Wisdom of the Elders?

Ethnobiological Knowledge across the Lifespan

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A common assumption is that individuals continue to accumulate ethnobiological knowledge throughout their lives, resulting in greater expertise among the elder generations. Alternative theoretical perspectives suggest that ethnobiological knowledge about animals should peak earlier in life, paralleling and facilitating the emergence of foraging proficiency among younger adults. We test these competing models among indigenous Nicaraguans with three measures of knowledge about fish behavior. Our results indicate that individuals exhibit considerable domain knowledge as relatively young adults. There is also a positive correlation between some measures of knowledge and fishing ability, suggesting that knowledge may promote and develop from specialization and the allocation of effort to fishing. These results imply a model of humans as flexible learners, assimilating ethnobiological knowledge via social learning and related experiences. Contrary to conventional perspectives, we suggest that age-related variation in knowledge among adults is attributable primarily to proximate factors, such as acculturation, time allocation to related productive tasks, and social-learning opportunities.

A common belief among social scientists is that ethnobiological knowledge continues to accumulate with age (Berlin 1992). To some extent, this belief may stem from local stereotypes about the ecological wisdom of elders, because community leaders and other informants tend to nominate elders as the premier sources of expert ecological knowledge (Davis and Wagner 2003). The pervasive assumption that knowledge continuously increases over the lifespan might help to explain why researchers who examine age-related variation in ethnobiological knowledge sometimes consider only linear functions of age, not curvilinear effects (Byg and Balsev 2004; Godoy et al. 1998; Mathez-Stiefel et al. 2012; Quinlan and Quinlan 2007; see also Joyal 1996).[1]

Although earlier research is limited primarily to botanical domains, numerous ethnobiological studies indicate that older informants indeed are more knowledgeable than their younger counterparts (Figueiredo et al. 1993; Ghorbani et al. 2012; Ladio and Lozada 2004; Phillips and Gentry 1993; Reyes-Garcia et al. 2005; Somnasang and Moreno-Black 2000; Wester and Yongvanit 1995).[2] In cross-sectional research, such results are often interpreted as evidence of eroding knowledge, as acculturated younger generations in modernizing societies fail to match their elder peers' attentiveness to local ecologies (Figueiredo et al. 1993; Ladio and Lozada 2004; see also Turner et al. 2000). However, such age-related variation in knowledge is also consistent with the hypothesis that individuals continue to learn throughout their lives (Godoy et al. 2009). An emerging literature suggests that, when subsistence activities and local biodiversity remain relatively constant over time, variation in knowledge by age remains stationary, primarily stemming from learning across the lifespan (Reyes-Garcia et al. 2013). For example, Tzeltal Mayan children in 1999 identified the same number of plants as their counterparts from a study in 1968, which apparently reflects the persistence of children's work and play activities (Zarger and Stepp 2004).

Among ecological anthropologists, there is an unresolved debate about the adaptive importance of ethnobiological knowledge and its relationship with foraging ability. In some cases, return rates among foragers in small-scale societies primarily reflect variation in physical abilities, such as size and strength (Bird and Bliege Bird 2005; Bleige Bird and Bird 2002). Such results suggest that individuals expediently accumulate the requisite knowledge to be proficient foragers. Conversely, studies of hunting returns in tropical forests indicate that peak efficiency is achieved at around 40 years of age, considerably after the age at which hunters exhibit maximum strength (Gurven et al. 2006; McElreath and Koster 2014; Walker et al. 2002). These results are consistent with the "embodied capital hypothesis," which contends that the delayed maturation of humans facilitates the gradual learning of skills and knowledge that allow individuals to become highly productive foragers later in life (Kaplan et al. 2000). Unlike the "wisdom of the elders" model, however, the embodied capital perspective suggests that ethnobiological knowledge should plateau by approximately 40 years of age, when individuals in natural fertility populations tend to have the highest number of dependent offspring and a consequently high need for subsistence-related expertise and productive skills (Kramer 2005).

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[1] Other studies also do not present statistical tests of polynomial effects of age, but they present scatterplots that do not suggest curvilinear effects (Ladio and Lozada 2004; Souto and Ticktin 2012).

[2] By contrast, other studies do not reveal comparable effects of age (e.g., Guest 2002). In some settings, evidence suggests that teenagers exhibit knowledge that is comparable to the knowledge of their adult peers (Hynes et al. 1997; Zarger 2002; Zent and López-Zent 2004).

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Although some of the aforementioned studies of foraging efficiency have incorporated measures of individuals' strength (e.g., Gurven et al. 2006), there have evidently been no attempts to disentangle the independent effects of strength and knowledge as predictors of foraging ability across the lifespan. In other contexts, however, ethnographers have shown that ethnobiological knowledge approaches its peak for individuals in their mid-thirties (Demps et al. 2012; Zent 1999). Yet there is little evidence that such individual-level differences in knowledge can explain variation in proficiency in subsistence-related activities (Kightley et al. 2013).

Drawing on this literature, we conducted an investigation among indigenous Nicaraguan forager-farmers to evaluate hypotheses about age-related variation in fish knowledge and the relationship between knowledge and fishing ability. We address two predictions: (1) *Ethnobiological knowledge increases with age*. The "wisdom of the elders" model presupposes lifelong increases in knowledge, whereas the embodied capital hypothesis suggests that individuals will exhibit the highest levels of knowledge by the time they reach 35–40 years of age. (2) *Individuals' knowledge about fish predicts their fishing ability*. A correlation between knowledge and ability could emerge either because knowledge is a prerequisite to fishing proficiency or because talented fishers acquire this knowledge as a consequence of their attention and time allocation to fishing.

