Again, we found several indirect effects. For example, the population density of neighboring countries in the mid-childhood and adolescence period positively predicted focal country sex differences in narcissism scores (mid-childhood: $b < 0.001$, $SE < 0.001$, $z = 2.25$, $p = .024$; adolescence: $b < 0.001$, $SE < 0.001$, $z = 2.13$, $p = .033$). Early childhood total number affected by disease in neighboring countries negatively predicted focal countries' sex differences in narcissism scores ($b < -0.001$, $SE < 0.001$, $z = -3.02$, $p = .003$). Lastly, sex differences in Machiavellianism in neighboring countries were positively associated with focal country sex differences in narcissism ($b = 0.90$, $SE = 0.40$, $z = 2.23$, $p = .026$).

5.2. Machiavellianism

As shown in Table 4, the mid-childhood and adolescence sex ratio was negatively associated with country-level Machiavellianism scores (mid-childhood: $b = -7.91$, $SE = 3.24$, $z = -2.44$, p 0.015; adolescence: -8.27, $SE = 3.51$, $z = -2.36$, $p = .018$). Likewise, the total affected by disease per million in the adolescence period was also negatively associated with country-level Machiavellianism scores ($b = -0.001$, $SE < 0.001$, $z = -2.77$, $p = .006$).

In terms of indirect effects, total affected by disease in neighboring countries in the mid-childhood period was negatively associated with focal country Machiavellianism ($b = -0.012$, $SE = 0.005$, $z = -2.29$, $p = .02$). On the other hand, inequality in neighboring countries in both the mid-childhood and adolescence period was positively associated with focal country Machiavellianism (mid-childhood: $b = 6.20$, $SE = 2.36$, $z = 2.63$, $p = .009$; adolescence: $b = 3.26$, $SE = 0.95$, $z = 3.43$, $p = .001$).

Table 2
Pairwise zero-order correlations.

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. Narcissism																				
2. Machiavellianism	0.29*																			
3. Psychopathy	0.47***	0.58***																		
4. Population Density (2000–2004)	0.05	0.12	0.18																	
5. Sex Ratio (2000–2004)	0.41**	0.03	0.12	0.06																
6. Survival to 65+ (2000–2004)	−0.39**	0.04	−0.10	0.16	0.08															
7. Total Aff. Nat. Disaster (2000–2004)	0.24	−0.18	0.01	−0.05	0.52***	−0.23														
8. Total Aff. Disease (2000–2004)	−0.06	0.08	0.08	0.01	−0.11	−0.10	0.04													
9. Inequality (2000–2004)	−0.03	−0.34*	−0.16	−0.01	−0.18	−0.39**	0.22	0.29*												
10. Population Density (2005–2009)	0.06	0.12	0.18	0.99***	0.05	0.15	−0.04	0.01	0.00											
11. Sex Ratio (2005–2009)	0.40**	0.01	0.11	0.04	0.99***	0.08	0.58***	−0.11	−0.15	0.04										
12. Survival to 65+ (2005–2009)	−0.37**	0.03	−0.10	0.17	0.10	0.99***	−0.23	−0.11	−0.38**	0.17	0.09									
13. Total Aff. Nat. Disaster (2005–2009)	0.16	−0.19	−0.02	−0.06	0.42**	0.00	0.52***	0.01	0.07	−0.06	0.47***	0.02								
14. Total Aff. Disease (2005–2009)	−0.27	−0.31*	−0.28	0.00	−0.23	−0.17	0.00	0.08	0.35*	0.00	−0.23	−0.17	−0.04							
15. Inequality (2005–2009)	−0.03	−0.34*	−0.14	−0.02	−0.18	−0.39**	0.30*	0.27	0.96***	−0.01	−0.15	−0.38**	0.08	0.36*						
16. Population Density (2010–2015)	0.06	0.12	0.18	0.99***	0.05	0.15	−0.04	0.01	0.01	0.99***	0.04	0.16	−0.06	0.00	−0.01					
17. Sex Ratio (2010–2015)	0.35*	0.02	0.11	0.03	0.95***	0.10	0.59***	−0.13	−0.21	0.03	0.98***	0.12	0.49***	−0.25	−0.21	0.03				
18. Survival to 65+ (2010–2015)	−0.39**	0.05	−0.10	0.18	0.11	0.99***	−0.21	−0.09	−0.40**	0.17	0.10	0.99***	0.01	−0.19	−0.40**	0.17	0.13			
19. Total Aff. Nat. Disaster (2010–2015)	0.15	−0.17	0.00	−0.08	0.28	−0.06	0.61***	0.02	0.32*	−0.07	0.33*	−0.04	0.49***	0.03	0.33*	−0.07	0.32*	−0.06		
20. Total Aff. Disease (2010–2015)	−0.34*	−0.36*	−0.28	−0.06	−0.15	−0.09	0.02	0.28	0.44**	−0.06	−0.14	−0.07	0.04	0.57***	0.41**	−0.06	−0.16	−0.09	0.20	
21. Inequality (2010–2015)	−0.02	−0.37*	−0.13	0.02	−0.15	−0.37**	0.37**	0.21	0.92***	0.02	−0.12	−0.37**	0.08	0.38**	0.98***	0.03	−0.18	−0.39**	0.35*	0.36*

* $p < .05$. ** $p < .01$, *** $p < .001$.

Lastly, neighboring countries' psychopathy was negatively associated with focal country Machiavellianism scores ($b = -0.46$, $SE = 0.21$, $z = -2.18$, $p = .029$).

