Age-Appropriate Wisdom?

Ethnobiological Knowledge Ontogeny in Pastoralist Mexican Choyeros

Eric Schniter¹ · Shane J. Macfarlan^{2,3,4} · Juan J. Garcia⁵ ·
Gorgonio Ruiz-Campos⁶ · Diego Guevara Beltran⁷ · Brenda B. Bowen^{4,8} ·
Jory C. Lerback⁸

Accepted: 28 January 2021

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Abstract

We investigate whether age profiles of ethnobiological knowledge development are consistent with predictions derived from life history theory about the timing of productivity and reproduction. Life history models predict complementary knowledge profiles developing across the lifespan for women and men as they experience changes in embodied capital and the needs of dependent offspring. We evaluate these predictions using an ethnobiological knowledge assessment tool developed for an off-grid pastoralist population known as Choyeros, from Baja California Sur, Mexico. Our results indicate that while individuals acquire knowledge of most dangerous items and edible resources by early adulthood, knowledge of plants and animals relevant to the age and sex divided labor domains and ecologies (e.g., women's house gardens, men's herding activities in the wilderness) continues to develop into middle adulthood but to different degrees and at different rates for men and women. As the demands of offspring on parents accumulate with age, reproductive-aged adults continue to develop their knowledge to meet their children's needs. After controlling for vision, our analysis indicates that many post-reproductive adults show the greatest ethnobiological knowledge. These findings extend our understanding of the evolved human life history by illustrating how changes in embodied capital and the needs of dependent offspring predict the development of men's and women's ethnobiological knowledge across the lifespan.

Keywords Traditional ecological knowledge · Ethnobiological knowledge · Learning · Embodied capital · Life history theory · Baja California Sur · México

✉ Eric Schniter
eschniter@gmail.com

Extended author information available on the last page of the article

Life history models predict knowledge profiles developing across the lifespan as organisms learn, grow, reproduce, invest (e.g., nutritionally, educationally) in dependent offspring, and senesce. Debates in anthropology have centered on alternative interpretations of what shapes these age-specific knowledge profiles should take across the lifespan. One view, inspired by general life-history models applied to primate foraging (e.g., Schuppli et al. 2012), suggests that effort allocated to productivity (which includes investments in acquiring knowledge) should increase up until physical maturation and plateau for the remainder of the life course (e.g., see discussion in Kramer and Ellison 2010). This “wise adults” view suggests that the wisdom of younger adults should be equally developed as that of older adults. A different view, held widely among social scientists, is that vocabulary and worldly knowledge, which relies on experience (what Cattell 1963 called “crystallized intelligence”), continues to accumulate past the age of physical maturation, resulting in “wisdom of elders” (Berlin 1992; Gurven et al. 2017; Koster et al. 2016). Heterogeneity in aging and the experience of stochastic shocks (e.g., injury, illness) contribute to unequal abilities among elders to develop this wisdom, challenging the universality of a “wise elders” claim. Previous studies have reported peak ages for ethnobiological knowledge through a wide range of adult ages: around 30–80 years of age for Mayangna and Miskito forager-horticulturalists of Nicaragua (Koster et al. 2016), around 30–40 years for Djerma farmers, and 40–50 years for Peulh herdsman of Nigeria (Ayantunde et al. 2008).¹

The embodied capital perspective (Kaplan 1996) considers (from a biological fitness maximization perspective) how individuals and their parents optimally invest in growing and maintaining the body’s physical capital (e.g., bones, muscles, neurons) and functional capital (e.g., strength and coordination, skill, knowledge). According to embodied capital theory, extreme investments in cognitive capital have led to a human life history pattern of complementary “age appropriate” knowledge profiles developing across the lifespan for women and men as they experience changes in their stocks of embodied capital and demand of their dependent offspring (Del Giudice et al. 2016). This perspective predicts that levels of productivity and childrearing increase through reproductive parent ages when offspring provisioning demands (for both calories and knowledge/experience) are growing (peaking approximately 35–45 years of age) and should remain high until impacted by senescence (e.g., of physical mobility, visual, and hearing systems). We use “age appropriate” to refer to the nuanced view that an older adult’s ability to demonstrate knowledge is constrained by their particular abilities (e.g., to see, to move about, to remember), and that there is increasing heterogeneity in these abilities with age.

To gauge ethnobiological knowledge, we evaluate responses to a set of images showing culturally salient plants and animals that we presented to Mexican Choyeros, an off-grid arid land pastoralist population whose livelihood has been closely tethered to arid land springs and open rangelands of the Sierra de la Giganta mountains of Baja California Sur for more than 300 years (Cariño

¹ Others also report ethnobiological knowledge variation at different ages and across generations (Hewlett et al. 2011; Kline et al. 2013; Ohmagari and Berkes 1997; Schniter et al. 2015; Zarger and Stepp 2004; Zent 2001).

Olvera 2014; Koster et al. 2019). From an evolved life history strategy perspective, we predict how age-appropriate complementary knowledge profiles develop across the lifespan for Choyero men and women as they experience changes in embodied capital and the needs of dependent offspring. We report age profiles of Choyero ethnobiological knowledge development that are consistent with predictions derived from life history theory. This paper sheds new light on the distribution of ethnobiological knowledge maintained by a relatively isolated and small-scale subsistence society.

Hypotheses and Predictions

We test predictions based on our overarching hypothesis that the time-path of ethnobiological knowledge development corresponds with functional “life goals” and embodied capital constraints specific to each of three stages of the human life course. In the *pre-reproductive life stage* the goals are to (1) acquire basic skills and knowledge (e.g., ability to recognize and name edible and dangerous plants and animals) to support one’s self and (2) attract and secure a mate, which often involves demonstrating basic competence consistent with the first goal. The goals of the *reproductive life stage* are to (3) reproduce, optimally developing and using skills and knowledge to support reproduction, such that (4) offspring are successfully raised to be able to accomplish pre-reproductive and reproductive goals 1, 2, 3, and 4 (this entails transferring both material resources and *knowledge* to dependents). After reproduction ceases with menopause, additional years of life are needed for the last-born offspring to fully achieve goals 1, 2, 3, and 4. During transition to the *post-reproductive life stage*, (5) adults continue making contributions towards fulfilling kin’s goals 1, 2, 3, and 4, despite (and in compensation for limitations related to) age-related senescence. Below we derive several predictions concerning ethnobiological knowledge development across the life course.

Pre-reproductive Life Stage

The pre-reproductive life stage includes gestation, infancy, childhood, adolescence, and ends at first reproduction. During this period, young adults are generally protected, remain relatively free of responsibilities that require great exertion or risk, and are supported by the surplus food production and knowledge provided by older adults (Kaplan 1994; Kaplan et al. 2000; Lee 2013; Lee and Kramer 2002). Social learning of conceptual elements and procedures needed for survival in a subsistence society is well underway during childhood (Hewlett et al. 2011; Kline et al. 2013; Ruddle and Chesterfield 1977; Stieglitz et al. 2013).

Cross-culturally, people name and classify plants and animals—a key to rapid and effective learning (Atran 1990; Berlin 1992; Mithen 2006). What is even more striking is the ease with which some of this knowledge is acquired at young ages—human minds appear to be pre-tuned for acquiring and processing information about

certain classes of animals and plants relevant to adaptive challenges in early life stages throughout our evolutionary past (Atran 1990; Barrett et al. 2016). Below we consider the reasons and evidence for preferential knowledge of plants and animals that are potentially dangerous and/or food.

It is important for youngsters to prioritize acquiring information about dangerous plants and animals without experiencing morbid and mortal hazards firsthand. It appears that children are born with an innate understanding of what distinguishes living from inanimate things and begin learning about plants and animals at the youngest ages (Atran 1990; Barrett and Behne 2005; Carey and Spelke 1994; Keil 1987, 1994). Infants in the first and second year of life selectively identify plants over artifacts as food sources but also show a greater reluctance to manipulate plants because of the dangers they can pose (Wertz and Wynn 2014a, b). As an alternative to direct hands-on exploration, infants prefer to learn about plants indirectly by watching or receiving cues from adults (Elsner and Wertz 2019; Oña et al. 2019). Likewise, cross-cultural evidence shows that children show preferential attention to, learning of, and ability to remember culturally transmitted information about dangerous animals (Barrett and Broesch 2012).

Over the course of evolutionary history, it was also likely important for youngsters to identify plants and animals as natural sources of food or as competitors for food, the latter of which could present danger (Barrett 2005; Brantingham 1998). Though dangerous hazards prevent child foraging opportunities in many ecologies, some children as young as 3–5 years of age forage with other children or while accompanying their mothers on foraging trips, providing rich opportunities to gain important information about plant and animal dangers (Bliege Bird and Bird 2002; Crittenden et al. 2009; Hewlett and Lamb 2017). Brown (1985) has suggested that, given the hazards of agricultural crop and livestock failures, an interest in wild plants and animals that are potential food sources may have been crucial to the survival of small-scale agricultural groups. Others have noted that edible plants and animals are more salient than inedible things in the minds of horticultural people (e.g., Berlin 1992; Malinowski 1925).

During the pre-reproductive life stage, ethnobiological knowledge is transmitted via specific social vectors. Vertical transmission of important knowledge and subsistence skills during childhood often comes from same-sex parental figures (Borgerhoff Mulder et al. 2019; Garfield et al. 2016; Reyes-García et al. 2009; Schniter et al. 2015). This vertical transmission pattern promotes information stability over generations, even in the face of sociopolitical, economic, and environmental change (Hewlett and Cavalli-Sforza 1986; Ohmagari and Berkes 1997; Zarger and Stepp 2004). The necessary strength and size needed for coping with dangers, independent performance, and dedicated practice of difficult and physically demanding skills are often undeveloped until after the adolescent growth spurt (Bogin and Smith 1996), when adult stature is nearly attained and most subsistence skills are finally mastered (e.g., Cain 1977; Draper 1976; Ruddle and Chesterfield 1977). As learning-by-doing continues during adolescence and early adulthood, people often have greater opportunities to work and play alongside peers, learn horizontally from peers, and socialize beyond the nuclear family (Gallois et al. 2017; Hewlett and Cavalli-Sforza 1986; Reyes-García et al. 2016). Oblique transmission (from older

relatives other than parents), often same-sex, is reported to be a dominant mode of ethnobotanical knowledge learning and subsistence skill development after early childhood (Garfield et al. 2016; Reyes-García et al. 2009; Schniter 2009; Setalaphruk and Price 2007). A pattern of knowledge acquisitions that includes delays resulting from physical strength development and delayed social opportunities for learning suggests the possibility of continued knowledge development into adulthood (consistent with wisdom of elders and embodied capital model predictions).

Prediction 1 Knowledge of plants and animals will develop monotonically in the pre-reproductive life stage, and children will develop more knowledge of plants and animals that are potentially food and/or dangerous.

Reproductive Life Stage

The reproductive life stage for females is defined by fertility, spanning from the onset of reproduction to its cessation prior to menopause. During the reproductive stage, a primary goal is maintaining sufficient food production, education, and care to meet the waxing and waning demands of a family of dependents accumulated under a fertility schedule. The embodied capital model proposes that parental and grandparental childcare and support allow children the learning and on-the-job training opportunities in areas of food production, craft production, and childrearing (Kaplan 1996). Parental costs of provisioning and caring for young are offset by their offspring's increasing surplus returns over the long reproductive and post-reproductive lifespan (Kaplan et al. 2000; Robson and Kaplan 2003).

Maintaining proximity to helpful kin may be important because one's ability to be economically self-sufficient and fully support dependents is often achieved later than sexual maturity (Hill and Hurtado 2009; Howell 2010; Lee 2013; Marlowe 2007; Walker et al. 2013). Delayed productivity and downward resource flows among adults means parenting and grandparenting roles will often blend together toward the end of this stage, with adults possibly contributing support to two generations of dependents prior to cessation of the reproductive stage.

During fertile adult years, as the number and net caloric demands of dependents increase within a family, parents and grandparents are faced with greater provisioning and caregiving demands. Children's daily caloric net consumption requirements almost double between early childhood and teenage years (Trumbo et al. 2002).

When the net caloric demand of dependents is at its highest, adults who rely on subsistence skills produce the greatest amount of food of their life (Gurven and Walker 2006). During these times of high productivity, adults will also be actively engaged with relevant knowledge. Others have proposed that ethnobiological knowledge appears to develop as a function of time allocated to related tasks (Guest 2002; Koster et al. 2016; Reyes-García et al. 2013). In general, we expect that performance with knowledge skills related to subsistence (such as plant and animal identification and naming) is needed, practiced, and thus occurs at high levels around the time of greatest offspring demand.