Study Site

This research was based in two indigenous Mayangna and Miskito communities, Arang Dak and Suma Pipi, located along the Lakus River in Nicaragua's Bosawas Biosphere Reserve (fig. A1; figs. A1, A2 are in CA+ online supplement A). The residents are primarily horticulturalists who augment their diet via animal husbandry, hunting, fishing, and importing processed foods (Koster 2008*a*). Whereas hunted game contributes more consumable biomass than fishing, there is less household-level variation in the harvests of fish, and fishing represents the leading source of harvested meat for most households.[3] Combined with harvest data from 4 months in 2013, earlier data collected in this setting indicate that fishing effort and harvests have remained stable for at least two decades (Koster 2007; Nature Conservancy 1997).

The Mayangna and Miskito use a variety of fishing technologies and strategies (fig. A2). When the water is clear, during the dry season (January to May), men use either bows and arrows or scuba masks and handmade crossbows to target fish both during the daytime and at night with the aid of flashlights. Nets are useful primarily at the onset of the rainy season, when it is common for adolescent girls to harvest *Phallichthys* species along the riverbank. Both male and female fishers use fishhooks throughout the year, but harvests are greater during the rainy season. Twenty-seven fish species inhabit the rivers of the reserve (table A1; tables A1–A4 are in CA+ online supplement B).

From an early age, children regularly observe the practice of fishing strategies, as they are frequently brought on excursions in dugout canoes with older relatives who fish. As youngsters, children often contribute by gathering and managing the fish caught by family members. Juveniles are often free to experiment with fishing technologies in pools near the community. As adolescents, residents occasionally form fishing parties with same-aged friends and peers. Adults likewise embark on fishing expeditions together. For example, multiple men may share a scuba mask and take turns fishing at night, or several adult women might opt to fish from the same canoe for a day. Overall, there are ample and diverse opportunities for both experiential and social learning about fish behavior.

Methods

Knowledge Interviews

In 2013, one of us (O.B.) conducted the interviews in the participants' preferred language, either Mayangna or Miskito. The sample of 213 participants includes all residents in the communities who were at least 12 years old and a subset of residents who were 10 or 11 years old. The average age (± standard deviation) was 28 ± 14.7 years old. Approximately 54% of the participants were male.

Using a "free listing" method (Quinlan 2005), participants were first asked to list as many fish species as they could. They were subsequently shown photographs of the 27 species and asked to identify them by name.[4] Finally, they were presented with 50 knowledge questions, generated by the lead author from biological reports, primarily about fish behavior and secondarily about information that would be relevant to fishing strategies (see supplement B, available online). For example, participants were asked to specify which of two species is more active at night.

As a rule, the 27 species in this study are those that have been identified by Western biologists as the species that inhabit the rivers of the Bosawas reserve. During the free listing exercise, approximately 90% of the 213 participants listed no types of fish beyond these 27 species, and there was no ambiguity about their lists. The remaining participants listed one of two types that have locally specific names but that are not classified by biologists as distinct species in Linnaean taxonomies (Gros and Miguel Frithz 2010).[5] These latter

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[3] Based on data collected during 2004–2005, the per capita household-level harvest of fish (CV = .84) is substantially lower than the household-level harvest of hunted game (CV = 2.56). See Koster (2008*b*) for methodological details pertaining to data collection on harvests of fish and game.

[4] The participants at this study site have considerable experience with photographic images, and there was little confusion about the intent of the exercise and that the photographs correspond to fish species that can be encountered in the rivers near the study communities.

[5] One of these subtypes pertains to the juvenile life stage of *Agnostomus monticola* and the other pertains to a morphological variant of the catfish, *Rhamdia guatemalensis*.

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types were not included in the analysis, and there were no cases in which informants who listed these subtypes did not also list the primary name for the species. During the photo identification exercise, either of the applicable names for these subtypes was deemed a correct response, although informants invariably provided the names in table A1.

Interviews typically occurred near the participants' homes, out of earshot of other residents. Upon completion, participants were instructed to not discuss the content of the interviews with other residents, and compliance with this request seemed high. Participants received a small monetary incentive for the interviews, which generally required approximately 35 minutes.

Informant Ratings of Ethnobiological Knowledge and Fishing Ability

Residents of the larger village, Arang Dak, were asked to evaluate the abilities of their peers in the community. The sample of evaluated individuals included all men older than 14 years of age ($n = 65$) and all women older than 13 years of age ($n = 63$). The names of these individuals were read in a random order to informants, who responded with a binary "yes" or "no" distinction when they were asked to evaluate whether a given individual met the criteria of the question. For local perspectives on the distribution of ethnobiological knowledge, informants were asked which residents were familiar with all of the species in the river and the forest. To assess fishing ability, residents were asked which women fished well with hooks and, separately, which men fished well with masks or bows. Previous research on hunting ability in this setting suggests that local rankings of ability accurately reflect measurable variation in foraging returns (Koster 2010).[6]

Complementary Data Collection

Demographic variables in this study stem from ongoing research in these communities (Koster and Leckie 2014; Winking and Koster 2015). In addition, we measured the physical strength of residents using methods described by Gurven et al. (2006). We used a manual muscle tester and a grip-strength tester to measure strength in five anatomical regions: hips, thighs, shoulders, chest, and forearms. These measurements were standardized within sex (i.e., separately for male and female sex) such that 1 represented the highest value, then aggregated within informants across the five measurements to yield a composite measure of strength, which was again standardized such that 1 was the maximum value.