Sex differences in Machiavellianism. As shown in Table 7, the total affected by natural disasters (per 1 million) in the adolescence period positively predicted sex differences in Machiavellianism ($b < 0.001$, $SE < 0.001$, $z = 1.99$, $p = .047$), while the total affected by disease (per 1 million) negatively predicted sex differences in Machiavellianism ($b < -0.001$, $SE < 0.001$, $z = -2.86$, $p = .004$). No indirect effects were found.

5.3. Psychopathy

As shown in Table 6, the total affected by disease (per 1 million) in mid-childhood and adolescence was negatively associated with country-level psychopathy (mid-childhood: $b = -0.001$, $SE < 0.001$, $z = -3.00$, $p = .003$; adolescence: $b = -0.001$, $SE < 0.001$, $z = -2.75$, $p = .006$). Country-level inequality in the early childhood period was negatively associated with country-level psychopathy ($b = -1.59$, $SE = 0.73$, $z = 2.19$, $p = .028$). In terms of indirect effects, population density in neighboring countries in the adolescence period positively predicted focal country psychopathy scores ($b = 0.001$, $SE < 0.001$, $z = 2.13$, $p = .033$).

Sex differences in psychopathy. As reported in Table 8, the total affected by natural disasters (per 1 million) in the adolescence period positively predicted sex differences in psychopathy ($b < 0.001$, $SE < 0.001$, $z = 2.66$, $p = .008$). Again, we found several indirect effects. Sex ratio of neighboring countries in the early childhood and adolescence period negatively predicted focal country sex differences in psychopathy scores (early childhood: $b = -1.356$, $SE = 0.50$, $z = -2.72$, $p = .007$; adolescence: $b = -2.47$, $SE = 0.71$, $z = -3.46$, $p = .001$). In the early childhood and adolescence period, survival to age 65 in neighboring countries positively predicted focal country sex differences in psychopathy (early-childhood: $b = 0.018$, $SE = 0.006$, $z = 3.07$, $p = .002$; adolescence: $b = 0.029$, $SE = 0.009$, $z = 3.02$, $p = .003$). Lastly, in the early childhood period, sex differences in Machiavellianism in neighboring countries positively predicted focal country psychopathy ($b = 0.70$, $SE = 0.32$, $z = 2.18$, $p = .029$).

6. Discussion

Researchers from different disciplines agree; contextual variables pay a pivotal role in the formation of personality traits (De Vries et al., 2016; Nettle, 2006). However, these researchers—ranging from Freudian, to trait theorists, to evolutionists—focus on midlevel predictions about people's family (e.g., death in the family, child abuse) and local (e.g., experiencing poverty or crime, situations of insecurity) experiences more than large, distal ecological factors in trying to explain why people have the traits, attitudes, and cognitions they do. In this study, we take an evolutionary approach to begin to understand why specific ecological conditions could play a role in shaping people's personalities and, perhaps, make progress in determining the national "character" vis-à-vis a consideration of evolved cultural mechanisms.

This study examined how early-life ecological and demographic factors, measured at the country level across different developmental periods (early childhood: 2000–2004; mid-childhood: 2005–2009; adolescence: 2010–2015), predict adult population-level differences in the Dark Triad traits assessed from (ca.) 2016 to 2018. We also explored how these early-life environments related to the magnitude of sex differences in these traits. Importantly, we incorporated indirect ecological effects by assessing whether conditions in neighboring countries similarly influenced personality outcomes.

6.1. Explaining national variance in the Dark Triad traits

First, we found that higher childhood sex ratios (indicating a

Table 3
Ecological factors predicting country-level narcissism.