With a focus on labor substitution within the household, Bock (2002a, 2002b) suggested that family members make optimal contributions to fitness given their strength and knowledge as a function of age, and differences in energetics of reproduction. From this a sexual division of labor is expected in which men and women invest in household and childrearing contributions that complement one another (Del Giudice et al. 2016; Macfarlan 2016). Over the course of human evolution and across cultures today, starting in early childhood, females typically move through smaller home ranges while males range over significantly larger areas (Gaulin and Hoffman 1988). In subsistence societies we see evidence of a clear sexual division of labor that affects men's and women's activities in and experience of the environment (Gurven et al. 2012; Kaplan et al. 2009). Plants may be differentially distributed (e.g., near human habitation vs. in the wilderness) and encountered differently by men and women who range across, and frequent, different environments.² Sex differences in men's and women's activities in their respective economic domains could affect reproductive-aged adults' exposure to and knowledge of plants.

Prediction 2 Ethnobiological knowledge should continue to develop into reproductive adulthood as parents continue to meet their offspring's burgeoning needs.

Prediction 3 During the reproductive life stage, ethnobiological plant knowledge relevant to gender-associated domains develops to different degrees and at different rates for women and men.

Post-reproductive Life Stage

The post-fertility period that we call the "post-reproductive life stage" is mostly an extension of the reproductive career. Physical strength that contributes to productive subsistence work is greatest earlier in adulthood and declines into later adulthood, a human aging process referred to as sarcopenia (Rosenberg 1997; Walker and Hill 2003; Walker et al. 2002). By the seventh decade of life, when one's children are all economically self-sufficient, caloric production among subsistence people declines (Amoss and Harrell 1981; Gurven and Kaplan 2006; Gurven et al. 2012; Walker and Hill 2003), food transfers to kin decline (Hooper 2011; Kaplan et al. 2000), and functional disability increases (Kaplan et al. 2010; Stieglitz et al. 2015). Despite their functional deficits, older adults are often capable of transferring important information to, and helping, younger kin (Burke and Mackay 1997; Schniter 2014). Delayed productivity, extending beyond peak ages of offspring dependency, is consistent with the expectations of both the embodied capital model and the grandmother hypothesis (Hawkes 2003; Hawkes et al. 1989). The grandmother hypothesis is a one-sex model of life history evolution that focuses on selection for older females who are grandmothers, whereas the embodied capital model is a two-sex model that predicts both sexes will make important complementary

² Like plants, animals may also be differentially distributed across environments (e.g., human inhabited vs. uninhabited), but often less so because of their mobility and movements across environments.

post-reproductive contributions to fitness—for example, by sharing their late life wisdom with close kin.

Wisdom late in life is also consistent with a cognitive reserve hypothesis arguing that encephalization of brain tissue, particularly in the cerebral cortex, which is specialized in the storage, retrieval, and processing of experiences, represents an increased investment in the capacity to transfer important information (Parker and McKinney 2012). Returns from accumulated “cognitive capital,” for example via transfers of ethnobiological knowledge (e.g., via applied and communicated knowledge and experience), may show stability with advancing adult age or even increase until the final decade of life (Park et al. 2002; Salthouse 1993; Schaie 1994). Thus, conceptual and procedural learning may continue in the post-reproductive life stage, producing wise elders decades after the expected age of peak transfers needed to meet dependents’ needs.

Specific physical and cognitive abilities (e.g., strength, hearing, seeing) may decline with age and negatively impact older adults’ ability to develop or recall knowledge stored in memory. Overall memory performance is traditionally understood in terms of the concerted functioning of three stages: encoding, storage, and retrieval (Craik and Rose 2012). The encoding and storage of plant and animal information tends to take place at early ages when people are first exposed to information about them. Retrieval of stored information based on stimulus prompt (e.g., recognizing a seen item which triggers the retrieval of its name) is improved with practice, a process sometimes called “rehearsal” but also consistent with practice and “general use models” predicting knowledge. Age-related decrements in ability to correctly name recognized items may reflect inefficiencies of retrieval operations involved in memory but may also reflect age-related changes in activity and experience that affect how and whether older adults interact with memory prompts in their environment.

Finally, visual acuity directly affects how carefully one can recognize encountered items. Recognition affects rehearsal and recall ability. If people are not seeing well, they might not be recognizing things as clearly as when they saw better and therefore have less reason to recall and rehearse their memories (e.g., details and names). Perceptual deterioration reduces recall of specific detail from the encoded record, leading to degraded memory (Craik and Rose 2012; Schneider and Pichora-Fuller 2000).

As heterogeneity in physical (Maddox and Clark 1992; Nelson and Dannefer 1992) and mental abilities (Ardila 2007; Christensen et al. 1999) increases at later ages, it reinforces greater specialization in the post-reproductive life stage, with older adults increasingly focusing on skills best suited to their abilities and contribution opportunities. Heterogeneous patterns of aging suggest that while a “wisdom of elders” pattern may not emerge for most or on average, the highest levels of knowledge demonstrated among adults may be differentially represented by a few wise individuals in their post-reproductive years.

Prediction 4 The highest level of ethnobiological knowledge will be observed among a subset of adults in their post-reproductive years.

Prediction 5 Knowledge in gender-associated economic domains among post-reproductive adults is explained by visual acuity variation and the different male and female activity patterns in their gender-associated economic domains.

Methods

Below we present information about our study sample, their biogeographical setting, way of life, and ethnobiological knowledge breadth. We also describe research we conducted that contributed to our knowledge about our sample, including their fertility schedules, family budgets, and ethnobiological knowledge.

Study Sample and Ecology

Our study was conducted across four ranching communities (Santa Maria de Toris, San Pedro de la Presa, La Higuera, and La Soledad) in the southern Sierra de La Giganta mountain range within the municipality of La Paz, Baja California Sur, México (Fig. 1).

Fig. 1 Loess smooth lines (50% fit) showing number of dependent offspring for each Choyero head of household ($n = 143$)

Choyeros Approximately 4000 people known as Choyeros currently occupy the Sierra de La Giganta (hereafter “Giganta”) mountain range of Baja California Sur, one of the least populated areas in one of the least inhabited states in Mexico (Comisión Nacional de Areas Naturales Protegidas 2020). Choyeros refer to themselves by this name, which roughly means people of the local cholla cactus (*Cylindropuntia cholla*) desert. With the Giganta covering approximately 7,400 km² (Leon de la Luz et al. 2008), Choyero population density is about 1 person per 2 km². These Choyeros reside on working ranches distributed over the many drainages found throughout the Giganta, and most are descended through consanguineal and/or affinal ties from the original Euro-American families who colonized the region over the past 300 years (Koster et al. 2019; Macfarlan et al. 2019a). Choyeros share a cultural history with other ranching populations found throughout the peninsula and have been referred to as *rancheros*, *Californios*, or *Oasiana-Rancheros* in the academic literature (Crosby 2015; Cariño Olvera 2014).

Biogeographical Setting Biogeographically, the Giganta is characterized as Sonoran Desert (Shreve and Wiggins 1964) with sacrocaulescent scrubland vegetation. It has a hot arid climate with most of its rainfall generated by tropical storms and hurricanes occurring during the late summer and early fall (August–October) (INEGI 2016). The Giganta is Baja California Sur’s largest mountain range, spanning approximately 150 km along a NW-SE axis (León de la Luz and Coria Benet 2018). The mountain range is situated in a geological complex known as the Comondú Formation, which is composed of clastic sandstones, volcanic rock, and conglomerates. Although the range is situated more closely to the Gulf of California along its precipitous eastern escarpment, the majority of its surface slopes towards the Magdalena Plain in the west, producing a number of intermittent drainages that terminate at the Pacific Ocean. It is along these drainages that a variety of perennial wetlands emerge, either as perched water tables, springs, or hanging gardens (Maya et al. 1997; Ruiz-Campos et al. 2014). These wetlands are species-rich and diverse (León de la Luz and Domínguez Cadena 2006; Riemann and Ezcurra 2005; Ruiz-Campos et al. 2002). The wetlands act as waypoints for resident and migratory species (Erickson et al. 2008; Rodríguez-Estrella 2005), provide forage and pasture for livestock, and have been making human life possible in this harsh and unforgiving landscape for at least the past 4000 years (Henrickson 2014; Macfarlan and Henrickson 2010).

Cultural Adaptation to Arid Land Pastoralism in the Giganta Choyeros have accommodated the Giganta’s hot arid climate and sparse rainfall over the past three centuries by culturally adapting to the perennial springs scattered along mountain drainages (Cariño Olvera 2001; CONANP 2014). Any spring able to water a suitable homesite creates potential for a Choyero ranch. The population maintains many of the productive traditions that were first brought to the region during the Jesuit mission era by the colonists, such as leather working, metal smithing, heritage crop production, and ranching (de Grenade and Nabhan 2013a, 2013b; Nabhan et al. 2010). Historically and still today, Choyeros have been relatively isolated from the larger Mexican society: they are outside the reach of market places, paved roads, mail

service, the electrical grid, cell-phone networks, potable water systems, sewage, and waste disposal systems (Cariño Olvera 2001; CONANP 2014; Crosby 2015).

The primary subsistence mode is goat and cattle ranching, with an emphasis on meat and cheese production for export by roaming merchants to local and regional markets. The average ranch has four or more people, mostly related as kin extended across multigenerational families. Households may also maintain sheep, pigs, turkeys, chickens, and rabbits for domestic consumption, as well as horses, donkeys, and mules for transportation. Households supplement their diet through the government-sponsored food program CONASUPO, as well as with food purchased from urban markets in Las Pocitas, Ciudad Constitución, and La Paz. Near their homes, most ranches maintain *huertas* and/or *jardines*. Huertas are typically tended by adult male and female family members and provide edible foods for the household, as well as feed for domestic livestock (e.g., alfalfa, sorghum). Beyond their collaboration in the huertas, Choyeros have divided labor domains and ecologies that affect the genders' differential exposure to plants (encounters of which vary by ecology). Jardines are most often tended by female heads of household and serve important household functions, such as providing shade, decorative flowers, culinary herbs, and medicine (e.g., for herbal infusion into teas). When not tending to livestock near the ranch, men are most often tending to livestock in the *campo* or the open-range desert wilderness of the Giganta. Although Choyero children can assist parents with household chores, they do not engage in substantial ranch work outside of the house.

Because they are in places where fertile soils and fresh water come together, both huertas and jardines serve as attractive oases for a variety of plant and animal species. Many huertas that were quite important for ranch-level subsistence throughout Baja California's mountains a few generations ago are now less productive as ranchers have increasingly focused on milk, cheese, and meat production for sale to the market (Cariño Olvera 2001; Crosby 2015; de Grenade and Nabhan 2013a). Aside from market sales and occasional itinerant wage labor, Choyeros remain relatively unintegrated into the larger market economy and subsist on yearly incomes that lie below the poverty line (CONAPO 2010). According to government statistics, Choyero ranches are classified as "*muy bajo*," indicating Mexico's lowest (poorest and most underdeveloped) socioeconomic stratum (SEDESOL 2010).

Open range lands such as those used by Choyeros are distinguished by their rugged landscapes and the vast distances traversed owing to the far-reaching mobility of livestock (Huntsinger 2016). Cattle and goats often travel long distances (>10 miles a day) between elevations, to water and food, and away from harsh weather or to avoid predators. Cattle and goats are able to make use of a wide variety of rangeland plants of low nutritional quality and that may present dangers to other animals and humans. Because food and water are scarce in the arid ranges of the Giganta, the ability for livestock to find scarce resources is key to the rancher's success. The movement of livestock is also sometimes under the control of the herder (who depends on wayfinding knowledge to traverse the vast landscape), such as when rounded up and brought back to an enclosure or when moved to greener pasture after a rain. As such, pastoralists who depend on livestock in harsh environments have developed culturally specific subsistence traditions and bodies of knowledge that allow them to both support and control the grazing and reproduction of livestock in otherwise unproductive

landscapes (Fernandez-Gimenez and Febre 2006). For example, Choyeros make use of horses, donkeys, and mules that facilitate human travel over these ranges, whether ridden or loaded with packs, and herding dogs, which, when well-trained, can effectively herd livestock without the guidance or instructions of human herders. Choyeros have a keen sense of when and where resources can be found in the landscape, and when hazards need to be avoided (e.g., coyote and mountain lions during the dry season, floods and storms during the summer monsoonal season). Currently, no information exists concerning Choyero ecological knowledge variation.

Choyero Ethnobiological Knowledge and School Education To meet the challenges of becoming competent off-grid ranchers in the Giganta, Choyeros acquire, develop, maintain, and transmit a rich body of knowledge about the local ecology associated with springs, gardens, and wild rangeland. This includes knowledge of (1) predators (e.g., coyotes, pumas), (2) vectors for infectious disease (e.g., raccoons, skunks), (3) venomous animals (e.g., rattlesnakes, scorpions), (4) poisonous and dangerous plants (e.g., arrowpoison plant, cacti), (5) wild and domesticated plants and animals eaten by humans or livestock, and (6) plants and animals for construction, shade, cooking fuel, medicine, ritual, and artisanal crafts. Choyero knowledge may also be supplemented or complemented by education and social exposure gained with schooling.