Analysis

Drawing on multilevel modeling applications of item-response theory (Gelman and Hill 2007), the statistical models in this article are generalized linear mixed models (GLMM), specifically logistic regression models. All models include cross-classified random effects (varying intercepts) for the informants who responded to the questions and the items being evaluated. The models are notated as follows:

$$y_{ij} \sim \text{Bernouilli}(\pi_{ij}),$$

$$\text{logit}(\pi_{ij}) = \beta_0 + r_i + s_j,$$

$$r_i \sim \text{N}(0, \sigma_r^2),$$

$$s_j \sim \text{N}(0, \sigma_s^2),$$

where the dichotomous responses are modeled via a Bernouilli distribution with a response probability of π_{ij}. The intercept parameter, β_0, measures the average expected probability for a correct or positive response, r_i is a random effect that measures the extent to which positive responses by informant i deviate from the intercept, and s_j is a random effect that measures the extent to which positive responses for ratee or question j deviate from the intercept. In both cases, these random effects are assumed to have a mean of zero and variances, σ_r^2 and σ_s^2, respectively. For simplicity, we present the statistical notation for an intercept-only (empty) version of the model with no covariates, but the models easily accommodate fixed-effect predictor variables, including the informant-level and ratee-level covariates that are the focus of this article.

Modeling Knowledge

We specify three sets of models that correspond to the three knowledge assessments. Our binary outcome variables are whether participants listed the fish species (listed or not), whether participants correctly identified the fish species in the photographs (correct or not), and whether the participants answered the question correctly (correct or not). Following Demps et al. (2012), we model the effect of age using a cubic polynomial. We also include a binary variable to control for the effect of sex on the outcome variables, noting that previous research in this population has demonstrated gendered variation in hunting knowledge (Koster and Venegas 2012).

As a comparison with local perspectives on age-related variation in ethnobiological knowledge, we use a similar logistic regression GLMM to model the informant ratings as a function of the ratees' age.

Modeling Fishing Ability

For the three types of fishing strategies (masks, bows, and hooks), we model the informants' binary evaluations of their peers' fishing ability. To assess the effect of knowledge on fishing ability, we consider models that include the respective out-

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[6] A consensus analysis of each of these ratings indicates that there is high agreement among the informants about the individuals who exemplify these traits (see table A2). This table also includes the sample sizes of informants who participated in the respective peer evaluations.

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Table 1. Descriptions of variables used in the analyses of fishing skill

Variable	Description	Mean	SD	Minimum	Maximum
Men					
Age	Age in years of the fisher being evaluated	32.84	13.60	15	73
Strength	Composite strength measure	.70	.13	.36	.89[a]
Free-listed fish	Number of fish listed by the fisher	19.60	3.47	9	27
Photo identification	Number of photos correctly identified by the fisher	21.36	3.38	9	27
Knowledge questions	The number of questions correctly answered by the fisher	42.84	4.72	27	49
Women					
Age	Age in years of the fisher being evaluated	31.20	15.10	14	75
Strength	Composite strength measure	.67	.14	.26	1
Free-listed fish	Number of fish listed by the fisher	17.48	3.33	9	23
Photo identification	Number of photos correctly identified by the fisher	18.27	3.58	8	25
Knowledge questions	Number of questions correctly answered by the fisher	39.33	5.93	22	48

Note. The summary statistics are based on the samples of the 65 male and 63 female fishers whose fishing skills were evaluated by peers. For men, skills were evaluated for two methods, diving with masks and using bows. For women, skill with hooks and lines was evaluated.

[a] Drawing on a sample of men from two communities, this variable was standardized such that 1 represents the maximum possible value. That value is not represented in this sample of data, because the highest value corresponds to a man who lives in the study community in which fishing skills were not evaluated.

comes of the knowledge examinations as covariates, specifically the number of species listed, the number of photos identified correctly, and the number of questions answered correctly.[7] These models also include covariates for the fishers' age, again modeled as a cubic polynomial. We also include the composite variable for strength, which is hypothesized to have a positive effect on fishing ability (Bock 2005). See table 1 for additional descriptions of these predictor variables.

Results

Age-Related Variation in Knowledge

As a comparison to the results of the knowledge assessments, it is helpful to examine local perspectives on age-related variation in knowledge. Figure 1 displays the peer evaluations of knowledge as a function of the ratees' age. The local informants clearly believe the oldest locals to be more knowledgeable, because endorsements do not peak until after 50 years of age (see table A3 for model estimates). In other words, the Mayangna and Miskito plainly subscribe to the "wisdom of the elders" model of ethnobiological knowledge.

The participants' performance on the knowledge assessments reveals a different trend (table 2). On the one hand, there is evidence for an effect of age, because adults exhibit greater knowledge than adolescents and children on all three assessments. On the other hand, knowledge evidently plateaus among relatively young adults. As seen in figure 2, although the statistical models of free listing and photo identification predict minor gains into middle age, the width of the confidence intervals precludes strong conclusions about the differences in knowledge of a 30-year-old individual and a 50-year-old individual, for example. Performance on the questions (panel C) provides clearer evidence of the tendency for knowledge to peak among younger adults, because participants in their twenties and thirties demonstrate as much expertise as their older peers. Overall, the results from these models suggest that knowledge does not increase much once individuals reach their thirties.

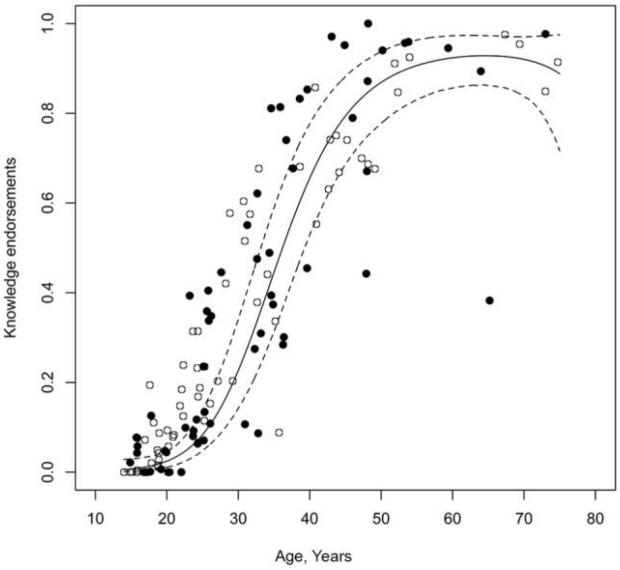

Figure 1. Ratings of ethnobiological knowledge by local peers. The predicted line and 95% confidence intervals are derived from the model estimates reported in table A3, assuming that the rated individuals are female. Filled circles indicate men, and open circles indicate women. The points have been jittered to promote visualization.