	2000–2004			2005–2009			2010–2015		
	b	*SE*	[CI 95 %]	*b*	*SE*	[CI 95 %]	*b*	*SE*	[CI 95 %]
Direct effects									
Population Density	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]
Sex Ratio	8.24***	1.77	[4.77, 11.71]	5.56**	2.03	[1.59, 9.53]	4.58	2.86	[−1.03, 10.18]
Survival 65+	−0.02***	0.01	[−0.03, −0.01]	−0.02*	0.01	[−0.03, <0.01]	−0.02**	0.01	[−0.04, −0.01]
Total Affected Nat. Disaster	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]	<0.01	0.00	[<0.01, <0.01]
Total Affected Disease	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]
Inequality	−0.42	0.74	[−1.88, 1.04]	−0.21	0.73	[−1.64, 1.21]	−1.17	1.12	[−3.37, 1.03]
Machiavellianism	<0.01	0.03	[−0.06, 0.07]	−0.02	0.05	[−0.13, 0.08]	−0.11	0.16	[−0.42, 0.20]
Psychopathy	<0.01	0.01	[−0.02, 0.02]	<0.01	0.02	[−0.04, 0.04]	0.05	0.08	[−0.11, 0.21]
Indirect effects									
Population Density	<0.01	<0.01	[<0.01, <0.01]	<0.01*	<0.01	[<0.01, <0.01]	<0.01*	<0.01	[<0.01, <0.01]
Sex Ratio	−0.95	2.19	[−5.24, 3.34]	−1.58	1.09	[−3.71, 0.56]	−1.41	1.51	[−4.37, 1.56]
Survival 65+	0.01	0.01	[−0.02, 0.03]	<0.01	0.01	[−0.01, 0.02]	0.01	0.01	[−0.01, 0.02]
Total Affected Nat. Disaster	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]	<0.01*	<0.01	[<0.01, <0.01]
Total Affected Disease	<0.01	<0.01	[<0.01, <0.01]	−0.01*	<0.01	[−0.01, <0.01]	<0.01**	<0.01	[[<0.01, <0.01]
Inequality	0.11	1.26	[−2.36, 2.58]	1.93	1.08	[−0.19, 4.04]	2.11*	0.87	[0.40, 3.82]
Machiavellianism	0.17	0.22	[−0.26, 0.60]	0.15	0.18	[−0.21, 0.51]	0.29	0.19	[−0.08, 0.66]
Psychopathy	−0.05	0.21	[−0.45, 0.36]	−0.01	0.13	[−0.27, 0.24]	−0.14	0.16	[−0.45, 0.17]
Total effects									
Population Density	<0.01	<0.01	[<0.01, <0.01]	<0.01*	<0.01	[<0.01, <0.01]	<0.01**	<0.01	[<0.01, <0.01]
Sex Ratio	7.29**	2.76	[1.88, 12.70]	3.99*	1.57	[0.91, 7.06]	3.17*	1.57	[0.09, 6.26]
Survival 65+	−0.01	0.01	[−0.04, 0.01]	−0.01*	0.01	[−0.03, 0.00]	−0.02***	<0.01	[−0.02, −0.01]
Total Affected Nat. Disaster	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]	<0.01**	<0.01	[<0.01, <0.01]
Total Affected Disease	<0.01	<0.01	[<0.01, <0.01]	−0.01*	<0.01	[<−0.01, <0.01]	<0.01***	<0.01	[<0.01, <0.01]
Inequality	−0.31	1.31	[−2.89, 2.26]	1.71	1.23	[−0.70, 4.13]	0.94	0.55	[−0.14, 2.02]
Machiavellianism	0.18	0.21	[−0.23, 0.59]	0.13	0.14	[−0.15, 0.40]	0.18**	0.06	[0.07, 0.29]
Psychopathy	−0.05	0.21	[−0.46, 0.36]	−0.01	0.11	[−0.22, 0.20]	−0.09	0.10	[−0.28, 0.11]

Note: Total Affected Nat. Disaster/Disea*SE* = per 1 million.
* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 4
Ecological factors predicting country-level Machiavellianism.

	2000–2004			2005–2009			2010–2015		
	b	*SE*	[CI 95 %]	*b*	*SE*	[CI 95 %]	*b*	*SE*	[CI 95 %]
Direct effects									
Population Density	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]
Sex Ratio	−3.48	3.22	[−9.79, 2.84]	−7.91*	3.24	[−14.26, −1.56]	−8.27*	3.51	[−15.15, −1.39]
Survival 65+	−0.01	0.01	[−0.03, 0.01]	−0.01	0.01	[−0.03, 0.01]	−0.01	0.01	[−0.02, 0.01]
Total Affected Nat. Disaster	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]
Total Affected Disease	<0.01	<0.01	[<0.01, <0.01]	<0.01	0.01	[−0.01, 0.01]	<0.01**	<0.01	[<0.01, <0.01]
Inequality	−4.67	3.25	[−11.04, 1.71]	−3.98	3.02	[−9.90, 1.94]	−2.94	1.61	[−6.10, 0.22]
Narcissism	−0.31	0.61	[−1.50, 0.87]	−0.24	0.32	[−0.87, 0.38]	−0.20	0.25	[−0.69, 0.29]
Psychopathy	0.08	0.12	[−0.17, 0.32]	0.14	0.13	[−0.11, 0.39]	0.15	0.12	[−0.09, 0.39]
Indirect effects									
Population Density	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]
Sex Ratio	0.36	1.99	[−3.53, 4.26]	1.59	2.32	[−2.95, 6.13]	1.81	2.22	[−2.54, 6.16]
Survival 65+	0.01	0.01	[−0.01, 0.03]	0.01	0.01	[−0.02, 0.03]	0.01	0.01	[−0.02, 0.03]
Total Affected Nat. Disaster	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]
Total Affected Disease	<0.01	<0.01	[<0.01, <0.01]	−0.01*	0.01	[−0.02, <0.01]	<0.01	<0.01	[<0.01, <0.01]
Inequality	3.92	2.57	[−1.11, 8.94]	6.20**	2.36	[1.58, 10.81]	3.26***	0.95	[1.40, 5.13]
Narcissism	0.61	0.65	[−0.66, 1.89]	0.50	0.37	[−0.23, 1.24]	0.60	0.31	[−0.01, 1.21]
Psychopathy	−0.15	0.23	[−0.60, 0.31]	−0.29	0.20	[−0.69, 0.10]	−0.46*	0.21	[−0.87, −0.05]
Total effects									
Population Density	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]
Sex Ratio	−3.11	1.70	[−6.44, 0.21]	−6.32***	1.45	[−9.16, −3.48]	−6.46**	2.14	[−10.66, −2.27]
Survival 65+	<0.01	<0.01	[−0.01, 0.01]	<0.01	0.01	[−0.01, 0.01]	<0.01	0.01	[−0.01, 0.01]
Total Affected Nat. Disaster	<0.01	<0.01	[<0.01, <0.01]	<0.01***	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]
Total Affected Disease	<0.01	<0.01	[<0.01, <0.01]	−0.01**	<0.01	[−0.01, <0.01]	<0.01*	<0.01	[<0.01, <0.01]
Inequality	−0.75	1.07	[−2.84, 1.34]	2.22	1.26	[−0.26, 4.70]	0.32	1.12	[−1.87, 2.52]
Narcissism	0.30*	0.14	[0.03, 0.57]	0.26*	0.11	[0.05, 0.48]	0.40**	0.13	[0.15, 0.65]
Psychopathy	−0.07	0.15	[−0.36, 0.21]	−0.15	0.14	[−0.43, 0.13]	−0.30	0.21	[−0.71, 0.10]