Educational achievement has been on the rise for the past several decades (INEGI 2004). Nevertheless, costs of transportation and school supplies prevent some Choyeros from maximal exposure to education. Families who wish their children to pursue a formal education must send them to public schools for primary through high school education. Because of the challenge of transporting children from remote ranches to schoolhouses on a daily basis, a unique feature of the educational system in Baja California Sur is the placement of schools, cafeterias, dormitories, teachers, and social welfare officers in rural locations through the Coordinación Estatal de Albergues Escolares. Most children attending school are brought to the school for five days and four overnights a week and then return home every weekend. The *albergues escolares* program established rural schools in La Soledad in 1969 and in Santa María de Toris in 1980.

Local history and culture of Baja California Sur is neglected in the school curriculum, which is taught by nonlocal teachers and features the history and culture of mainland Mexico. Knowledge about the local ecology and about subsistence skills is also not gained directly from a school education. As such, as in many of the ranching cultures of Baja California Sur, Choyeros are expected to acquire most of their ethnobiological education informally in the social and work contexts of ranch life. This kind of practical ranching knowledge is typically learned from same-sex peers and adults (Caríño Olvera 2001; Crosby 2015).

Although ethnobiological information is not taught in the schools, educational achievement and ethnobiological knowledge might still be related. One possibility is that formal education and experience of nature and subsistence activities are mutually exclusive opportunities for children, such that those who choose to develop their knowledge through scholastic studies do so at the expense of developing their ethnobiological knowledge (Nabhan and St Antoine 1993; Zent 2001). However, a mix of both kinds of learning should be possible for Choyero children

because formal education is coming from non-Choyeros in a schoolhouse setting, whereas ethnobiological education is likely coming from a combination of older kin at home on the ranch and near-aged peers (who may be encountered at school). As adolescents and young adults, Choyeros might also learn ethnobiological information from Choyeros living on other ranches, especially neighbors whom they might see more often. As such, a positive correlation between school education and ethnobiological knowledge may exist if more capable individuals self-select into both achieving more years of education and acquiring more ethnobiological knowledge from others.

Choyero Demographics and Fertility

Based on community censuses, we implemented interviews and demographic surveys with 143 heads of household from 70 ranches in four communities across five field seasons (2014–2018). We used information from these interviews and surveys to determine characteristics of Choyero demographics, fertility schedules, and childrearing demands on parents.

Fertility Schedules Based on a sample of 46 women across four communities (born between 1930 and 2000), the mean female age of first reproduction among Choyeros is 22.6 (SD = 5). On average, Choyero men become fathers by the age of 27; the average husband is 4.4 (SD = 7) years older than his wife. The average fertility schedule of a Choyero man is tied to that of his wife, with an interbirth interval (IBI) of 3.9 years and a total fertility rate (TFR) of 3.7 surviving offspring. As such, Choyero fertility schedules extend roughly from age 16 to about age 46. See Table 1 for additional details about Choyero fertility.

Table 1 Choyero reproductive demographics

	<i>N</i>	Mean (SD)	Median	Min, Max
Age at first birth (years) among women	53	22.6 (5)	22	15, 42
IBI* between offspring 1 and 2 (days)	43	1335 (761)	1190	224, 2985
IBI between offspring 2 and 3 (days)	33	1565 (1108)	1307	244, 4204
IBI between offspring 3 and 4 (days)	19	1719 (1688)	896	367, 6768
IBI between offspring 4 and 5 (days)	7	864 (728)	661	314, 2466
IBI between offspring 5 and 6 (days)	6	1530 (1736)	649	377, 4822
IBI between offspring 6+ (days)	4	809 (538)	656	342, 1586
IBI All (days)	112	1430 (1125)	1044	224, 6768
Total fertility rate among women ¹	27	3.7 (2)	3	1, 9

* *IBI* Interbirth intervals

¹Total fertility based on our sample of women who were >45 years of age

Childrearing Demands on Parents We estimated the parent ages at which dependent offspring impose peak dependency (for food and essential information) on parents based on a cumulative model of relative costs from generalizable features of human nutritional demand schedules across the pre-reproductive life stage (Trumbo et al. 2002) and estimated fertility schedules based on the Choyero IBIs and TFR reported in Table 1. According to this model, the average Choyero mother aged 40–45 (and her husband of expected age 44.4–49.4) is at peak dependency of 3.7 expected offspring younger than age 20 (two of them adolescents and one a very young adult).

Among Choyeros, offspring that remain at natal ranches maintain net dependency (consuming more than they produce) until they marry and start living more independently—typically after age 20. Choyero last-borns will often remain dependent until their mother is in her sixties. Young Choyero parents tend to live in close proximity to and are affiliated with older kin from whom they receive support (Crosby 2015).

Consistent with these estimates for parent ages at peak offspring dependency, our sampling at the household level from across 70 ranches indicates that the number of coresident dependent offspring (2 on average) relying on a head of household is greatest for heads of household in the 35- to 45-year-old age range (Fig. 2). The number of dependent offspring observed for heads of households of a given age is always less than the number of expected offspring because a large proportion of our sample included adults with no coresident dependents.

Fig. 2 Choyero ranches and communities in the southern Sierra de La Giganta of Baja California Sur, México

Choyero Ethnobotanical Lexicon

In 2015, two authors (SJM and JJG) asked 46 heads of households from 28 ranches ($n_{\text{males}} = 29$; $n_{\text{females}} = 17$; mean age = 52 years) within one community (Santa Maria de Toris) to free-list plants and animals they associated with Giganta spring ecosystems to develop an initial lexicon for discussing ecosystem knowledge. This free-list task identified an initial set of 218 animals and 201 plants. Following the free-list task, the researchers, along with a focus group of 10 adults (seven males, three females; mean age = 43 years; min/max age = 21/74 years) from four ranches, linked the emic plant and animal terms with the Linnaean classification system (family, genus, and species) using photos and descriptions from botanical and faunal field guides (Grismer 2002; Howell and Webb 1995; Kays and Wilson 2009; León de la Luz and Coria Benet 2018; Rebman et al. 2012; Rodd et al. 2007; Wiggins 1980). Furthermore, this focus group clarified that certain plants and animals were referred to by multiple emic terms. Based on this information, we used a process of consensus to obtain from this focus group the term that was most likely to be used among the ranching community. We noted and consolidated these terms. If, as occurred occasionally, a plant description could not be linked to a field guidebook photo, we asked the focus group to find examples of the plant for us to photograph. These photos were then sent to botanical experts from the Red Butte Garden at the University of Utah, the San Diego Natural History Museum, and the Departamento de Biología at the Universidad Autónoma de Baja California, who assisted with linking the photo to its associated Linnaean classification. Three plant species could not be reconciled, resulting in a final set of 162 plant and 125 animal species. Of these 287 species, 72 plants and 50 animals were included in our ethnobiological assessment task (described below).

Plant and Animal Categorizations

In May 2016, two key informants (one male and one female) suggested to two authors (SJM and JJG) that the consolidated list of 162 plants mentioned above could be categorized according to where the plants are found: jardines, huertas, or in the campo. Using a process of consensus, the two key informants provided their assessments (45 jardin plants; 18 huerta plants; 99 campo plants).

In June 2018, four authors (SJM, ES, JJG, and DGB) employed surveys about plant and animal uses with heads of households from 38 ranches from three communities (Santa Maria de Toris, La Higuera, and San Pedro de La Presa) as part of our larger project on Choyero ethnobiological knowledge. In these surveys we asked participants to enumerate plants and animals that conform to a number of use categories, two of which we report on here: “human plant comestibles” (food) and “dangerous plants and animals” (danger). For our purposes, a plant item was considered “food” if a single respondent identified it as such and provided information on its preparation for consumption. Respondents provided 210 unique plant concepts, 60 of which were identified as human food. We then linked these reports

of food uses to our initial plant database. Of the 87 plants shown in our ethnobiological assessment task (described below), 27 were categorized as “food” (ESM, Table A1). Of the 50 animals shown in the ethnobiological assessment task, we also categorized five (three species of birds, a jackrabbit, and a fish) as “food,” based on reports and evidence that these were eaten. Among a subset of these ranches ($n = 3$) we also asked participants to enumerate dangerous plants and animals. Respondents provided examples of ten dangerous plants and five dangerous animals along with common reasons for their danger: poisonous sap, sharp thorns, dangerous and potentially disease-transmitting bite. Based on these dangerous features we categorized 28 items as dangerous: 7 cacti, 7 shrubs and trees with thorns or toxicity, and 14 predatory or disease transmitting animals (see ESM, Table A1).

Ethnobiological Knowledge Assessment Task

In 2017 and 2018, 71 individuals (33 females and 38 males) aged 5 to 86 years old from 40 ranches across three communities (Santa Maria de Toris: $n = 55$; La Higuera: $n = 5$; and La Soledad: $n = 11$) were presented an ethnobiological knowledge assessment task (see Table 2 for sample characteristics). As a first step, individuals took a vision acuity test using “tumbling E” eye charts presented on a laptop computer, a robust and easy-to-use diagnostic tool that is practical for populations with innumerate or analphabetic participants (Evans 2006). From this test we derived a visual acuity score (ranging from 1 to 11). A higher score indicates better visual acuity. Visual acuity across the sample was 10.6 on average ($SD=0.77$, $min=6$ $max=11$) on the 1–11 scale (Table 2). Visual acuity scores are reported by age group and plotted by age in the ESM, Table B1 and Fig. B1, showing no variance and maximum scores among pre-reproductive and reproductive ages, but increasing variance with lower average scores among older adults. The ethnobiological knowledge assessment task presented a sequence of 137 slides on a laptop

Table 2 Choyero ethnobiological knowledge sample characteristics for full sample (all), females, and males

	Mean (SD)	Median	Min, Max
Full sample ($N = 71$)			
Age	46.6 (17.73)	48	5, 86
Visual acuity	10.6 (0.77)	11	6, 11
Educational achievement (years)	5.0 (3.71)	6	0, 12
Females ($N = 33$)			
Age	47.3 (18.33)	49	5, 79
Visual acuity	10.5 (0.97)	11	6, 11
Educational achievement (years)	4.6 (3.39)	6	0, 10
Males ($N = 38$)			
Age	45.8 (17.42)	45.5	16, 86
Visual acuity	10.7 (0.53)	11	9, 11
Educational achievement (years)	5.3 (3.98)	6	0, 12

computer featuring images of 87 plants and 50 animals (ESM, Table A1). The set of plants and animals used in our ethnobiological knowledge assessment task was informed by the ethnobiological research methods described above and selected based on the availability of clear and representative photographs.

The order of items presented was varied, with about half of participants seeing the items in reversed order. Assessments of ethnobiological knowledge were conducted in Spanish in the privacy of individual homes and occurred as part of a larger set of household interviews regarding ranching demography and lifestyles. These household interviews also informed us of individuals' educational achievement, ranch affiliation, and community membership. For each of the 137 plant and animal images presented in the sequence, the researcher (ES) asked the participant whether they recognized the item in the image. If the participant answered affirmatively, the researcher asked the follow-up question about what the item is called. Responses were recorded and coded "correctly named" if matching any of the locally appropriate, culturally correct names used for species identification (see Macfarlan et al. 2020).

Analytic Models

Our analytic models are performed using STATA/IC 16.1 (Rabe-Hesketh and Skrondal 2012). We investigate ethnobiological knowledge with two-stage logistic regression models. In the first stage of these models we predict an individual's ability to recognize (R_i) a plant or animal item shown to them ($R_i = 1$ if item i is recognized, and 0 otherwise). In the second stage, we predict an individual's ability to correctly name (C_i) a recognized plant or animal item ($C_i = 1$ if item i is named correctly, and 0 otherwise).

Multiple individuals may reside at the same ranch, so we nest the outcome variable at both the level of the individual and the ranch. As such, we employ multi-level logistic regressions, whereby we use an exchangeable variance-covariance structure at the level of the individual and ranch. Furthermore, we employ robust standard errors for all fixed effects in all models. We assess six classes of models of ethnobiological knowledge: (1) a model that examines knowledge across all life stages; (2) a model that examines knowledge of food and/or dangerous items (relative to all other investigated items) across all life stages; (3) a model that examines sex differences in knowledge of jardin plants only; (4) a model that examines sex differences in knowledge of campo plants only; (5) a model of sex differences in jardin plant knowledge for post-reproductive adults only; (6) a model of sex differences in campo plant knowledge for post-reproductive adults only. For the age ranges of pre-reproductive (< 23 years), reproductive (23 to 45 years), and post-reproductive (> 45 years) life stages demarcated in or bounding the models, we used the observations of Choyero life stage tendencies detailed in the "Fertility Schedules" subsection above.