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[7] When we allude to the effect of these variables on the response variable, the ratees' fishing ability, we are referencing the structure of the statistical models, not suggesting that there is a clear causal relationship between these variables.

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Table 2. Models of knowledge as a function of demographic variables

Variable	Free listing	Photo identification	Knowledge questions
Empty model:			
DIC	5,776	4,402	9,205
Varying effect:			
Participant	.61774	1.04788	.74006
Species/question	1.37953	2.75977	.7495
Full model:			
DIC	5,746	4,374	9,196
Varying effect:			
Participant	.46543	.76513	.66826
Species/question	1.38541	2.76989	.74935
Intercept	.90520 (.30171)*	2.00511 (.56814)*	1.85122 (.14716)*
Age	.03028 (.00531)*	.04510 (.00795)*	.01091 (.00618)
Age^2	−.00069 (.00035)*	−.00144 (.00049)*	−.00156 (.00040)*
Age^3	.0000004 (.0000099)	.00001 (.00001)	.00003 (.00001)*
Sex (male)	.43828 (.09471)*	.73491 (.12997)*	.35104 (.10819)*
Outlier	. . .	−3.60705 (1.11893)*	. . .

Note. In all models, the participant's age has been centered at 30 years old. Following Langford and Lewis (1998), the model for photo identification includes a binary variable to control for responses by an elderly woman who reported vision problems. These models were estimated via Markov chain Monte Carlo sampling, as implemented in the rstan package (Stan Development Team 2014), as accessed via the glmer2stan package (see McElreath and Koster 2014). We specify diffuse ("flat") priors. After a warm-up of 5,000 iterations, we sampled 10,000 iterations for inference. Coefficients are on the log-odds scale. Asterisks denote parameters for which the 95% credibility interval does not encompass zero. Varying effects are presented as standard deviations of the random intercepts. For comparative purposes, we also include output from an "empty" model to demonstrate how the inclusion of covariates affects model fit and the variance estimates. DIC = deviance information criterion.

Included primarily as a control variable, all models reveal a significant effect of sex. Men perform better on the free listing, photo identification, and knowledge questions.

Correlations among the Knowledge Assessments

Before addressing the relationship between knowledge and fishing ability, we note that individual-level performances on the three knowledge assessments exhibit imperfect correlations (table 3). The strongest correlation ($r = 0.68$) was between the length of participants' free lists and their scores on the photo identification task. The correlations between those respective scores and the performance on the knowledge questions were substantially lower. These results are consistent with other research that typically shows moderate correlations across data-collection formats (Reyes-Garcia et al. 2004). This evidence suggests that the different assessments capture heterogeneous aspects of ethnobiological knowledge and that they merit independent consideration as predictors of fishing ability.

Fishing Ability and Knowledge

Figure 3 depicts the effect of knowledge on fishing ability, controlling for other covariates in the models (see table A4 for model estimates). In general, knowledge has a positive effect on fishing ability, but significant effects are evident in only five of the nine models. All three models that include performance on the photograph identification reveal significant effects of knowledge, and performance on the free listing predicts fishing ability with masks and hooks but not with bows. By contrast, performance on the knowledge questions is an uninformative predictor of fishing ability with all three technologies. In all of the models, physical strength is likewise an uninformative covariate (see table A4).[8]

Discussion

Contrary to conventional perspectives, fishing knowledge peaks relatively early in life, with few discernible age-related differences in knowledge past the age of 30 years. These results conform to a general model in which gains in knowledge parallel the time allocated to related foraging tasks (Ellen 1979; Guest 2002; Reyes-Garcia et al. 2013). As the Mayangna and Miskito learn about fish and fishing strategies, first via observations during childhood and then via experience as participants on fishing trips, they exhibit high levels of knowledge relatively early in life. An embodied capital perspective suggests

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[8] Among men, fishing ability with masks is evidently uncorrelated with ability with bows. That is, the proportion of endorsements that men receive for fishing with masks is not informatively correlated with the proportion of endorsements that they receive for fishing with bows (Pearson's $r = 0.14$; $P = .28$; $n = 65$). These results reflect the apparent specialization by men on either one method or the other (or on neither method). Only 3 of the 65 men in the sample received endorsements from 60% of the informants for both fishing with masks and fishing with bows.

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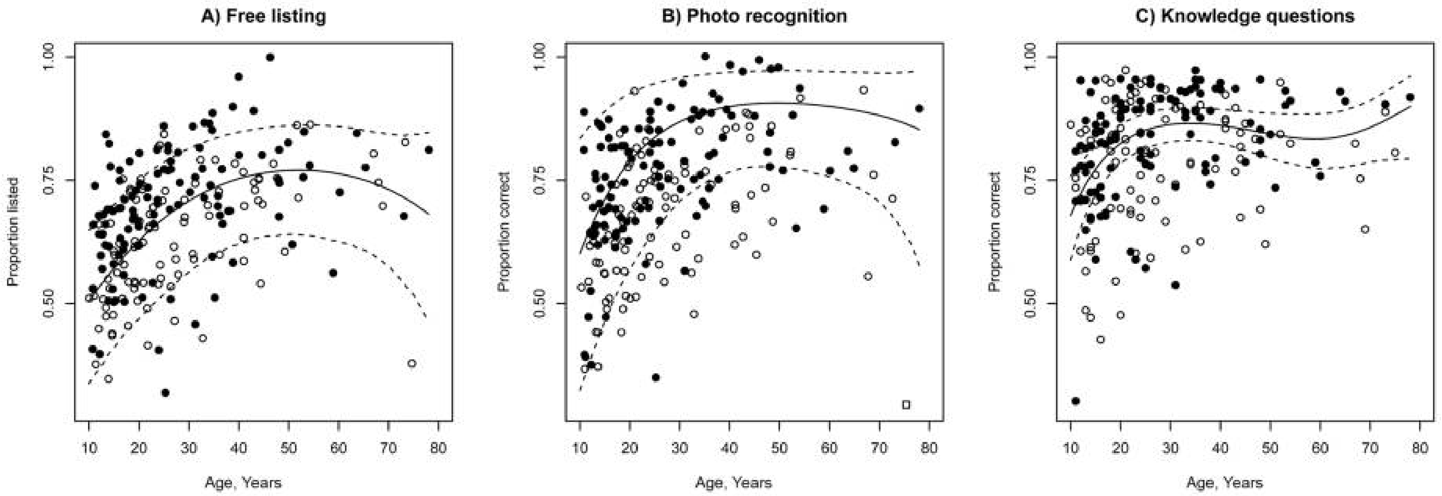