Note: Total Affected Nat. Disaster/Disea*SE* = per 1 million.
* $p < .05$, ** $p < .01$, *** $p < .001$.

relatively higher number of males) were positively associated with adult narcissism scores. This pattern supports an interpretation based on intensified male-male sexual competition: when potential mates are scarce, men may resort more to status signaling and self-promotion (i.e., behaviors characteristic of narcissism). Women may also mimic these strategies in competitive mating environments, contributing to a population-level increase. Conversely, lower national survival rates were also associated with higher narcissism, consistent with a fast life

Table 5
Ecological factors predicting country-level psychopathy.

	2000–2004			2005–2009			2010–2015		
	b	*SE*	[CI 95 %]	*b*	*SE*	[CI 95 %]	*b*	*SE*	[CI 95 %]
Direct effects									
Population Density	<0.01	<0.01	[<−0.01,< 0.01]	<0.01	<0.01	[<−0.01, <0.01]	<−0.01	<0.01	[<−0.01, <0.01]
Sex Ratio	−1.44	2.42	[−6.19, 3.30]	−4.20	2.67	[−9.43, 1.02]	−6.23	3.68	[−13.44, 0.98]
Survival 65+	<−0.01	<0.01	[<−0.01,< 0.01]	<−0.01	<0.01	[−0.01, 0.01]	<0.01	0.01	[−0.01, 0.01]
Total Affected Nat. Disaster	−0.00	<0.01	[<−0.01, <0.01]	- < 0.01	<0.01	[<−0.01, <0.01]	<0.01	<0.01	[<−0.01, <0.01]
Total Affected Disease	<0.01	<0.01	[<−0.01, <0.01]	<−0.01***	<0.01	[−0.00, −0.00]	<−0.01**	<0.01	[−0.00, −0.00]
Inequality	−1.59*	0.73	[−3.02, −0.17]	−0.62	0.68	[−1.95, 0.71]	−1.16	0.69	[−2.50, 0.19]
Narcissism	<−0.01	<0.01	[−0.01, 0.01]	−0.01	0.03	[−0.07, 0.05]	<−0.01	0.04	[−0.08, 0.08]
Machiavellianism	<0.01	0.02	[−0.03, 0.04]	0.02	0.05	[−0.09, 0.12]	0.02	0.03	[−0.05, 0.08]
Indirect effects									
Population Density	<0.01	<0.01	[<−0.01, <0.01]	<0.01	<0.01	[<−0.01, <0.01]	<0.01*	<0.01	[<0.01, 0.00]
Sex Ratio	0.27	1.27	[−2.21, 2.75]	1.62	1.43	[−1.19, 4.43]	2.62	1.98	[−1.27, 6.51]
Survival 65+	<−0.01	0.01	[−0.02, 0.01]	−0.02	0.01	[−0.04, 0.01]	−0.02	0.01	[−0.04, 0.01]
Total Affected Nat. Disaster	<0.01	<0.01	[0.00, 0.00]	<−0.01	<0.01	[0.00, 0.00]	<0.01	<0.01	[<−0.01, <0.01]
Total Affected Disease	<−0.01	0.00	[<−0.01, <0.01]	<−0.01	<0.01	[<−0.01, <0.01]	<−0.01	0.00	[<−0.01, <0.01]
Inequality	0.62	0.87	[−1.07, 2.32]	1.31	1.58	[−1.79, 4.41]	1.37	0.73	[−0.06, 2.80]
Narcissism	0.03	0.42	[−0.80, 0.85]	0.26	0.30	[−0.33, 0.84]	<0.01	0.27	[−0.53, 0.54]
Machiavellianism	−0.12	0.35	[−0.80, 0.56]	−0.50	0.33	[−1.15, 0.19]	−0.12	0.21	[−0.52, 0.28]
Total effects									
Population Density	<0.01	<0.01	[<−0.01, <0.01]	<0.01	<0.01	[<−0.01, <0.01]	<0.01*	<0.01	[<0.01, <0.01]
Sex Ratio	−1.17	2.19	[−5.47, 3.12]	−2.58	2.83	[−8.13, 2.96]	−3.61	2.55	[−8.61, 1.39]
Survival 65+	−0.01	0.01	[−0.02, 0.01]	−0.02	0.01	[−0.04, 0.01]	−0.02	0.01	[−0.03, <0.01]
Total Affected Nat. Disaster	<0.01	0.00	[<−0.01, <0.01]	<−0.01	<0.01	[<−0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]
Total Affected Disease	<0.01	0.00	[<−0.01, <0.01]	<−0.01	<0.01	[<−0.01, <0.01]	<−0.01	<0.01	[<−0.01, <0.01]
Inequality	−0.97	0.91	[−2.74, 0.81]	0.69	1.81	[−2.85, 4.23]	0.22	0.77	[−1.30, 1.73]
Narcissism	0.03	0.42	[−0.80, 0.85]	0.25	0.29	[−0.33, 0.82]	<0.01	0.23	[−0.45, 0.46]
Machiavellianism	−0.12	0.35	[−0.80, 0.56]	−0.48	0.34	[−1.15, 0.19]	−0.10	0.18	[−0.45, 0.25]

Note: Total Affected Nat. Disaster/Disea*SE* = per 1 million.
* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 6
Ecological factors predicting country-level sex differences in narcissism.