Where appropriate for each class of model, we specify the results of the following covariates: age (in years), age², sex (1=male, 0=female), visual acuity or *vision* (scored 1 to 11), educational achievement or *education* (in years), and whether or not the item

is potential food and/or danger (1=food or danger; 0=Other). All models presented in this study can be replicated using the associated STATA DO and Data files provided as electronic supplementary materials.

Results

Original data for this study are available at Mendeley Data (Schniter et al. 2020). Although the scope of our research is to understand how factors associated with specific life-stage moments affect ethnobiological knowledge, we first consider the variables generated by our ethnobiological knowledge assessment task. Across all ages, most participants recognized the majority of plant ($M = 71.0\%$) and animal ($M = 85.9\%$) items presented, but fewer were able to correctly name those plant ($M = 42.6\%$) and animal ($M = 59.0\%$) items according to local nomenclature. 63.54% of all recognized items were correctly named.

By life stage, we see that pre-reproductive individuals (3 females and 4 males) correctly named an average of 30.8% species, reproductive adults (11 females and 15 males) correctly named an average of 52.7% species, and post-reproductive adults (19 females and 19 males) correctly named an average of 49.0% species. The ESM presents additional details about ethnobiological knowledge among the full sample, males, and females in each of the three life stages. Below we begin with a review of our results across all life stages. We then follow with attention to how ethnobiological knowledge develops across the age ranges associated with pre-reproductive, reproductive, and post-reproductive life stages.

What Explains Knowledge across All Life Stages?

We fit a two-stage model of ethnobiological knowledge across all life stages. This allows our results to be compared with previous work on the topic (e.g., Koster et al. 2016) and portrays the overall development of knowledge across the life course within our sample. We find that reported recognition of plant and animal species takes a quadratic, concave shape over the life course (Age: Odds Ratio [OR] = 1.1, $p < .001$; Age²: OR = 0.99, $p < .001$) and that better visual acuity is associated with improved ability to recognize (OR = 1.50, $p < .001$; Table 3, Model 1). Educational achievement has no effect on recognition (OR = 1.02, $p = .41$) and the difference between males' and females' recognition is not significant (OR = 1.17, $p = .19$; Table 3, Model 1). We find that the ability to correctly name recognized species takes a quadratic, concave shape over the life course (Age: OR = 1.1, $p < .001$; Age²: OR = 0.99, $p < .001$) and that better visual acuity is associated with improved ability to name correctly (OR = 1.20, $p = .032$; Table 3, Model 1, and Fig. 3). Educational achievement has no effect (OR = 1.00, $p = .87$) and males correctly name recognized species more than females (OR = 1.20, $p = .03$; Table 3, Model 1).

What Explains Ethnobiological Knowledge in the Pre-reproductive Life Stage?

To evaluate whether the rates of ethnobiological knowledge development in pre-reproductive individuals are continuously increasing yet different for species that

Table 3 Two-stage multilevel logit regression model coefficients associated with Choyero ethnobiological knowledge

	Model 1			Model 2				
	B (RSE) ¹	OR (RSE) ²	z	p	B (RSE) ¹	OR (RSE) ²	z	p
DV: Recognized ^{3,4}								
Age (years)	0.097 (0.02)	1.10 (0.02)	4.9	<.001	0.100 (0.02)	1.11 (0.02)	4.9	<.001
Age ² (years)	-0.001 (0.0002)	0.99 (0.0002)	-4.3	<.001	-0.001 (0.0002)	0.99 (0.0002)	-4.7	<.001
Visual Acuity	0.410 (0.11)	1.50 (0.17)	3.7	<.001	0.460 (0.12)	1.59 (0.2)	3.9	<.001
Education (years)	0.023 (0.028)	1.02 (0.03)	0.8	.41				
Sex Male (=1)	0.160 (0.12)	1.17 (0.14)	1.3	.19				
Food or Danger (=1)								
Constant	-5.400 (1.4)	0.005 (0.006)	-4.0	<.001	0.720 (0.05)	2.05 (0.1)	13.6	<.001
					-6.100 (1.5)	0.01 (0.003)	-4.1	<.001
DV: Named ^{5,6}								
Age (years)	.0930 (0.016)	1.10 (0.02)	5.9	<.001	0.097 (0.01)	1.11 (0.02)	7.1	<.001
Age ² (years)	-0.001 (0.00019)	0.99 (0.0002)	-4.9	<.001	-0.001 (0.0001)	0.99 (0.0001)	-6.5	<.001
Visual Acuity	0.150 (0.07)	1.20 (0.08)	2.1	.032	0.190 (0.06)	1.20 (0.07)	3.1	.002
Education (years)	0.003 (0.018)	1.00 (0.02)	0.2	.87				
Sex Male (=1)	0.160 (0.07)	1.20 (0.08)	2.2	.03				
Food or Danger (=1)					0.580 (0.05)	1.80 (0.09)	11.7	<.001
Constant	-3.190 (0.089)	0.04 (0.04)	-3.6	<.001	-3.900 (0.8)	0.02 (0.02)	-4.7	<.001

¹ B(RSE): Unstandardized coefficient (Robust Standard Errors)²OR(RSE): OR (Robust Standard Errors)³Model 1 Wald $\chi^2 = 46.6$; *n* observations = 9,727; *n* ranches = 40; *N* individuals = 71; *p* < .0001; Random effects estimates of estimated standard deviation in the intercept on the logit scale (and its standard error) include Ranch = 0.09(0.09) and Ego = 0.4(0.2)⁴Model 2 Wald $\chi^2 = 266.4$; *n* observations = 9,727; *n* ranches = 40; *N* individuals = 71; *p* < .0001; Random effects estimates of estimated standard deviation in the intercept on the logit scale (and its standard error) include Ranch = 0.01(0.01) and Ego = 0.4(0.2)⁵Model 1 Wald $\chi^2 = 113.1$; *n* observations = 7,435; *n* ranches = 40; *N* individuals = 71; *p* < .0001; Random effects estimates of estimated standard deviation in the intercept on the logit scale (and its standard error) include Ranch = 0.03(0.03) and Ego = 0.8(0.3)⁶Model 2 Wald $\chi^2 = 181.7$; *n* observations = 7,435; *n* ranches = 40; *N* individuals = 71; *p* < .0001; Random effects estimates of estimated standard deviation in the intercept on the logit scale (and its standard error) include Ranch = 0.05(0.03) and Ego = 0.8(0.3)

Fig. 3 Predicted probabilities plotted with 95% confidence intervals. The predicted Choyero ability to correctly name recognized plant and animal species is extracted from the regression model and plotted as a function of age, age square, sex, visual acuity, and education, with random effects for data nested at the level of ranches and individuals

are potentially dangerous and/or food (relative to those that are not), we employ a two-stage model of ethnobiological knowledge across all life stages. We observed no variation in vision for participants in the pre-reproductive life stage. We find that recognition of plant and animal species continuously increases during the pre-reproductive life stage (Age: OR = 1.11, $p < .001$) and that recognition of dangerous and/or food species increases at more than twice the rate than for other species (OR = 2.05, $p < .001$; Table 3, Model 2).

We also find that the ability to correctly name recognized species continuously increases during the pre-reproductive life stage (Age: OR = 1.11, $p < .001$) and that correct naming of dangerous and/or food species increases by 80% relative to other species (OR = 1.80, $p < .001$; Table 3, Model 2, and Fig. 4). On average, we see evidence of greater knowledge of dangerous and/or food species (relative to other species) during the pre-reproductive life stage, with 42.65% of these species correctly named compared with 20.78% of other species (ESM, Table B3). Fig. 4 illustrates how rates of knowledge acquisition change across the lifespan: the greater knowledge of food and dangerous species clearly emerges by age 11 and remains evident across reproductive and post-reproductive life stages.

Fig. 4 Predicted probabilities plotted with 95% confidence intervals. The predicted Choyero ability to correctly name recognized plant and animal species is extracted from the regression model and plotted as a function of age, age square, visual acuity, and whether or not the species were potentially food and/or dangerous, with random effects for data nested at the level of ranches and individuals

What Explains Ethnobiological Knowledge in the Reproductive Life Stage?

Results of our estimated family budgets suggest that parents face growing offspring needs at least until the end of the reproductive lifestage, when offspring demands may be highest, and that those demands fade but can continue for decades after, stretching into parents' post-reproductive years. To evaluate whether the rates of ethnobiological knowledge development in reproductive adults are continuously increasing as parents continue to meet their offspring's burgeoning needs, we first focus on trends in the reproductive lifestage revealed by our models of ethnobiological knowledge development across the lifespan (Table 3, Models 1 and 2). We observed no variation in vision for participants in the reproductive life stage. These models both reveal that correct naming of plant and animal species continuously increases with younger adult ages such that the highest levels of correctly named recognized species occur at the end of the reproductive life stage (Figs. 3 and 4), when offspring demands are highest.

To address predictions about gender differences across gender-specific economic domains, we rely on two subsets of our data: one that examines jardin plants only, and a second that examines campo plants only. During the reproductive life stage, females correctly name 61.4% of jardin plants compared with males, who correctly name 44.6%, while males correctly name 49.4% of campo plants compared with

Table 4 Two-stage multilevel logit regression model coefficients associated with Choyero ethnobiological plant knowledge

	Model 3: Jardim Plants				Model 4: Campo Plants			
	B (RSE) ¹	OR (RSE) ²	z	p	B (RSE) ¹	OR (RSE) ²	z	p
DV: Recognized ^{3,4}								
Age (years)	0.09 (0.02)	1.09 (0.03)	3.6	<.001	0.09 (0.02)	1.1 (0.02)	4.2	<.001
Age ² (years)	−0.001 (0.0003)	0.99 (0.0003)	−3.5	<.001	−0.001 (0.0002)	0.99 (0.0002)	−3.9	<.001
Visual Acuity	0.410 (0.11)	1.74 (0.3)	3.7	<.001	0.5 (0.1)	1.6 (0.02)	3.7	<.001
Sex Male (=1)	−0.6 (0.20)	0.55 (0.09)	−3.7	<.001	0.3 (0.2)	1.4 (0.2)	2.1	.04
Constant	−6.2 (1.8)	0.002 (0.004)	−3.4	.001	−6.4 (1.6)	0.002 (0.003)	−3.9	<.001
DV: Named ^{5,6}								
Age (years)	.1 (0.03)	1.13 (0.03)	4.7	<.001	0.1 (0.02)	1.11 (0.02)	5.5	<.001
Age ² (years)	−0.001 (0.0003)	0.99 (0.0003)	−4.6	<.001	−0.001 (0.0002)	0.99 (0.0002)	−4.7	<.001
Visual Acuity	0.3 (0.1)	1.37 (0.2)	2.9	.004	0.2 (0.1)	1.2 (0.1)	4.2	.08
Sex Male (=1)	−0.6 (0.1)	0.55 (0.07)	−4.4	<.001	0.4 (0.1)	1.5 (0.1)	4.2	<.001
Constant	−5.1 (1.5)	0.006 (0.009)	−3.5	<.001	−4.2 (1.2)	0.02 (0.02)	−3.5	<.001

¹B(RSE): Unstandardized coefficient (Robust Standard Errors)

²OR(RSE): OR (Robust Standard Errors)

³Model 3 Wald $\chi^2 = 30.1$; *n* observations = 2,556; *n* ranches = 40; *N* individuals = 71; *p* < .0001; Random effects estimates of estimated standard deviation in the intercept on the logit scale (and its standard error) include Ranch = 0.2(0.09) and Ego = 0.3(0.1)

⁴Model 4 Wald $\chi^2 = 31.7$; *n* observations = 3,7673; *n* ranches = 40; *N* individuals = 71; *p* < .0001; Random effects estimates of estimated standard deviation in the intercept on the logit scale (and its standard error) include Ranch = 0.05(0.01) and Ego = 0.5(0.2)

⁵Model 3 Wald $\chi^2 = 31.1$; *n* observations = 1,893; *n* ranches = 40; *N* individuals = 71; *p* < .0001; Random effects estimates of estimated standard deviation in the intercept on the logit scale (and its standard error) include Ranch = 0.1(0.06) and Ego = 0.1(0.06)

⁶Model 4 Wald $\chi^2 = 78.5$; *n* observations = 2,575; *n* ranches = 40; *N* individuals = 71; *p* < .0001; Random effects estimates of estimated standard deviation in the intercept on the logit scale (and its standard error) include Ranch = 7.84e-32(5.47e-31) and Ego = 0.2(0.06)

Fig. 5 Predicted probabilities plotted with 95% confidence intervals. The predicted Choyero ability to correctly name recognized house garden (*jardin*) plants is extracted from the regression model and plotted as a function of age, age square, sex, and visual acuity, with random effects for data nested at the level of ranches and individuals

females, who correctly name 36.0% (ESM Table B4). To assess the role of age and gender on *jardin* and *campo* plant knowledge in the reproductive lifespan we use two multilevel two-stage logistic regression models. For brevity, we report only results of the second stage of these models 3 and 4 in the text, concerning the ability to correctly name recognized *jardin* plants and *campo* plants, respectively (see Table 4 for complete model results). Our first model shows that males correctly name substantially fewer recognized *jardin* plants than females do ($OR = 0.55$, $p < .001$; Table 4, Model 3). Our second model shows that males correctly name more recognized *campo* plants than females do ($OR = 1.5$, $p < .001$; Table 4, Model 4). These models show that, overall and relative to their opposite gender, being a reproductive-aged female improves the probability of naming recognized plants associated with house gardens by 45%, while being a reproductive-aged male improves the probability of naming recognized plants associated with herding activities by 50% (Figs. 5 and 6).