Figure 2. Performance on the knowledge assessments as a function of participant age for free listing (*A*), photo recognition (*B*), and knowledge questions (*C*). The predicted lines and 95% confidence intervals are derived from the corresponding statistical models in table 1, assuming that the participants are female. In all figures, age is plotted on the horizontal axis, filled circles indicate men, and open circles indicate women. The points have been jittered to promote visualization. In *B*, the open square depicts the outlier.

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Table 3. Pearson correlations (95% confidence intervals) between informants' performance on the three knowledge assessments

	Knowledge questions	Free list
Free list	.41 (.29–.51)	. . .
Photo identification	.31 (.19–.43)	.68 (.61–.75)

Note. The knowledge assessments include the number of fish species listed during the free-listing exercise, the number of photographed species that were correctly identified, and the number of questions about fish behavior that were answered correctly.

that hunting knowledge is acquired slowly, plateauing only around age 40, whereas the acquisition of fishing knowledge in Nicaragua seems to be accelerated by the ease and low risks of participating in fishing activities as children and young adults. The extent to which such participation and familiarity seem to facilitate the acquisition of relevant ethnobiological knowledge could help to explain why young adults often match their older peers' efficiency rates in foraging activities other than hunting, such as fishing and tuber extraction (Bliege Bird and Bird 2002; Tucker and Young 2005). In other words, if the acquisition of ethnobiological knowledge among adolescents and adults is largely a function of time allocated to foraging tasks, then further research on age-related variation in knowledge should also address the causes of variation in time allocation.

It is tempting to portray domain knowledge as either a prerequisite to successful foraging or, alternatively, an outcome or by-product of foraging experience. In practice, the relationship between learning and experience is likely to be recursive as knowledge and skill increase concurrently. Irrespective of the temporal dynamics, a straightforward prediction is that ethno-