	2000–2004			2005–2009			2010–2015		
	b	*SE*	[CI 95 %]	*b*	*SE*	[CI 95 %]	*b*	*SE*	[CI 95 %]
Direct effects									
Population Density	<0.01	<0.01	[<−0.01, <0.01]	<0.01	<0.01	[<−0.01, <0.01]	<0.01	<0.01	[<−0.01, <0.01]
Sex Ratio	−4.43***	1.11	[−6.60, −2.25]	−2.06	1.49	[−4.99, 0.87]	−1.72	1.78	[−5.20, 1.77]
Survival 65+	<−0.01	<0.01	[−0.01, 0.01]	−0.01	0.01	[−0.02, 0.01]	<−0.01	0.01	[−0.01, 0.01]
Total Affected Nat. Disaster	<0.01*	<0.01	[<0.01, <0.01]	<0.01	<0.01	[0.00, 0.00]	<0.01	<0.01	[<0.01, <0.01]
Total Affected Disease	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<−0.01, <0.01]	<0.01	<0.01	[<−0.01, <0.01]
Inequality	−0.42	0.53	[−1.45, 0.62]	0.11	0.58	[−1.04, 1.25]	0.68	0.65	[−0.60, 1.95]
Sex Differences Machiavellianism	−0.05	0.14	[−0.32, 0.22]	−0.19	0.25	[−0.68, 0.31]	−0.19	0.34	[−0.86, 0.47]
Sex Differences Psychopathy	−0.01	0.04	[−0.09, 0.07]	−0.07	0.08	[−0.22, 0.08]	−0.02	0.04	[−0.08, 0.05]
Indirect effects									
Population Density	<0.01	<0.01	[<0.01, <0.01]	<0.01*	<0.01	[<0.01, <0.01]	<0.01*	<0.01	[<0.01, <0.01]
Sex Ratio	0.16	1.17	[−2.14, 2.45]	−0.28	0.83	[−1.90, 1.34]	−0.21	0.60	[−1.38, 0.96]
Survival 65+	<0.01	0.01	[−0.01, 0.01]	0.01	0.01	[−0.01, 0.02]	<0.01	0.01	[−0.01, 0.02]
Total Affected Nat. Disaster	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]
Total Affected Disease	<−0.01**	<0.01	[<−0.01, <0.01]	<−0.01	0.00	[<−0.01, <0.01]	<0.01	<0.01	[<−0.01, <0.01]
Inequality	0.96	0.51	[−0.04, 1.97]	1.34	0.77	[−0.17, 2.84]	0.67	0.69	[−0.69, 2.03]
Sex Differences Machiavellianism	0.31	0.32	[−0.31, 0.93]	0.56	0.33	[−0.10, 1.21]	0.90*	0.40	[0.11, 1.68]
Sex Differences Psychopathy	0.06	0.27	[−0.47, 0.59]	0.22	0.22	[−0.22, 0.65]	0.08	0.20	[−0.31, 0.47]
Total effects									
Population Density	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]
Sex Ratio	−4.27***	1.24	[−6.70, −1.85]	−2.34*	0.92	[−4.15, −0.53]	−1.93	1.35	[−4.57, 0.72]
Survival 65+	<0.01	<0.01	[−0.01, 0.01]	- < 0.01	<0.01	[−0.01, 0.01]	<−0.01	0.01	[−0.01, 0.01]
Total Affected Nat. Disaster	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]
Total Affected Disease	<0.01	<0.01	[<−0.01, <0.01]	<−0.01	<0.01	[<−0.01, <0.01]	<0.01	<0.01	[<−0.01, <0.01]
Inequality	0.55	0.40	[−0.24, 1.34]	1.44*	0.70	[0.07, 2.81]	1.35**	0.48	[0.40, 2.30]
Sex Differences Machiavellianism	0.26	0.21	[−0.14, 0.67]	0.37**	0.12	[0.13, 0.61]	0.70***	0.19	[0.34, 1.07]
Sex Differences Psychopathy	0.05	0.23	[−0.41, 0.51]	0.15	0.18	[−0.21, 0.50]	0.06	0.17	[−0.27, 0.39]

Note: Total Affected Nat. Disaster/Disea*SE* = per 1 million.
* $p < .05$, ** $p < .01$, *** $p < .001$.

history strategy, where self-enhancing and status-seeking traits become more prominent in harsh or unpredictable ecologies (Del Giudice et al., 2015).

Second, higher (male -biased) sex ratios during mid-childhood and adolescence were linked to *lower* Machiavellianism in adulthood. Similarly, a higher national disease burden was associated with lower Machiavellianism. These findings suggest that manipulative and strategic interpersonal behavior may be less adaptive in environments

Table 7
Ecological factors predicting country-level sex differences in Machiavellianism.