What Explains Ethnobiological Knowledge in the Post-reproductive Life Stage?

Post-reproductive adults are most representative of the top decile of ethnobiological knowledge in our sample, occupying seven of the eight highest ranks for recognizing and correctly naming plants and animals. The ages of these most expert adults in the

Fig. 6 Predicted probabilities plotted with 95% confidence intervals. The predicted Choyero ability to correctly name recognized wild (campo) plants is extracted from the regression model and plotted as a function of age, age square, sex, and visual acuity, with random effects for data nested at the level of ranches and individuals

top decile ranged from 46 to 63 with a mean age of 53. On average, post-reproductive adults correctly name 49.0% of plants and animals, while reproductive adults correctly name 52.7% (ESM, Tables B4 and B5).

During the post-reproductive life stage, females correctly name 50.0% of jardin plants compared with males who correctly name 35.4%, while males correctly name 44.3% of campo plants compared with females who correctly name 35.5% (ESM Table B5). To evaluate whether the rates of ethnobiological knowledge in post-reproductive adults are predicted by visual acuity, age, sex, and gender-associated economic domains, we employ a pair of multilevel two-stage logistic regression models that consider only adults in the post-reproductive lifespan (Table 5, Models 5 and 6). These models rely on two subsets of our data for this age group: one that examines jardin plants only, and a second that examines campo plants only. For brevity, we report only results of the second stage of these models (5 and 6) in the text, concerning male and female abilities to correctly name recognized jardin plants and campo plants, respectively (see Table 5 for complete model results).

We find that sex ($OR = 0.53$, $p = .001$) is a significant predictor of correctly naming recognized jardin plants, even after controlling for age ($OR = 0.96$, $p = .01$) and visual acuity ($OR = 1.46$, $p = .023$), with post-reproductive females able to name more of the house garden plants they recognize than post-reproductive males (Table 5, Model 5). Among post-reproductive adults, we do not find an

Table 5 Two stage multi-level logit regression model coefficients associated with Choyero post-reproductive ethnobiological plant knowledge

	Model 5: Jardin Plants				Model 6: Campo Plants			
	B (RSE) ¹	OR (RSE) ²	<i>z</i>	<i>p</i>	B (RSE) ¹	OR (RSE) ²	<i>z</i>	<i>p</i>
DV: Recognized ^{3,4}								
Age (years)	-0.03 (0.02)	0.97 (0.01)	-2.2	.027	-0.03 (0.01)	0.97 (0.01)	-2.2	.03
Visual Acuity	0.6 (0.2)	1.8 (0.3)	3.5	<.001	0.5 (0.1)	1.69 (0.2)	3.7	<.001
Sex Male (=1)	-0.7 (0.3)	0.48 (0.1)	-2.5	.012	0.2 (0.3)	1.21 (0.3)	0.7	.048
Constant	-2.5 (1.7)	0.08 (0.1)	-1.5	.15	-2.8 (1.6)	0.068 (0.1)	-1.8	.08
DV: Named ^{5,6}								
Age (years)	-0.04 (0.01)	0.96 (0.01)	-2.6	.01	-0.03 (0.01)	0.97 (0.01)	-2.6	.01
Visual Acuity	0.4 (0.2)	1.46 (0.2)	2.3	.023	0.3 (0.1)	1.38 (0.2)	2.5	.01
Sex Male (=1)	-0.6 (0.3)	0.53 (0.1)	-2.4	.015	0.2 (0.1)	1.27 (0.2)	1.7	.09
Constant	-1.0 (1.4)	0.4 (0.5)	-0.7	.47	-1.4 (1.0)	0.26 (0.3)	-1.3	.19

¹B(RSE): Unstandardized coefficient (Robust Standard Errors)²OR(RSE): OR (Robust Standard Errors)³Model 5 Wald $\chi^2 = 18.1$; *n* observations = 1,368; *n* ranches = 26; *N* individuals = 38; *p* = .0004; Random effects estimates of estimated standard deviation in the intercept on the logit scale (and its standard error) include Ranch = 0.17(0.1) and Ego = 0.4(0.1)⁴Model 6 Wald $\chi^2 = 19.4$; *n* observations = 2014; *n* ranches = 26; *N* individuals = 38; *p* = .0002; Random effects estimates of estimated standard deviation in the intercept on the logit scale (and its standard error) include Ranch = 0.1(0.01) and Ego = 0.5(0.2)⁵Model 5 Wald $\chi^2 = 12.2$; *n* observations = 972; *n* ranches = 26; *N* individuals = 38; *p* = .00067; Random effects estimates of estimated standard deviation in the intercept on the logit scale (and its standard error) include Ranch = 0.3(0.3) and Ego = 0.2(0.3)⁶Model 6 Wald $\chi^2 = 18.5$; *n* observations = 1348; *n* ranches = 26; *N* individuals = 38; *p* = .0003; Random effects estimates of estimated standard deviation in the intercept on the logit scale (and its standard error) include Ranch = 0.2(0.09) and Ego = 0.03(0.05)

effect of sex (OR = 1.27, *p* = .09) on correctly naming recognized campo plants, after controlling for age (OR = 0.97, *p* = .01) and visual acuity (OR = 1.38, *p* = .01; Table 5, Model 6). Although the average proportion of campo plants correctly named by women does not change between reproductive and post-reproductive life stages, the portion of campo plants correctly named by males declines, with post-reproductive-aged adults naming 10.3% fewer campo plants than younger reproductive-aged adults (calculated from life stage proportions reported in ESM Tables B4 and B5).

Discussion

We investigated whether age profiles of Choyero ethnobiological knowledge development are consistent with predictions derived from life history theory about the timing of productivity and reproduction. We see evidence of age-appropriate complementary knowledge profiles developing for Choyero men and women as

they experience changes in embodied capital and needs of dependent offspring. We find that while individuals acquire most knowledge of dangerous items and edible resources by early adulthood, knowledge of plants and animals relevant to the age- and sex-divided labor domains and ecologies (e.g., women's house gardens, men's herding activities in the wilderness) develops into middle adulthood but to different degrees and at different rates for women and men. Across our models, we see peak predicted ethnobiological knowledge for men and women aged 35–65, including the ages at which parents experience the greatest demand from dependent offspring, bearing support for both a “wisdom of adults” and a nuanced “wisdom of elders” view of ethnobiological knowledge development.

That reproductive- and post-reproductive-aged Choyero women and men maintain separate but complementary ethnobiological knowledge fits both the literature on the evolution of the sexual division of labor in humans generally (e.g., Gurven et al. 2012) as well as the human ecology of the Giganta, specifically. In the Giganta, ranches are typically established in valley bottoms on level ground near springs. Because springs and flat terrain occur in a sporadic fashion throughout this region, ranches can be separated by large distances from one another. This has caused households to become highly independent (Crosby 2015). In response, women and men have developed distinct divisions of labor and associated knowledge to support autarkic household functioning. Although this produces strongly gendered economic domains, there is a complementarity to gender dynamics within Choyero communities, whereby people explicitly recognize the value of each gender's role in household economics. Among Choyeros, men's greater knowledge of campo plants complements women's greater knowledge of jardin plants during the reproductive life stage, and while women retain their relative advantage in jardin knowledge into post-reproductive years, men lose a relative advantage in campo knowledge—possibly associated with declining exposure to species in the campo with advancing post-reproductive years.

A widespread “wisdom of elders” view has suggested that highest levels of ethnobiological knowledge should be found among post-reproductive older adults generally (Koster et al. 2016). When we consider the top decile of most knowledgeable Choyeros sampled, we find that almost all of these experts are post-reproductive-aged adults ranging from 46 to 63 years old—bearing support for a nuanced “wisdom of elders” view of ethnobiological knowledge development. On the other hand, average rates of recognition and correct naming for reproductive adults are higher than for post-reproductive adults, challenging a “wisdom of elders” view. Our study resolves this apparent paradox by showing the effects of vision on ethnobiological knowledge, and the possible effects of reduced activity by older males in the campo on their revealed knowledge of campo plants. The effects of sensory acuity (vision and hearing) on intelligence among older adults are known to be large; after controlling for age and hearing, Lindenberger and Baltes (1994) found that vision accounts for 43% of the variance in intelligence among a sample of older adults. Additional cognitive and physiological measures affecting men and women's activities in their economic domains might explain additional variance in ethnobiological knowledge and should be considered for future research on older adult knowledge. Although age-associated limitations to mobility, hearing, and sight may prevent many older

adults from reliably transmitting ethnobiological knowledge, a small subset of older adults appear to be differentially advantaged with better abilities to function as ethnobiological experts. Local experts can be of great cultural value and of great value with conservation efforts, as we discuss below.

Conservation biologists (e.g., León de la Luz and Domínguez Cadena 2006; Riemann and Ezcurra 2005; Rodríguez-Estrella 2005) and nongovernmental agencies (e.g., World Wildlife Fund) have implicated rancher lifestyles as primary vectors for Giganta ecosystem decline, suggesting ignorance of the local ecology, but those conclusions are typically drawn from nonrepresentative samples in areas of relatively high population densities or vehicular traffic that tend to be more depleted of biodiversity. Elsewhere, in natural protected areas of Baja California Sur, conservation biologists have suggested that local ranchers' environmental traditional knowledge is of value for developing conservation, sustainable use, and local economic development policies (Pío-León et al. 2017). Our research shows that, as a group, Choyero ranchers embody a great body of ethnobiological knowledge: they generated for us a vast inventory of 287 known plants and animals and provided detail about various names used to refer to those species, and species traits and uses that are important to their way of life. Our own partnerships leveraging this local ethnobiological knowledge have led to novel findings regarding species range extensions (Macfarlan et al. 2019b). As primary stakeholders whose economic and cultural livelihoods have been tethered to arid land springs for the past 300 years, it is possible that Choyero knowledge and social institutions either support or can be leveraged to improve the goal of long-term Giganta ecosystem sustainability. For example, their detailed understanding of the biota and its natural occurrence can facilitate cost-effective biological inventory programs seeking to identifying species presence-absence, abundance, distributions, range extensions, or introductions (Berkes et al. 2000).

In aggregate, our ethnobiological lexicon results, species classification results, and the analytic results of models predicting knowledge of species included in the ethnobiological knowledge assessment task are important evidence of the rich ethnobiological knowledge that Choyeros maintain. Although there is substantial variability in ecological knowledge among Choyero ranchers, most are knowledgeable of most items in our ethnobiological knowledge assessment tool by adulthood. Furthermore, a few older adult experts are highly knowledgeable of almost all items in our assessment tool.

Limitations and Future Prospects

Our methods to capture a portrait of ethnobiological knowledge development across the life course are based on cross-sectional sample design, rather than longitudinal study. Cross-sectional sample design may not correctly reveal the path of knowledge development over the life course if secular changes might differentially affect the life stage cohorts (e.g., educational opportunity has improved since at least 1980). We controlled for possible effects of educational achievement on ethnobiological knowledge across our full sample and found no effect. Our analyses also reveal that

substantial differences in ethnobiological knowledge exist at the ranch level; however, ranches have also changed over the past century. Future research on pastoralist ethnobiological knowledge should carefully investigate whether ranch-level differences may be associated with economic differentiation between households, distance from neighbors, and different family histories in the Giganta.