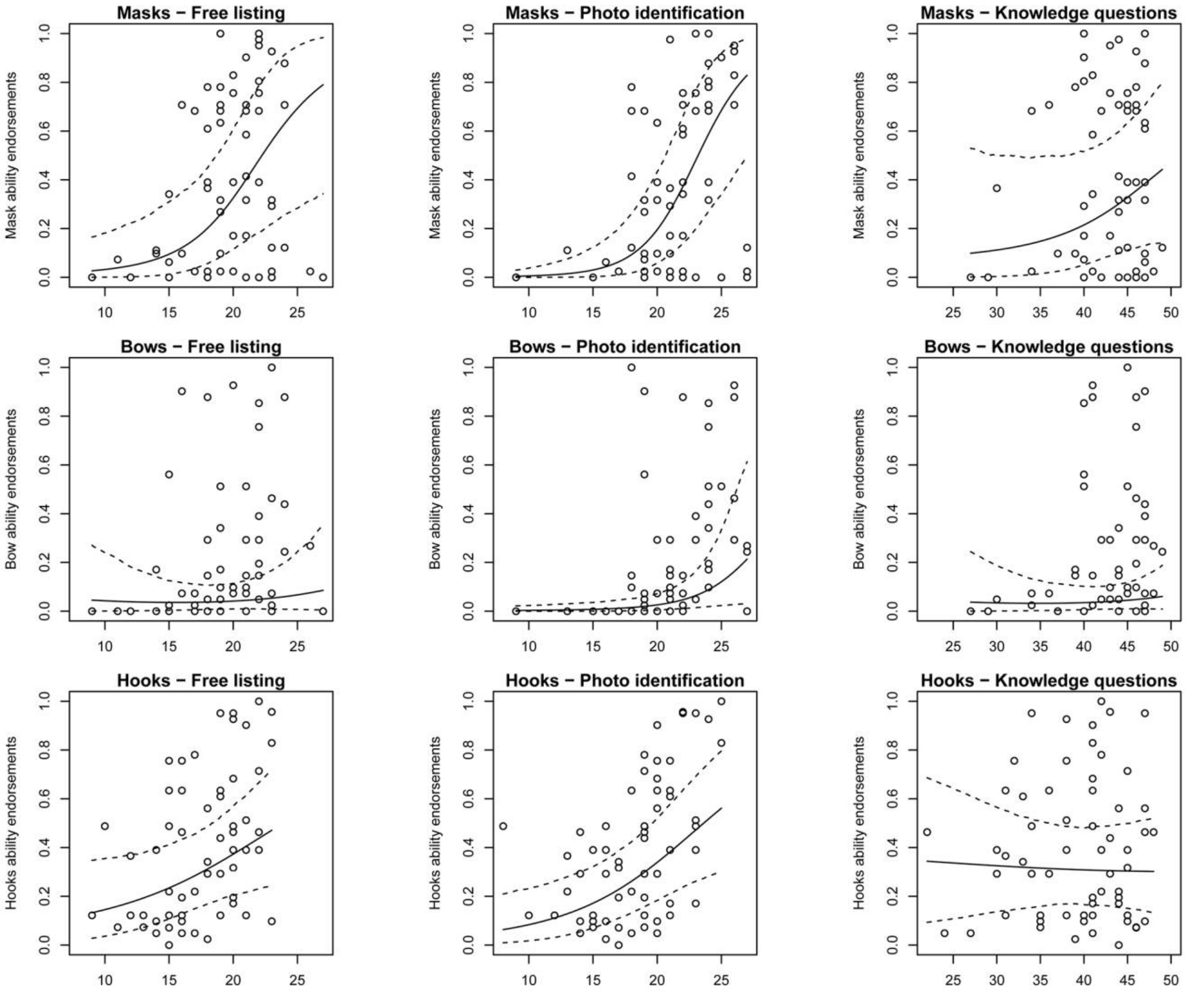

Figure 3. Fishing ability as a function of performance on three knowledge assessments. Ability ratings for masks and bows are based on informants' ratings of male residents, whereas ability ratings for hooks are based on ratings of female residents. All model predictions and 95% confidence intervals are derived from the corresponding statistical models in table A4. These predictions assume an age of 30 years and average strength for the rated individuals.

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biological knowledge and foraging ability are positively correlated. Previous research has failed to reveal such correlations (Kightley et al. 2013), whereas the results of this study show that fishing ability is predicted by knowledge, particularly by performance on the photograph identification task. In other words, talented fishers are more likely to match the images and names of the depicted fish species. Surprisingly, although the length of individuals' free lists was also predictive of fishing ability in two analyses (masks and hooks), the performance on the knowledge questions was an uninformative predictor of fishing ability.

This latter result is unexpected, because research on hunting success indicates that the challenge of locating prey is the primary source of age-related delays in peak return rates (Gurven et al. 2006). We therefore designed the questions to address knowledge of fish behavior that would plausibly help fishers make effective decisions about where, when, and how to fish. Because the acquisition of this knowledge seems to require substantial firsthand experience with fish and their habitats, we expected that performance on the knowledge questions would show both greater age-related delays and stronger correlations with fishing ability. Neither of these expectations was supported, because the presumably easier tasks of naming and identifying fish were not mastered at younger ages than were the fish questions, but they were nevertheless more predictive of fishing ability.

Such results speak to the methodological challenges of evaluating age-related variation in ethnobiological knowledge and its contribution to foraging performance. This research in Nicaragua incorporated three different assessments of knowledge that have been frequently used by ethnobiological scholars as indicators of individual-level knowledge (Reyes-Garcia et al. 2007). In this study, however, these measures provide contrasting perspectives on both knowledge across the lifespan and the ways in which knowledge underlies foraging skill. It is possible that these methods are inadequate for characterizing the practical knowledge needed by successful foragers to locate, stalk, and capture prey. Moreover, the results of this analysis suggest that neither the measurements of ethnobiological knowledge (i.e., embodied capital) nor strength (i.e., physical capital) are conclusive predictors of fishing ability. Human ecologists who seek to pinpoint the proximate determinants of variation in foraging ability would benefit from methodological alternatives that more directly reflect the specific expertise and skills that are required for different subsistence activities.

Conclusion

Despite widespread assumptions that elders are authorities of ethnobiological knowledge in small-scale societies, this study demonstrates that younger adults generally match the knowledge of their older peers. These results do not discount the aforementioned possibility that acculturation and economic change in some settings can lead to the loss of traditional ecological knowledge among younger generations, thus casting elders as the only surviving possessors of detailed knowledge (Turner et al. 2000). Such considerations, however, imply a more general conceptual model, where the acquisition of ecological knowledge stems primarily from experience in relevant domains, not explicitly from age-related changes. In other words, we expect disproportionate consolidation of ethnobiological knowledge among the elder generations only when younger individuals allocate little time to activities that promote the accumulation of knowledge via experience or social learning.

Among the Mayangna and Miskito, the distribution of knowledge about fish behavior conforms to this conceptual model. An analysis of time allocation to fishing at this study site suggests that children spend as much time fishing as their adolescent and adult peers (Koster 2007). Combined with opportunities for social learning, particularly from parents, children receive considerable exposure to fishing activities. Upon reaching adulthood, their fishing activities become more varied, including nocturnal trips and long-distance fishing expeditions. For men, adolescence and adulthood also entail opportunities to develop proficiency with technologies like scuba masks and bows, which become specializations for some men. This variability in fishing experience and activities evidently results in a distribution of knowledge that includes the approximation of peak knowledge by early adulthood, moderately greater knowledge among male fishers than female fishers, and marginally superior knowledge among individuals who are dedicated and capable fishing specialists. These results therefore suggest a model of humans as flexible learners, acquiring ecological knowledge relatively swiftly as needs and opportunities arise, limited primarily by exposure and experience, and otherwise largely independent of age-related constraints.

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CA + Supplement A from Koster et al., "Wisdom of the Elders?" (Current Anthropology, vol. 57, no. 1, p. 113)

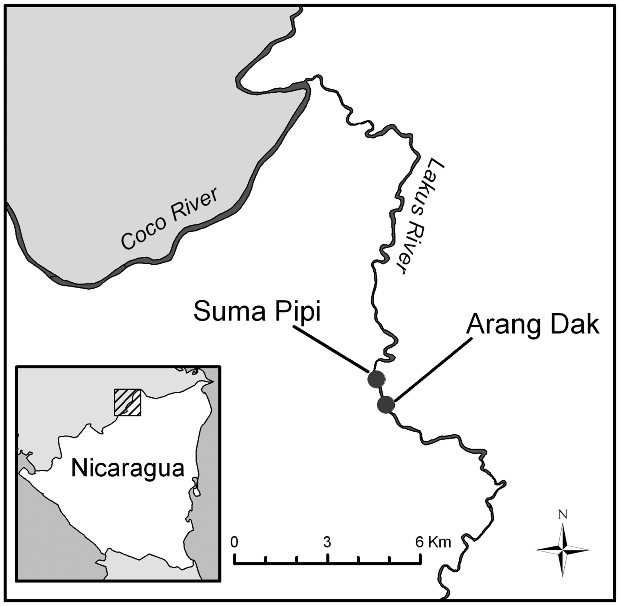

Figure A1. Location of the study site.