	2000–2004			2005–2009			2010–2015		
	b	*SE*	[CI 95 %]	*b*	*SE*	[CI 95 %]	*b*	*SE*	[CI 95 %]
Direct effects									
Population Density	<0.01	<0.01	[<−0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]
Sex Ratio	−1.87	1.92	[−5.64, 1.90]	−0.13	1.08	[−2.24, 1.99]	−0.07	1.28	[−2.57, 2.44]
Survival 65+	<0.01	0.01	[−0.02, 0.03]	−0.01	<0.01	[<−0.01, <0.01]	<−0.01	<0.01	[<−0.01, <0.01]
Total Affected Nat. Disaster	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]	<0.01*	<0.01	[<0.01, <0.01]
Total Affected Disease	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<−0.01, <0.01]	−0.00**	<0.01	[<−0.01, <−0.01]
Inequality	−0.20	0.35	[−0.88, 0.48]	0.25	0.41	[−0.56, 1.06]	0.12	0.52	[−0.90, 1.13]
Sex Differences Narcissism	−0.08	0.43	[−0.92, 0.76]	<0.01	0.01	[−0.02, 0.02]	<0.01	0.01	[−0.02, 0.02]
Sex Differences Psychopathy	−0.03	0.21	[−0.44, 0.37]	<0.01	0.04	[−0.07, 0.08]	<0.01	0.02	[−0.03, 0.04]
Indirect effects									
Population Density	<−0.01	<0.01	[−0.01, 0.01]	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]
Sex Ratio	−3.02	15.54	[−33.48, 27.44]	−0.87	0.73	[−2.30, 0.57]	−0.75	0.96	[−2.62, 1.13]
Survival 65+	0.03	0.11	[−0.20, 0.25]	0.01	0.01	[−0.01, 0.02]	0.01	0.01	[−0.01, 0.02]
Total Affected Nat. Disaster	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]
Total Affected Disease	<0.01	<0.01	[<−0.01, <0.01]	<−0.01	<0.01	[<−0.01, <0.01]	<0.01	<0.01	[<−0.01, <0.01]
Inequality	−0.61	3.14	[−6.76, 5.54]	1.10	0.97	[−0.80, 2.99]	0.41	0.69	[−0.95, 1.76]
Sex Differences Narcissism	−0.70	3.98	[−8.50, 7.09]	0.09	0.18	[−0.26, 0.44]	0.08	0.27	[−0.45, 0.60]
Sex Differences Psychopathy	−0.31	1.91	[−4.05, 3.43]	0.27	0.24	[−0.20, 0.73]	0.10	0.19	[−0.27, 0.47]
Total effects									
Population Density	<−0.01	<0.01	[−0.01, 0.01]	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]
Sex Ratio	−4.89	17.22	[−38.64, 28.86]	−0.99	1.49	[−3.92, 1.93]	−0.81	1.66	[−4.06, 2.44]
Survival 65+	0.03	0.13	[−0.22, 0.27]	<0.01	<0.01	[−0.01, 0.01]	<0.01	0.01	[−0.01, 0.02]
Total Affected Nat. Disaster	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[0.00, 0.00]	<0.01	<0.01	[<0.01, <0.01]
Total Affected Disease	<0.01	<0.01	[<−0.01, <0.01]	<−0.01	<0.01	[<−0.01, <0.01]	<0.01	<0.01	[<−0.01, <0.01]
Inequality	−0.81	3.35	[−7.39, 5.76]	1.34	1.17	[−0.96, 3.64]	0.52	0.93	[−1.30, 2.34]
Sex Differences Narcissism	−0.78	4.40	[−9.41, 7.85]	0.09	0.17	[−0.25, 0.43]	0.08	0.27	[−0.45, 0.61]
Sex Differences Psychopathy	−0.34	2.11	[−4.48, 3.80]	0.27	0.25	[−0.22, 0.76]	0.11	0.20	[−0.28, 0.50]

Note: Total Affected Nat. Disaster/Disea*SE* = per 1 million.
* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 8
Ecological factors predicting country-level sex differences in psychopathy.