Our set of items presented for visual identification may not provide the most appropriate representations of the actual items and may not be adequately characterizing the breadth of species knowledge essential for ranching. The color photographs of items we presented were assembled from images opportunistically gathered from a variety of personal and publicly available plant photo archives. Our method of displaying photographs was also conveniently deployed in the participant's home, rather than in the environments where the species in question were most typically encountered. An alternative approach for visual identification is to present participants controlled transects of the environment or a collection of specimens in situ (both of which present practical challenges for locating, permitting, and for controlling quality and reliable stability of over time) (e.g., see Begossi 1996; Quinlan et al. 2016; Zarger and Stepp 2004). While some participants interviewed about species encountered in situ might benefit from available contextual clues (e.g., soil, topography, the greater ecological community)³ when attempting to recognize and name species, others may be limited by associated transportation costs to reach the sites or by mobility limitations away from the home. Visual identification and naming tasks are commonly used methods for investigating knowledge, but there are others (some of which we also used) that reveal dimensions of ethnobiological knowledge, including questionnaire (pile sort, multiple choice, free-listing), semi-structured interview, and observation (Reyes-García et al. 2007). Missing from this report on Choyero ethnobiology is related knowledge about insects, fungi, and about agriculture, animal husbandry, weather, hydrology (e.g., of local springs), and geology.

Last, interpretation of survey results from older adult respondents as evidence of their ethnobiological “knowledge” necessitates careful consideration of the difficulty in lexical access that many older adults experience, which may be distinct from their ability to see and recognize, recall familiarity with, and produce knowledge of the species example (Craik 1999; Grady and Craik 2000). Word-finding failures increase with age (Burke et al. 1991), and almost all elderly people experience increased difficulty in retrieving proper names for recognized things (Cohen and Burke 1993). Although we rely on knowledge revealed by participants in response to questions on our survey, we have no measure of how people view one another's contributions or expertise. We also have no independent measure of subsistence ability to directly correlate with knowledge as others did (Koster et al. 2016; Reyes-García et al. 2007; Schniter et al. 2018). And although we fall short of providing a comprehensive measure of ethnobiological knowledge based on a full range of complementary methods, we leverage a mix of ethnobiological research methods that contributed to a detailed study of the ability to name recognized plants and animals

³ We thank an anonymous reviewer for pointing out the merits of the “plant trail interview” (Quinlan et al. 2016).

across the life course. From this study we can draw several conclusions about characteristics of the evolved human life history.

Conclusion

This research represents an important contribution to the literature on ethnobiological knowledge among a small-scale subsistence population since pastoralism (practiced by Choyeros) is the subsistence mode least represented in this literature (Reyes-García et al. 2007). Furthermore, the research highlights the ethnobiological knowledge of an understudied culture that is feared to be in rapid decline (Crosby 2015). With this research we also provide a new test of the embodied capital model hypothesis that the life course of ethnobiological knowledge development is shaped by the changing risks, capabilities, and wisdom of individuals with age and experience (Del Giudice et al. 2016), and the changing needs of the family budget (Bock 2002a, b; Crittenden et al. 2013; Gurven and Kaplan 2006; Schniter et al. 2015). As adults become grandparents and advance through their post-reproductive years, a number of physical and sensory declines reduce the profitability of various types of economic activities. In response to these declines, older adults are expected to shift their efforts toward low-strength yet knowledge-intensive service niches (Schniter et al. 2018). The knowledge required to know what plants and animals look like (to recognize them) and what recognized plants and animals are called (according to culturally correct names) bears characteristics making it optimal for continued development over the life course; these forms of knowledge require extensive learning and facilitate communication for teaching about features of the local ecology, supporting the childrearing, subsistence goals, and conservation efforts distributed within and between multigenerational familial groups.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s12110-021-09387-8>.

Funding This research project was supported by National Geographic Society (Research and Exploration Award HJ-099R-17), National Science Foundation (IBSS-L Award# 1743019), Funding Incentive Seed Grant (University of Utah), Center for Latin American Studies (University of Utah), Society, Water, and Climate Seed Grant (University of Utah), and NEXUS Pilot Grant (University of Utah), Economic Science Institute (Chapman University), Division of Anthropology (California State University Fullerton).

Availability of data and material (data transparency) Raw data for this study is available at *Mendeley Data* <https://doi.org/10.17632/hgd8zdyf2c.1>

Declarations

Ethics approval All procedures were in accordance with the ethical standards of the Declaration of Helsinki and the University of Utah Human Research Ethics Committee (approval number IRB 00083096)

Consent to participate Informed consent was obtained from all adult individuals included in this study. Both child assent and parental permission were obtained for all child participants included in this study.

Conflicts of interest/Competing interests We have no conflicts of interest to declare.

References

- Amoss, P. T., & Harrell, S. (1981). *Other ways of growing old: Anthropological perspectives*. Palo Alto: Stanford University Press.
- Ardila, A. (2007). Normal aging increases cognitive heterogeneity: Analysis of dispersion in WAIS-III scores across age. *Archives of Clinical Neuropsychology*, 22(8), 1003–1011.
- Atran, S. (1990). *Cognitive foundations of natural history: Towards an anthropology of science*. Cambridge: Cambridge University Press.
- Ayantunde, A. A., Briejer, M., Hiernaux, P., Udo, H. M. J., & Tabo, R. (2008). Botanical knowledge and its differentiation by age, gender and ethnicity in southwestern Niger. *Human Ecology*, 36(6), 881–889.
- Barrett, H. C. (2005). Cognitive development and the understanding of animal behavior. In B. J. Ellis & D. F. Bjorklund (Eds.), *Origins of the social mind: Evolutionary psychology and child development* (pp. 438–467). New York: The Guilford Press.
- Barrett, H. C., & Behne, T. (2005). Children's understanding of death as the cessation of agency: A test using sleep versus death. *Cognition*, 96(2), 93–108.
- Barrett, H. C., & Broesch, J. (2012). Prepared social learning about dangerous animals in children. *Evolution and Human Behavior*, 33(5), 499–508.
- Barrett, H. C., Peterson, C. D., & Frankenhuys, W. E. (2016). Mapping the cultural learnability landscape of danger. *Child Development*, 87(3), 770–781.
- Begossi, A. (1996). Use of ecological methods in ethnobotany: Diversity indices. *Economic Botany*, 50(3), 280. <https://doi.org/10.1007/BF02907333>.
- Berkes, F., Colding, J., & Folke, C. (2000). Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications*, 10(5), 1251–1262.
- Berlin, B. (1992). *Ethnobiological classification: Principles of categorization of plants and animals in traditional societies*. Princeton: Princeton University Press.
- Bliege Bird, R., & Bird, D. W. (2002). Constraints of knowing or constraints of growing? *Human Nature*, 13(2), 239–267.
- Bock, J. (2002a). Evolutionary demography and intrahousehold time allocation: School attendance and child labor among the Okavango Delta peoples of Botswana. *American Journal of Human Biology*, 14(2), 206–221.
- Bock, J. (2002b). Learning, life history, and productivity. *Human Nature*, 13(2), 161–197.
- Bogin, B., & Smith, B. H. (1996). Evolution of the human life cycle. *American Journal of Human Biology*, 8(6), 703–716.
- Borgerhoff Mulder, M., Towner, M. C., Baldini, R., Beheim, B. A., Bowles, S., Colleran, H., Gurven, M., Kramer, K. L., Mattison, S. M., Nolin, D. A., Scelza, B. A., Schniter, E., Sear, R., Shenk, M. K., Voland, E., & Ziker, J. (2019). Differences between sons and daughters in the intergenerational transmission of wealth. *Philosophical Transactions of the Royal Society, B: Biological Sciences*, 374(1780), 20180076.
- Brantingham, P. J. (1998). Hominid-carnivore coevolution and invasion of the predatory guild. *Journal of Anthropological Archaeology*, 17(4), 327–353.
- Brown, C. H. (1985). Polysemy, overt marking, and function words. *Language Sciences*, 7(2), 283–332.
- Burke, D. M., & Mackay, D. G. (1997). Memory, language, and ageing. *Philosophical Transactions of the Royal Society, B: Biological Sciences*, 352(1363), 1845–1856.
- Burke, D. M., MacKay, D. G., Worthley, J. S., & Wade, E. (1991). On the tip of the tongue: What causes word finding failures in young and older adults? *Journal of Memory and Language*, 30(5), 542–579.
- Cain, M. T. (1977). The economic activities of children in a village in Bangladesh. *Population and Development Review*, 3(3), 201–227.
- Carey, & Spelke, E. S. (1994). *Mapping the mind: Domain specificity in cognition and culture*. Cambridge: Cambridge University Press.
- Cariño Olvera, M. (2001). La oasisidad: Núcleo de la cultura sudcaliforniana. *Gaceta Ecológica*, 60, 57–68.
- Cariño Olvera, M. (2014). Oasisidad: Identidad geográfica sudcaliforniana y expresión local de la sustentabilidad. In M. Cariño Olvera & A. Ortega (Eds.), *Oasis sudcalifornianos: Para un rescate de la sustentabilidad local* (pp. 73–106). Granada: Universidad de Granada.

- Christensen, H., Mackinnon, A. J., Korten, A. E., Jorm, A. F., Henderson, A. S., Jacomb, P., & Rodgers, B. (1999). An analysis of diversity in the cognitive performance of elderly community dwellers: Individual differences in change scores as a function of age. *Psychology and Aging*, 14(3), 365–379.
- Cohen, G., & Burke, D. M. (1993). Memory for proper names: A review. *Memory*, 1(4), 249–263.
- Comisión Nacional de Areas Naturales Protegidas (CONANP). (2014). Estudio Previo Justificativo para el establecimiento del área natural protegida de competencia de la Federación con la categoría de Reserva de la Biosfera “Sierras La Giganta y Guadalupe”, en el estado de Baja California Sur. SEMARNAT (Secretario de Medio Ambiente y Recursos Naturales). Available online at https://www.conanp.gob.mx/acciones/pdf/EPJ_RB_Sierras_La_Giganta_y_Guadalupe_23jun2014.pdf.
- Comision Nacional de Areas Naturales Protegidas. (2020). *Regiones de áreas naturales protegidas de México*. http://sig.conanp.gob.mx/website/pagsig/datos_anp.htm.
- Consejo Nacional de Población (CONAPO). (2010). *Índice de marginación por localidad 2010*. http://www.conapo.gob.mx/es/CONAPO/Indice_de_Marginacion_por_Localidad_2010.
- Craik, F. I. M. (1999). Memory, aging, and survey measurement. In N. Schwarz, D. Park, B. Knauper, & S. Sudman (Eds.), *Cognition, aging and self-reports* (pp. 95–115). London: Taylor and Francis.
- Craik, F. I. M., & Rose, N. S. (2012). Memory encoding and aging: A neurocognitive perspective. *Neuroscience and Biobehavioral Reviews*, 36(7), 1729–1739.
- Crittenden, A. N., Conklin-Brittain, N. L., Marlowe, F. W., Schoeninger, M. J., & Wrangham, R. (2009). Foraging strategies and diet composition of Hadza children (abstract). *American Journal of Physical Anthropology*, 138(S48), 112.
- Crittenden, A. N., Conklin-Brittain, N. L., Zes, D. A., Schoeninger, M. J., & Marlowe, F. W. (2013). Juvenile foraging among the Hadza: Implications for human life history. *Evolution and Human Behavior*, 34(4), 299–304.
- Crosby, H. W. (2015). *California portraits: Baja California's vanishing culture*. Norman: University of Oklahoma Press.
- de Grenade, R., & Nabhan, G. P. (2013a). Baja California peninsula oases: An agro-biodiversity of isolation and integration. *Applied Geography*, 41, 24–35.
- de Grenade, R., & Nabhan, G. P. (2013b). Agrobiodiversity in an oasis archipelago. *Journal of Ethnobiology*, 33(2), 203–236.
- Del Giudice, M., Gangestad, S. W., & Kaplan, H. S. (2016). Life history theory and evolutionary psychology. In D. M. Buss (Ed.), *The handbook of evolutionary psychology: Foundations* (Vol. 1, 2nd ed., pp. 88–114). Wiley.
- Draper, P. (1976). Social and economic constraints on child life among the !Kung. In R. B. Lee & I. DeVore (Eds.), *Kalahari hunter-gatherers: Studies of !Kung San and their neighbors* (pp. 199–217). Cambridge: Harvard University Press.
- Elsner, C., & Wertz, A. E. (2019). The seeds of social learning: Infants exhibit more social looking for plants than other object types. *Cognition*, 183, 244–255.
- Erickson, R. A., Hamilton, R. A., & Mlodinow, S. G. (2008). Status review of Belding's yellowthroat *Geothlypis beldingi*, and implications for its conservation. *Bird Conservation International*, 18(3), 219–228.
- Evans, J. A. (2006). Standards for visual acuity. Report prepared for Elena Messina, Intelligent Systems Division, National Institute for Standards and Technology, in support of ASTM International Task Group E54.08.01 on Performance Measures for Robots for Urban Search and Rescue.
- Fernandez-Gimenez, M. E., & Febre, S. L. (2006). Mobility in pastoral systems: Dynamic flux or downward trend? *International Journal of Sustainable Development and World Ecology*, 13(5), 341–362.
- Gallois, S., Duda, R., & Reyes-García, V. (2017). Local ecological knowledge among Baka children: A case of “children's culture”? *Journal of Ethnobiology*, 37(1), 60–80.
- Garfield, Z. H., Garfield, M. J., & Hewlett, B. S. (2016). A cross-cultural analysis of hunter-gatherer social learning. In H. Terashima & B. S. Hewlett (Eds.), *Social learning and innovation in contemporary hunter-gatherers: Evolutionary and ethnographic perspectives* (pp. 19–34). Japan: Springer.
- Gaulin, S., & Hoffman, H. (1988). Evolution and development of sex differences in spatial ability. In L. Betzig, M. Borgerhoff Mulder, & P. Turke (Eds.), *Human reproductive behaviour: A Darwinian perspective* (pp. 129–152). Cambridge: Cambridge University Press.
- Grady, C. L., & Craik, F. I. (2000). Changes in memory processing with age. *Current Opinion in Neurobiology*, 10(2), 224–231.