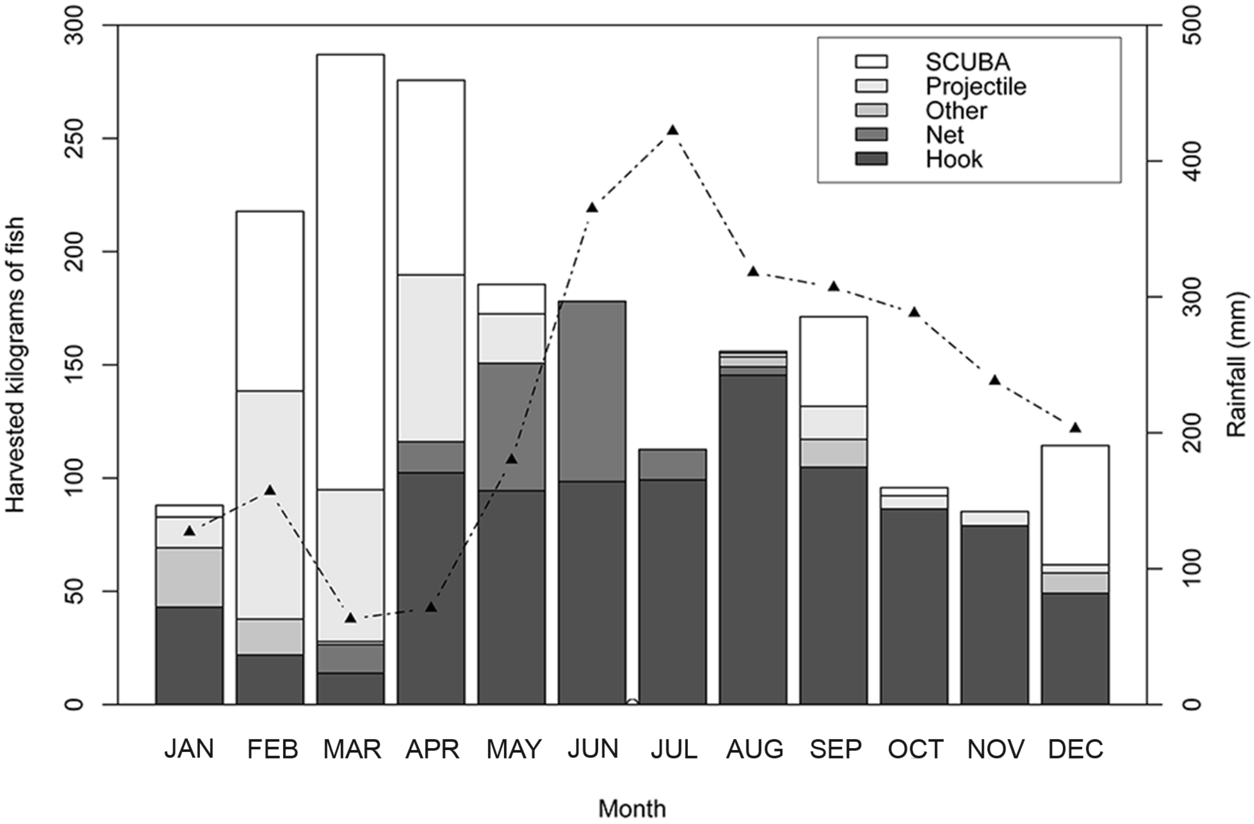

Figure A2. Harvested kilograms of fish by month and technology in Arang Dak during a yearlong study period in 2004–2005. The "Other" category refers to fish captured by hand, with machetes, with lures, or by traditional poisoning techniques. The triangles (and dashed line) depict average monthly rainfall as measured over a 10-year period at a nearby weather station.

Table A1. Fish species presented to participants and included in the analysis of ethnobiological knowledge

Scientific name	Miskito	Mayangna	Spanish
Agnostomus monticola	Walpa	Mûbis	Tepemechín
Archocentrus nigrofasciatus	Kirhsa	Kirhsa	Carate
Astatheros alfari	Truh	Turu	Pinto
Astatheros longimanus	Klanki	Taras	Mojarra
Astyanax aeneus	Bilim	Bilam	Sardina
Atherinella sardina	Plais yari	Plais naini	Sardina
Awaous banana	Bahya	Bahya	Guavina
Brycon guatemalensis	Srik	Sirik	Sabalete
Bryconamericus scleroparius	Muhpating	Mûpating	Sardina panza roja
Centropomus species	Kalwa	Mûsiwa	Róbalo mediano
Centropomus undecimalis	Mupih	Mûpih	Róbalo
Eugerres plumieri	Trisu	Tirisu	Palometa
Gobiomorus dormitor	Susu maya	Muaka	Cabo de hacha
Gymnotus cylindricus	Swiuri	Lalat	Anguila
Joturus pichardi	Iskia	Mumulukus	Cuyamel
Megalops atlanticus	Tapam	Tâpam	Sábalo real
Neetroplus nematopus	Ir tara	Kîtus	Unknown*
Oreochromis species	Krahna	Kisaris	Carpa
Parachromis dovii	Sahsin	Mûlalah	Guapote
Parachromis managuensis	Masmas	Masmas	Guapote podrido
Phallichthys species	Pupu	Tungkih	Puna
Poecilia species	Pupu wainkika	Subaturuk	Chaluca macho
Pomadasys crocro	Drumar	Anghangh	Roncador
Rhamdia guatemalensis	Batsi	Susum	Barbudo
Roeboides bouchellei	Sakahka	Mâbai	Sardina de sol
Synbranchus marmoratus	Suara	Mûsa kukuni	Anguila
Vieja maculicauda	Tuba	Pahwa	Tuba

Note. Adapted from Gros and Miguel (2010). This list excludes *Anguilla rostrata* and a few purported variants that have unique names in the indigenous languages but that are classified by biologists as one of the species listed in the table. Asterisks denote species for which the Spanish names are unknown.