	2000–2004			2005–2009			2010–2015		
	b	*SE*	[CI 95 %]	*b*	*SE*	[CI 95 %]	*b*	*SE*	[CI 95 %]
Direct effects									
Population Density	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<−0.01, <0.01]
Sex Ratio	0.24	1.50	[−2.69, 3.17]	1.72	1.16	[−0.55, 3.99]	1.81	1.42	[−0.98, 4.60]
Survival 65+	−0.01	0.01	[−0.02, 0.00]	<−0.01	0.01	[−0.02, 0.01]	−0.01	0.01	[−0.02, 0.01]
Total Affected Nat. Disaster	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]	<0.01**	<0.01	[<0.01, <0.01]
Total Affected Disease	<0.01	<0.01	[<0.01, <0.01]	<−0.01	<0.01	[<−0.01, <0.01]	<0.01	<0.01	[<−0.01, <0.01]
Inequality	−0.27	0.45	[−1.15, 0.62]	0.18	0.51	[−0.81, 1.17]	−0.11	0.54	[−1.15, 0.94]
Sex Differences Narcissism	0.06	0.10	[−0.14, 0.25]	−0.05	0.10	[−0.25, 0.15]	−0.01	0.05	[−0.10, 0.08]
Sex Differences Machiavellianism	−0.08	0.14	[−0.36, 0.20]	0.06	0.13	[−0.19, 0.31]	0.02	0.06	[−0.10, 0.14]
Indirect effects									
Population Density	<0.01	<0.01	[<−0.01, <0.01]	<0.01	0.00	[<−0.01, <0.01]	<0.01	<0.01	[<−0.01, <0.01]
Sex Ratio	−1.36**	0.50	[−2.33, −0.38]	−2.60	1.72	[−5.98, 0.78]	−2.47***	0.71	[−3.86, −1.07]
Survival 65+	0.02**	0.01	[0.01, 0.03]	0.03	0.02	[<−0.01, 0.06]	0.03**	0.01	[0.01, 0.05]
Total Affected Nat. Disaster	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, 0.00]	<0.01	<0.01	[<−0.01, <0.01]
Total Affected Disease	<0.01	0.00	[<−0.01, <0.01]	- < 0.01	<0.01	[−0.01, 0.01]	<0.01	<0.01	[<−0.01, <0.01]
Inequality	0.43	0.72	[−0.98, 1.83]	1.94	2.73	[−3.41, 7.28]	0.95	0.82	[−0.66, 2.56]
Sex Differences Narcissism	−0.48	0.28	[−1.03, 0.08]	−0.71	0.60	[−1.88, 0.47]	−0.52	0.28	[−1.07, 0.04]
Sex Differences Machiavellianism	0.70*	0.32	[0.07, 1.32]	0.92	0.76	[−0.58, 2.40]	0.70	0.42	[−0.13, 1.52]
Total effects									
Population Density	<0.01	<0.01	[<−0.01, <0.01]	<0.01	<0.01	[<−0.01, <0.01]	<0.01	<0.01	[<−0.01, <0.01]
Sex Ratio	−1.12	1.42	[−3.90, 1.67]	−0.88	2.53	[−5.84, 4.08]	−0.66	1.69	[−3.96, 2.65]
Survival 65+	0.01*	0.01	[<0.01, 0.02]	0.02	0.02	[−0.02, 0.06]	0.02*	0.01	[<0.01, 0.04]
Total Affected Nat. Disaster	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<0.01, <0.01]	<0.01	<0.01	[<−0.01, <0.01]
Total Affected Disease	<0.01	<0.01	[<−0.01, <0.01]	<−0.01	0.01	[−0.01, 0.01]	<0.01	<0.01	[<−0.01, <0.01]
Inequality	0.16	0.56	[−0.93, 1.25]	2.12	3.04	[−3.85, 8.08]	0.84	0.87	[−0.86, 2.54]
Sex Differences Narcissism	−0.42	0.27	[−0.95, 0.11]	−0.75	0.69	[−2.11, 0.61]	−0.53	0.31	[−1.14, 0.08]
Sex Differences Machiavellianism	0.61*	0.31	[0.00, 1.23]	0.98	0.88	[−0.74, 2.69]	0.71	0.46	[−0.18, 1.61]

Note: Total Affected Nat. Disaster/Disea*SE* = per 1 million.
* $p < .05$, ** $p < .01$, *** $p < .001$.

where overt competition (e.g., male-biased sex ratios) or health threats necessitate stronger conformity and social cohesion. This aligns with cross-cultural findings linking higher disease prevalence to collectivism and stricter social norms; these conditions may constrain the utility or social acceptability of manipulative behavior (Fincher et al., 2008).

Third, psychopathy followed a similar ecological pattern as Machiavellianism: higher disease burden was associated with lower psychopathy scores. These results further support the idea that exploitative

interpersonal strategies may be less prevalent or less functional in ecologies where group cohesion and norm enforcement are adaptive responses to pathogen threats. Unexpectedly, greater economic inequality during early childhood was associated with lower psychopathy, a finding that runs counter to theories predicting increased competition and social fragmentation under inequality. One possible interpretation is that in highly stratified societies, status hierarchies may suppress individual-level competition, thereby dampening the expression of psychopathic traits (Van Vugt and Tybur, 2015). Another explanation is that our samples were mainly students, who belong to the elite in most countries, which provides a buffer against threatening local ecologies.

Last, in terms of regional effects, we found indirect effects of neighboring countries' ecological conditions on the focal country's personality Dark Triad traits. Higher levels of population density, natural disaster impact, and inequality in neighboring countries were associated with higher narcissism and Machiavellianism in the focal country, suggesting that regional factors such as migration, economic interdependence, cultural diffusion, and shared environmental challenges shape national psychological profiles. Conversely, higher disease burden in neighboring countries was associated with lower levels of narcissism and Machiavellianism, while higher neighboring population density was associated with higher psychopathy. These patterns suggest that countries do not develop psychological profiles in isolation. Rather, country-level traits are embedded within broader regional systems. The distinction between evoked culture (similar traits emerging in response to similar ecological conditions) and transmitted culture (traits diffusing across borders through social learning and migration) provides a useful framework for interpreting these effects (Lonati and Van Vugt, 2024).

6.2. *Ecological conditions influence sex differences in the Dark Triad traits*

We also identified several predictors of national variation in sex differences in the Dark Triad traits. Natural disaster exposure was associated with *larger* sex differences across all three traits, supporting the theoretical expectation (based on life history and sexual selection theory) that unstable, high-threat ecologies amplify divergent male and female reproductive strategies. For instance, in such environments, men may adopt more risk-prone and exploitative behaviors, while women may become more cautious—thus increasing the psychological distance between the sexes. Surprisingly, male-biased sex ratios were associated with reduced sex differences, primarily observed as a direct effect on narcissism and indirect (spillover) effects on psychopathy. This finding runs counter to predictions derived from sexual selection theory; it may potentially reflect complex dynamics such as strategic convergence (e.g., women adopting male-typical self-promotional behaviors) or sampling effects. Indeed, the Dark Triad traits are positively associated with intrasexual competition only weakly and in a way that may require more nuanced measurement (Jonason et al., 2023). For instance, women report more intrasexual envy, men report more intrasexual superiority, but no difference is found in intrasexual jealousy. Further research is needed to unpack these interactions.