- Grismer, L. L. (2002). *Amphibians and reptiles of Baja California, including its Pacific islands and the islands in the Sea of Cortés*. Berkeley: University of California Press.
- Guest, G. (2002). Market integration and the distribution of ecological knowledge within an Ecuadorian fishing community. *Journal of Ecological Anthropology*, 6(1), 38–49.
- Gurven, M., & Kaplan, H. (2006). Determinants of time allocation across the lifespan. *Human Nature*, 17(1), 1–49.
- Gurven, M., & Walker, R. (2006). Energetic demand of multiple dependents and the evolution of slow human growth. *Proceedings of the Royal Society B: Biological Sciences*, 273(1588), 835–841.
- Gurven, M., Stieglitz, J., Hooper, P. L., Gomes, C., & Kaplan, H. (2012). From the womb to the tomb: The role of transfers in shaping the evolved human life history. *Experimental Gerontology*, 47(10), 807–813.
- Gurven, M., Fuerstenberg, E., Trumble, B., Stieglitz, J., Beheim, B., Davis, H., & Kaplan, H. (2017). Cognitive performance across the life course of Bolivian forager-farmers with limited schooling. *Developmental Psychology*, 53(1), 160–176.
- Hawkes, K. (2003). Grandmothers and the evolution of human longevity. *American Journal of Human Biology*, 15(3), 380–400.
- Hawkes, K., O'Connell, J. F., & Blurton Jones, N. G. (1989). Hardworking hadza grandmothers. In V. Standen & R. A. Foley (Eds.), *Comparative socioecology: The behavioral ecology of mammals and man* (pp. 341–366). London: Basil Blackwell.
- Henrickson, C. N. (2014). *The archaeology of Cueva Santa Rita: A Late Holocene rockshelter in the Sierra de La Giganta of Baja California Sur, Mexico*. PhD dissertation, University of California, Berkeley.
- Hewlett, B. S., & Cavalli-Sforza, L. L. (1986). Cultural transmission among aka pygmies. *American Anthropologist*, 88(4), 922–934.
- Hewlett, B. S., & Lamb, M. E. (Eds.). (2017). *Hunter-gatherer childhoods: Evolutionary, developmental, and cultural perspectives*. Abingdon: Routledge.
- Hewlett, B. S., Fouts, H. N., Boyette, A. H., & Hewlett, B. L. (2011). Social learning among Congo Basin hunter-gatherers. *Philosophical Transactions of the Royal Society, B: Biological Sciences*, 366(1567), 1168–1178.
- Hill, K., & Hurtado, A. M. (2009). Cooperative breeding in South American hunter-gatherers. *Proceedings of the Royal Society B: Biological Sciences*, 276(1674), 3863–3870.
- Hooper, P. (2011). *The structure of energy production and redistribution among Tsimane' forager-horticulturalists*. PhD dissertation, University of New Mexico.
- Howell, N. (2010). *Life histories of the Dobe !Kung: Food, fatness, and well-being over the life span*. Berkeley: University of California Press.
- Howell, S. N. G., & Webb, S. (1995). *A guide to the birds of Mexico and northern Central America*. Oxford: Oxford University Press.
- Huntsinger, L. (2016). Enabling sustainable pastoral landscapes: Building social capital to restore natural capital. In Casasús I. and Lombardi G. (Eds.), *Mountain pastures and livestock farming facing uncertainty: Environmental, technical and socio-economic challenges* (pp. 315–325). Options Méditerranéennes, Série A. Séminaires Méditerranéens 116. CIHEAM.
- Instituto Nacional de Estadística y Geografía (INEGI). (2004). *El rezago educativo en la población mexicana*. <http://en.www.inegi.org.mx/app/biblioteca/ficha.html?upc=702825497538>
- Instituto Nacional de Estadística y Geografía (INEGI). (2016). *Anuario estadístico y geográfico de Baja California*. http://internet.contenidos.inegi.org.mx/contenidos/Productos/prod_serv/contenidos/espanol/bvinegi/productos/nueva_estruc/anuarios_2016/702825083663.pdf
- Kaplan, H. (1994). Evolutionary and wealth flows theories of fertility: Empirical tests and new models. *Population and Development Review*, 20(4), 753–791.
- Kaplan, H. (1996). A theory of fertility and parental investment in traditional and modern human societies. *American Journal of Physical Anthropology*, 101(S23), 91–135.
- Kaplan, H., Hill, K., Lancaster, J., & Hurtado, A. M. (2000). A theory of human life history evolution: Diet, intelligence, and longevity. *Evolutionary Anthropology*, 9(4), 156–185.
- Kaplan, H., Hooper, P. L., & Gurven, M. (2009). The evolutionary and ecological roots of human social organization. *Philosophical Transactions of the Royal Society, B: Biological Sciences*, 364(1533), 3289–3299.
- Kaplan, H., Gurven, M., Winking, J., Hooper, P. L., & Stieglitz, J. (2010). Learning, menopause, and the human adaptive complex. *Annals of the New York Academy of Sciences*, 1204(1), 30–42.

- Kays, R. W., & Wilson, D. E. (2009). *Mammals of North America* (2nd ed.). Princeton: Princeton University Press.
- Keil, F. C. (1987). Conceptual development and category structure. In U. Neisser (Ed.), *Concepts and conceptual development: Ecological and intellectual factors in categorization* (pp. 175–200). Cambridge: Cambridge University Press.
- Keil, F. C. (1994). The birth and nurturance of concepts by domains: The origins of concepts of living things. In L. A. Hirschfeld & S. A. Gelman (Eds.), *Mapping the mind: Domain specificity in cognition and culture* (pp. 234–254). Cambridge: Cambridge University Press.
- Kline, M. A., Boyd, R., & Henrich, J. (2013). Teaching and the life history of cultural transmission in Fijian villages. *Human Nature*, 24(4), 351–374.
- Koster, J., Bruno, O., & Burns, J. L. (2016). Wisdom of the elders? Ethnobiological knowledge across the lifespan. *Current Anthropology*, 57(1), 113–121.
- Koster, J., Lukas, D., Nolin, D., Power, E., Alvergne, A., Mace, R., Ross, C. T., Kramer, K., Greaves, R., Caudell, M., Macfarlan, S., Schniter, E., Quinlan, R., Mattison, S., Reynolds, A., Yi-Sum. (2019). Kinship ties across the lifespan in human communities. *Philosophical Transactions of the Royal Society B*, 374, 2018.0069.
- Kramer, K. L., & Ellison, P. T. (2010). Pooled energy budgets: Resituating human energy allocation trade-offs. *Evolutionary Anthropology*, 19(4), 136–147.
- Lee, R. D. (2013). Intergenerational transfers, the biological life cycle, and human society. *Population and Development Review*, 38(Suppl 1), 23–35.
- Lee, R. D., & Kramer, K. L. (2002). Children's economic roles in the Maya family life cycle: Cain, Caldwell, and Chayanov revisited. *Population and Development Review*, 28(3), 475–499.
- León de la Luz, J. L., Rebman, J., Domínguez-León, M., & Domínguez-Cadena, R. (2008). The vascular flora and floristic relationships of the sierra de la Giganta in Baja California Sur, México. *Revista Mexicana de Biodiversidad*, 79(1), 29–65.
- León de la Luz, J. L., and Coria Benet, R. D. C. (2018). *Flora iconografica de Baja California Sur*. <http://dspace.cibnor.mx:8080/handle/123456789/2131>.
- León de la Luz, J. L., & Domínguez Cadena, R. (2006). Hydrophytes of the oases in the Sierra de la Giganta of Central Baja California Sur, Mexico: Floristic composition and conservation status. *Journal of Arid Environments*, 67(4), 553–565.
- Lindenberger, U., & Baltes, P. B. (1994). Aging and intelligence. In R. J. Sternberg (Ed.), *Encyclopedia of human intelligence* (pp. 52–66). Macmillan.
- Macfarlan, S. J. (2016). Social evolution: The force of the market. *Current Biology*, 26(16), R756–R758.
- Macfarlan, S. J., & Henrickson, C. N. (2010). Inferring relationships between Indigenous Baja California Sur and Seri/Comcaac populations through cultural traits. *Journal of California and Great Basin Anthropology*, 30(1), 51–67.
- Macfarlan, S. J., Schacht, R., Foley, C., Cahoon, S., Osusky, G., Vernon, K. B., Tayler, E., Henrickson, C. N., & Schniter, E. (2019a). Marriage dynamics in old Lower California: Ecological constraints and reproductive value in an arid peninsular frontier. *Biodemography and Social Biology*, 65(2), 156–171.
- Macfarlan, S. J., Garcia, J. J., Schniter, E., Guevara Beltran, D., Amador Bibo, J., & Ruiz-Campos, G. (2019). Geographic distribution: *Elgaria velazquezii* (Central Baja California alligator lizard). *Herpetological Review*, 50(1), 10.
- Macfarlan, S. J., Garcia, J. J., and Schniter, E. (2020). Choyero identified plants and animals. *Mendeley Data*, 1. <https://doi.org/10.17632/kjds8jztzv.1>.
- Maddox, G. L., & Clark, D. O. (1992). Trajectories of functional impairment in later life. *Journal of Health and Social Behavior*, 33(2), 114–125.
- Malinowski, B. K. (1925). *Magic, science, religion*. Souvenir Press.
- Marlowe, F. W. (2007). Hunting and gathering: The human sexual division of foraging labor. *Cross-Cultural Research*, 41(2), 170–195.
- Maya, Y., Coria, R., & Domínguez, R. (1997). Caracterización de los oasis. In L. Arriaga and R. Rodríguez-Estrella (Eds.), *Los oasis de la península de Baja California* (pp. 5–25). Publication 13. La Paz, Mexico: Centro de Investigaciones Biológicas de Noroeste SC (CIBNOR).
- Mithen, S. (2006). Ethnobiology and the evolution of the human mind. *Journal of the Royal Anthropological Institute*, 12(s1), S45–S61.
- Nabhan, G. P., & St Antoine, S. (1993). The loss of floral and faunal story: The extinction of experience. In S. R. Kellert & E. O. Wilson (Eds.), *The biophilia hypothesis* (pp. 229–250). Washington DC: Island Press.