Table A2. Output of consensus analysis of binary ratings of traits embodied by adult residents of Arang Dak

Evaluated trait	No. of informants	First eigenvalue	Second eigenvalue	Average competency (±SD)
Mens' ethnobiological knowledge	17	7.92	.77	.67 (.14)
Womens' ethnobiological knowledge	17	7.75	.89	.67 (.20)
Mens' mask fishing ability	41	19.08	1.54	.67 (.13)
Mens' bow fishing ability	41	14.38	1.48	.58 (.12)
Womens' hook fishing ability	41	13.11	1.71	.55 (.13)

Note. The ratings were elicited from a sample of village residents. Consensus among the informants is inferred when the ratio of the first eigenvalue to the second eigenvalue is greater than three to one, a threshold that is surpassed for all five evaluated traits. See Koster (2010) for additional details about consensus analysis. SD = standard deviation.

Table A3. Model of ethnobiological knowledge as a function of ratees' age and sex

Parameter	Estimate (±SD)
Varying effect: informant	1.833548
Varying effect: ratee	.902952
Intercept	−10.463492 (3.185840)*
Ratee age	.388822 (.249455)
Ratee age^2	−.002601 (.006037)
Ratee age^3	−.000004 (.000045)
Ratee sex (male)	.046384 (.135918)

Note. The ratings are based on binary ratings by residents of Arang Dak (see "Methods" for details). In contrast to the models in table 1, ages have not been centered. These models were estimated via Markov chain Monte Carlo sampling, as implemented in the rstan package (Stan Development Team 2014), as accessed via the glmer2stan package (McElreath and Koster 2014). We specify diffuse ("flat") priors. After a warm-up of 5,000 iterations, we sampled 10,000 iterations for inference. Coefficients are on the log-odds scale. Asterisks denote parameters for which the 95% credibility interval does not encompass zero. Varying effects are presented as standard deviations (SDs) of the random intercepts. Model predictions are depicted in figure 1*A*.

Table A4. Models of fishing ability as evaluated by residents of Arang Dak

Fishing method, variable	Free listing	Photo identification	Knowledge questions
Masks			
DIC	1,701	1,700	1,700
Varying effect: rater	1.09319	1.09306	1.0901
Varying effect: ratee	2.77044	2.58252	2.93532
Intercept	−10.44973 (3.35631)*	−14.12034 (3.50196)*	−11.06895 (5.16629)*
Age	−.04582 (.06751)	−.07255 (.06174)	.00250 (.07115)
Age^2	.00264 (.00476)	.00132 (.00482)	.00395 (.00526)
Age^3	−.00035 (.00024)	−.00025 (.00023)	−.00045 (.00027)
Strength	3.72094 (3.57646)	4.23568 (3.21536)	6.27363 (3.78379)
Free listed fish	.35320 (.14024)*	. . .	. . .
Photo identification	. . .	.48166 (.12688)*	. . .
Knowledge questions	. . .	. . .	.13124 (.09424)
Bows			
DIC	1,421	1,420	1,421
Varying effect: rater	1.22296	1.21596	1.22046
Varying effect: ratee	2.64526	2.51604	2.62031
Intercept	−7.65525 (3.51642)*	−12.63278 (3.99569)*	−9.13884 (4.75252)*
Age	.12993 (.04692)*	.09926 (.04420)*	.12961 (.04372)*
Age^2	.00502 (.00441)	.00483 (.00423)	.00529 (.00437)
Age^3	−.00013 (.00011)	−.00011 (.00010)	−.00014 (.00011)
Strength	4.19467 (3.69602)	3.10707 (3.40648)	4.58232 (3.50103)
Free listed fish	.06936 (.13776)	. . .	. . .
Photo identification	. . .	.33073 (.14532)*	. . .
Knowledge questions	. . .	. . .	.05978 (.09064)
Hooks			
DIC	2,162	2,162	2,163
Varying effect: rater	1.24904	1.25179	1.24571
Varying effect: ratee	1.56359	1.49938	1.61679
Intercept	−5.04896 (1.84504)*	−6.39878 (1.83840)*	−2.40816 (2.07994)
Age	.10611 (.02511)*	.09006 (.02529)*	.12766 (.02400)*
Age^2	.00147 (.00238)	.00197 (.00225)	.00122 (.00237)
Age^3	−.00005 (.00006)	−.00005 (.00005)	−.00006 (.00006)
Strength	2.58069 (1.89584)	2.81712 (1.76191)	2.70563 (1.88780)
Free listed fish	.13904 (.07027)*	. . .	. . .
Photo identification	. . .	.19107 (.06655)*	. . .
Knowledge questions	. . .	. . .	−.00598 (.03770)

Note. See "Methods" for details. In all models, the ratees' age has been centered at 30 years old. These models were estimated via Markov chain Monte Carlo sampling, as implemented in the rstan package (Stan Development Team 2014), as accessed via the glmer2stan package (see McElreath and Koster 2014). We specify diffuse ("flat") priors. After a warm-up of 5,000 iterations, we sampled 10,000 iterations for inference. Coefficients are on the log-odds scale. Asterisks denote parameters for which the 95% credibility interval does not encompass zero. Varying effects are presented as standard deviations (SDs) of the random intercepts. DIC = deviance information criterion.