Moreover, traits and conditions in neighboring countries (e.g., sex ratio, survival rates, and personality scores) were associated with sex differences in the focal country. This highlights that even the sex-typical expression of personality is subject to regional influences, again supporting both evoked and transmitted culture as explanatory mechanisms. Our findings suggest that the national prevalence of Dark Triad traits (and the sex differences therein) are shaped by ecological conditions experienced during key developmental periods, often decades before personality is measured. These patterns extend beyond national borders, with neighboring countries' ecological and demographic profiles exerting meaningful influence. There is likely a complex interplay between demographic (e.g., sex ratios), environmental (e.g., disease, natural disasters), and structural (e.g., inequality) factors in shaping population-level personality.

7. Limitations and conclusions

Despite the statistical and theoretical rigor and novelty presented herein, our study suffers from several shortcomings. First, our samples were primarily derived from college student pools and are thus biased by education, modernization, Westernization, and prosperity effects, as well as being female-biased. Furthermore, this clustered sampling approach, when analyzed against country-level ecological indicators, may confound cohort composition with macro-effects, potentially increasing the risk of Type-I error. Second, because we relied on secondary data, we cannot determine the nature of the sex differences further. Put differently, we cannot tell who goes up or down as we move from country to country. Third, the Dark Triad traits may be extended to include sadism (Neumann et al., 2021) but our data was collected before streamlined measures for that trait had been widely adopted. However, given the rather high overlap between psychopathy and sadism, we are dubious of the utility of including it. Fourth, while we have temporal precedence via our milieu approach (Jonason et al., 2022), we cannot say these ecological conditions cause adult Dark Triad scores or their sex differences, and because we only have data at one timepoint for the Dark Triad traits, we cannot test canalization (i.e., Waddington's landscape) here which would suggest that people solidify their life history strategy and personality as they age in response to recurrent conditions (Fawcett and Frankenhuis, 2015; Panchanathan and Frankenhuis, 2016). Fifth, our analytical approach focused on distinct developmental windows to identify potential sensitive periods. However, this design does not account for the cumulative effects of ecological exposure across the entire developmental trajectory (2000–2015). Future research could explore models that integrate the long-term, aggregated impact of ecological harshness and unpredictability on Dark Triad traits. And while we attempted to capture developmental periods, these were chosen as rough estimates based on the global average age of the sample. Substantial cross-national variance in participant age (e.g., ranging from 18.93 in Belgium to 27.65 in Latvia) means these calendar periods do not uniformly map onto specific developmental stages across all countries. Furthermore, the timing of developmental transitions might be sensitive to how local conditions in ecology, food availability, and familial consideration differ from nation to nation. Lastly, the Dirty Dozen measure is perhaps the most problematic measure of the Dark Triad because its brevity may undermine its validity (Miller et al., 2012), and it cannot be reduced to lower-order aspects (Maples et al., 2014). Future research should draw on sex-balanced big data to reduce estimation error and, ideally, examine ecological factors alongside social and personal factors to embed the development of the Dark Triad or the Dark Tetrad within a larger socio-ecological context.

Despite these limitations, some strengths are also noteworthy. This is, to our knowledge, the first attempt to link the prevalence of Dark Triad traits between nations to the ecologies in which these nations operate. Second, we looked at a list of key ecological predictors that have been shown to be associated in previous studies with national differences in culture, leadership preferences, personality, and various social psychological factors (e.g., Lonati and Van Vugt, 2024; Wormley et al., 2023). A third strength is that we developed a theoretical model, based on the integration of trait activation theory, life history theory with sexual selection, and parental investment theory, that can account for some of the variation between the sexes in Dark Triad trait scores. This model needs further development and testing. Fourth, it remains unclear whether the traits are alternative phenotypes or condition-dependent adaptations, and, more importantly, we cannot say anything about gene × environment interactions for the development of these traits (Buss, 2009). While our results lean more towards a local calibration interpretation, we cannot rule out genetic differences (e.g., founder effects) in our countries. More work will be needed to integrate the molecular to the ecological factors that *could* matter in this equation.

Lastly, we have identified two mechanisms, evoked culture, and transmitted culture, that could account for how ecology shapes personality variation. It would be worth teasing them out in subsequent research, perhaps looking at countries that have experienced recent migration patterns from both neighboring and more distant countries, the main question being whether people's Dark Triad traits change as they move from one ecology into another, and at what age this personality change happens.

In the end, we tested an ecological model of the prevalence of Dark Triad personality traits between nations. We found some systematic connections between high-threat ecologies that people experience at different life phases and the national averages on narcissism, Machiavellianism, and psychopathy. We could also link sex differences in these traits to specific ecological factors. While this is a preliminary attempt to study the relationship between ecology and the dark side of personality, more research is needed to understand how ecology shapes the traits as well as the interpersonal and societal consequences of them as well.

CRediT authorship contribution statement

Peter K. Jonason: Writing – review & editing, Writing – original draft, Project administration, Conceptualization. **Dritjon Gruda:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Mark van Vugt:** Writing – review & editing, Writing – original draft, Conceptualization.

Declaration of Competing Interest

None

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.evolhumbehav.2025.106780.

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