- Nabhan, G. P., García, J., Routson, R., Routson, K., & Cariño-Olvera, M. (2010). Desert oases as genetic refugia of heritage crops: Persistence of forgotten fruits in the mission orchards of Baja California, Mexico. *International Journal of Biodiversity and Conservation*, 2(4), 56–69.
- Nelson, E. A., & Dannefer, D. (1992). Aged heterogeneity: Fact or fiction? The fate of diversity in gerontological research. *The Gerontologist*, 32(1), 17–23.
- Ohmagari, K., & Berkes, F. (1997). Transmission of indigenous knowledge and bush skills among the Western James Bay Cree women of Subarctic Canada. *Human Ecology*, 25(2), 197–222.
- Oña, L., Oña, L. S., & Wertz, A. E. (2019). The evolution of plant social learning through error minimization. *Evolution and Human Behavior*, 40(5), 447–456.
- Park, D. C., Lautenschlager, G., Hedden, T., Davidson, N. S., Smith, A. D., & Smith, P. K. (2002). Models of visuospatial and verbal memory across the adult life span. *Psychology and Aging*, 17(2), 299–320.
- Parker, S. T., & McKinney, M. L. (2012). *Origins of intelligence: The evolution of cognitive development in monkeys, apes, and humans*. Baltimore: Johns Hopkins University Press.
- Pío-León, J. F., Delgado-Vargas, F., Murillo-Amador, B., León-de-la-Luz, J. L., Vega-Aviña, R., Nieto-Garibay, A., Córdoba-Matson, M., & Ortega-Rubio, A. (2017). Environmental traditional knowledge in a natural protected area as the basis for management and conservation policies. *Journal of Environmental Management*, 201, 63–71.
- Quinlan, M. B., Quinlan, R. J., Council, S. K., & Roulette, J. W. (2016). Children's acquisition of ethnobotanical knowledge in a Caribbean horticultural village. *Journal of Ethnobiology*, 36(2), 433–456.
- Rabe-Hesketh, S., & Skrondal, A. (2012). *Multilevel and longitudinal modeling using Stata, Vol. II: Categorical responses counts and survival* (3rd ed.). Stata Press.
- Rebman, J., Roberts, N., and Ezcurra, E. (2012). *Baja California plant field guide*. San Diego Natural History Museum.
- Reyes-García, V., Martí, N., McDade, T., Tanner, S., & Vadez, V. (2007). Concepts and methods in studies measuring individual ethnobotanical knowledge. *Journal of Ethnobiology*, 27(2), 182–203.
- Reyes-García, V., Broesch, J., Calvet-Mir, L., Fuentes-Peláez, N., McDade, T. W., Parsa, S., Tanner, S., Huanca, T., Leonard, W. R., & Martínez-Rodríguez, M. R. (2009). Cultural transmission of ethnobotanical knowledge and skills: An empirical analysis from an Amerindian society. *Evolution and Human Behavior*, 30(4), 274–285.
- Reyes-García, V., Guèze, M., Luz, A. C., Paneque-Gálvez, J., Macía, M. J., Orta-Martínez, M., Pino, J., & Rubio-Campillo, X. (2013). Evidence of traditional knowledge loss among a contemporary Indigenous society. *Evolution and Human Behavior*, 34(4), 249–257.
- Reyes-García, V., Gallois, S., & Demps, K. (2016). A multistage learning model for cultural transmission: Evidence from three Indigenous societies. In H. Terashima & B. S. Hewlett (Eds.), *Social learning and innovation in contemporary hunter-gatherers: Evolutionary and ethnographic perspectives* (pp. 47–60). Japan: Springer.
- Riemann, H., & Ezcurra, E. (2005). Plant endemism and natural protected areas in the peninsula of Baja California, Mexico. *Biological Conservation*, 122(1), 141–150.
- Robson, A. J., & Kaplan, H. S. (2003). The evolution of human life expectancy and intelligence in hunter-gatherer economies. *American Economic Review*, 93(1), 150–169.
- Rodd, T., Bryant, G., and Barnard, L. (2007). *The plant finder*. Firefly Books. <http://agris.fao.org/agris-search/search.do?recordID=US201300120161>.
- Rodríguez-Estrella, R. (2005). Terrestrial birds and conservation priorities in Baja California Peninsula. In *Bird conservation implementation and integration in the Americas: Proceedings of the Third International Partners in Flight Conference, March 20-24, 2002, Asilomar, California* (Vol. 1). U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station.
- Rosenberg, I. H. (1997). Sarcopenia: Origins and clinical relevance. *The Journal of Nutrition*, 127(5), 990S–991S.
- Ruddle, K., & Chesterfield, R. (1977). *Education for traditional food procurement in the Orinoco Delta*. Berkeley: University of California Press.
- Ruiz-Campos, G., Castro-Aguirre, J. L., Contreras-Balderas, S., de Lourdes Lozano-Vilano, M., González-Acosta, A. F., & Sánchez-González, S. (2002). An annotated distributional checklist of the freshwater fish from Baja California Sur, México. *Reviews in Fish Biology and Fisheries*, 12(2), 143–155.
- Ruiz-Campos, G., Camarena-Rosales, F., González-Acosta, A. F., Maeda-Martínez, A. M., García de León, F. J., Varela-Romero, A., & Andreu-Soler, A. (2014). Estatus actual de conservación de seis

- especies de peces dulceacuícolas de la península de Baja California, México. *Revista Mexicana de Biodiversidad*, 85(4), 1235–1248. <https://doi.org/10.7550/rmb.43747>.
- Salthouse, T. A. (1993). Speed and knowledge as determinants of adult age differences in verbal tasks. *Journal of Gerontology*, 48(1), P29–P36.
- Schaie, K. W. (1994). The course of adult intellectual development. *American Psychologist*, 49(4), 304–313.
- Schneider, B. A., & Pichora-Fuller, M. K. (2000). Implications of perceptual deterioration for cognitive aging research. In F. I. M. Craik & T. A. Salthouse (Eds.), *The handbook of aging and cognition* (2nd ed., pp. 155–219). Lawrence Erlbaum Associates.
- Schniter, E. (2009). *Why old age? Non-material contributions and patterns of aging among older adult Tsimane'*. PhD dissertation, University of California, Santa Barbara.
- Schniter, E. (2014). Older adults' contributions to the Tsimane forager-farmer economy. *Anthropology and Aging*, 35(1), 56–58.
- Schniter, E., Gurven, M., Kaplan, H. S., Wilcox, N. T., & Hooper, P. L. (2015). Skill ontogeny among Tsimane forager-horticulturalists. *American Journal of Physical Anthropology*, 158(1), 3–18.
- Schniter, E., Wilcox, N. T., Beheim, B. A., Kaplan, H. S., & Gurven, M. (2018). Information transmission and the oral tradition: Evidence of a late-life service niche for Tsimane Amerindians. *Evolution and Human Behavior*, 39(1), 94–105.
- Schniter, E., Macfarlan, S. J., & Garcia, J. J. (2020). Choyero ethnobiological knowledge survey. *Mendeley Data*, 1. <https://doi.org/10.17632/hgd8zdyf2c.1>.
- Schuppli, C., Isler, K., & van Schaik, C. P. (2012). How to explain the unusually late age at skill competence among humans. *Journal of Human Evolution*, 63(6), 843–850.
- Secretaría de Desarrollo Social (SEDESOL). (2010). *Catálogo de localidades: Resumen de localidades del municipio* (Sistema de Apoyo Para la Planeación del PDZP). <http://www.microrregiones.gob.mx/catloc/Default.aspx>.
- Setalaphruk, C., & Price, L. L. (2007). Children's traditional ecological knowledge of wild food resources: A case study in a rural village in Northeast Thailand. *Journal of Ethnobiology and Ethnomedicine*, 3(1), 33. <https://doi.org/10.1186/1746-4269-3-33>.
- Shreve, F., & Wiggins, I. L. (1964). *Vegetation and flora of the Sonoran Desert*. Palo Alto: Stanford University Press.
- Stieglitz, J., Gurven, M., Kaplan, H., & Hooper, P. L. (2013). Household task delegation among high-fertility forager-horticulturalists of Lowland Bolivia. *Current Anthropology*, 54(2), 232–241.
- Stieglitz, J., Schniter, E., von Rueden, C., Kaplan, H., & Gurven, M. (2015). Functional disability and social conflict increase risk of depression in older adulthood among Bolivian forager-farmers. *The Journals of Gerontology: Series B*, 70(6), 948–956.
- Trumbo, P., Schlicker, S., Yates, A. A., Poos, M., & Food and Nutrition Board of the Institute of Medicine, The National Academies. (2002). Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein and amino acids. *Journal of the American Dietetic Association*, 102(11), 1621–1630. (Erratum in: *Journal of the American Dietetic Association*, 2003;103(5):563.)
- Walker, R., & Hill, K. (2003). Modeling growth and senescence in physical performance among the Ache of eastern Paraguay. *American Journal of Human Biology*, 15(2), 196–208.
- Walker, R., Hill, K., Kaplan, H., & McMillan, G. (2002). Age-dependency in hunting ability among the Ache of eastern Paraguay. *Journal of Human Evolution*, 42(6), 639–657.
- Walker, R., Beckerman, S., Flinn, M. V., Gurven, M., von Rueden, C. R., Kramer, K. L., Greaves, R. D., Córdoba, L., Villar, D., Hagen, E. H., Koster, J. M., Sugiyama, L., Hunter, T. E., & Hill, K. R. (2013). Living with kin in lowland horticultural societies. *Current Anthropology*, 54(1), 96–103.
- Wertz, A. E., & Wynn, K. (2014a). Thyme to touch: Infants possess strategies that protect them from dangers posed by plants. *Cognition*, 130(1), 44–49.
- Wertz, A. E., & Wynn, K. (2014b). Selective social learning of plant edibility in 6- and 18-month-old infants. *Psychological Science*, 25(4), 874–882.
- Wiggins, I. L. (1980). *Flora of Baja California*. Palo Alto: Stanford University Press.
- Zarger, R. K., & Stepp, J. R. (2004). Persistence of botanical knowledge among Tzeltal Maya children. *Current Anthropology*, 45(3), 413–418.

Zent, S. (2001). Acculturation and ethnobotanical knowledge loss among the Piaroa of Venezuela: Demonstration of a quantitative method for the empirical study of TEK change. In L. Maffi (Ed.), *On biocultural diversity: Linking language, knowledge, and the environment* (pp. 190–211). Harper Collins.

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Eric Schniter is a clinical assistant professor of economics in the Economic Science Institute at Chapman University and a lecturer in anthropology at California State University Fullerton, where he is a member of the Center for the Study of Human Nature. He received a PhD in anthropology from The University of California, Santa Barbara in 2009 and an MS in Anthropology from the University of Oregon in 2001. He studies the development of skill, knowledge and material production across the lifespan to better understand whether contributions of older adults may help explain the supported postmenopausal lifespan of humans. Related interests include relationship maintenance (communication, trust and cooperation) emotional calibration of interpersonal behaviors, and well-being across the lifespan.

Shane J. Macfarlan is an assistant professor of anthropology as well as a faculty affiliate of both the Center for Latin American Studies and The Global Change and Sustainability Center at the University of Utah. He received a PhD in anthropology from Washington State University in 2010 and an MA in Museum Science from Texas Tech University in 2004. His research interests include human social organization, cooperation and conflict, and human-ecosystem dynamics of the Baja California Peninsula.

Juan J. Garcia is a PhD candidate in the Education, Culture and Society Department with an emphasis on the anthropology of education at the University of Utah. He received both his BA (1999) and MAIS (2007) in anthropology from the University of Texas Pan-American (now University of Texas Rio Grande Valley). His research addresses the relationship between parents', school administrators', and community members' cooperative teaching methods in community gardens within school grounds.

Gorgonio Ruiz-Campos is a senior researcher-professor in the Science Faculty of the Universidad Autónoma de Baja California, campus Ensenada, Baja California, Mexico. He received a PhD in aquatic ecology and fish from Universidad Autónoma de Nuevo León in 1993, an MS in marine ecology from Centro de Investigación Científica y de Educación Superior de Ensenada in 1986, and a BS in biology from Universidad Autónoma de Nuevo León in 1982. His research interests include aspects of taxonomy, ecology and biogeography of vertebrates in northwestern México, with an emphasis in fish and birds from Baja California peninsula.

Diego Guevara Beltran received his bachelor's degrees in psychology and evolutionary anthropology from the University of New Mexico and his MA in social psychology from Arizona State University. His current research takes an evolutionary approach to answer questions about empathy, prosociality, and cooperation. He is currently a PhD student in psychology at Arizona State University, where he is affiliated with the Human Generosity Project.

Brenda B. Bowen is an associate professor of geology and geophysics and the director of the Global Change and Sustainability Center at the University of Utah. She received a BS and MS in Earth Science from the University of California, Santa Cruz, and a PhD in geology from the University of Utah. Her research focuses on advancing understanding of geologic processes related to landscape evolution, groundwater flow, and resource sustainability in human-modified sedimentary systems.

Jory C. Lerback received a PhD in geology and geophysics at the University of Utah in 2021 and a BA in Earth Science from Franklin and Marshall College in 2013. Her research addresses groundwater resources in arid environments, relationships between hydrological and social systems, and diversity in academia.

Authors and Affiliations

Eric Schniter¹ · **Shane J. Macfarlan**^{2,3,4} · **Juan J. Garcia**⁵ ·
Gorgonio Ruiz-Campos⁶ · **Diego Guevara Beltran**⁷ · **Brenda B. Bowen**^{4,8} ·
Jory C. Lerback⁸

¹ Economic Science Institute, Chapman University, Orange, CA, USA

² Department of Anthropology, University of Utah, Salt Lake City, UT, USA

³ Center for Latin American Studies, University of Utah, Salt Lake City, UT, USA

⁴ Global Change and Sustainability Center, University of Utah, Salt Lake City, UT, USA

⁵ Department of Education, Culture, and Society, University of Utah, Salt Lake City, UT, USA

⁶ Departamento de Biología, Universidad Autónoma de Baja California, Ensenada,
Baja California, México

⁷ Department of Psychology, University of Arizona, Tucson, AZ, USA

⁸ Department of Geology and Geophysics, University of Utah, Salt Lake City, UT, USA