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Fishing in the Amazonian forest: a gendered social network puzzle

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Abstract

We employ social network analysis (SNA) to describe the structure of subsistence fishing social networks and to explore the relation between fishers' emic perceptions of fishing expertise and their position in networks. Participant observation and quantitative methods were employed among the Tsimane' Amerindians of the Bolivian Amazonia. A multiple regression quadratic assignment procedure was used to explore the extent to which gender, kinship, and age homophilies influence the formation of fishing networks. Logistic regressions were performed to determine the association between the fishers' expertise, their socio-demographic identities, and network centrality. We found that fishing networks are gendered and that there is a positive association between fishers' expertise and centrality in networks, an association that is more striking for women than for men. We propose that a social network perspective broadens understanding of the relations that shape the intracultural distribution of fishing expertise as well as natural resource access and use.

Keywords

Gender relations; fishing expertise; fishing techniques; perceptions; Social Network Analysis; status; Tsimane' Amerindians

Introduction

Understanding the intracultural variation in ethnobiological knowledge, practices and expertise has been a research aim of anthropologists, human ecologists, and ethnobiologists for more than three decades. Researchers have mainly explored how individuals' socio-

demographic characteristics shape the distribution of knowledge and practices, where individual identities are defined, among others, by age, sex, kinship, formal education, or participation in the market economy (Boster and Johnson 1989; Reyes-García et al. 2005; McCarter and Gavin 2015).

Researchers have also argued that situational and relational factors (i.e. socially structured opportunities to learn, access to resources and technologies) are important to understanding the uneven distribution of cultural knowledge (Boster 1985, 1986), as intracultural variation in knowledge and expertise cannot be fully understood without considering the social world in which people learn and interact. However, much research exploring intracultural knowledge variation as a function of socio-demographic identities has largely overlooked the importance of social relations and social learning. For example, gender relations, or the cultural and power relations between women and men, strongly affect the division of labor and natural resource access, use, and knowledge (Rocheleau et al. 1996; Howard 2003; Sunderland et al. 2014) yet most research on intracultural knowledge variation continues to focus on sex¹ as a dichotomous variable, without considering gender as a relational category.

In this study, we empirically assess how social relations, specifically gender relations, shape intracultural variation in emic perceptions of fishing expertise in a small-scale society, the Tsimane'. In contrast with previous research, we focus on explaining gendered practices and expertise in the context of the social structure within which individuals are embedded, for what we employ social network analysis.

Access to information through social networks

In small-scale societies, cultural knowledge is mainly acquired through social learning, including observation, imitation, and conversation during daily activities, in a continual lifelong process (Ohgarni and Berkes 1997; Reyes-García et al. 2016). Knowledge is considered to be a major social asset (Acheson 1981; Turner et al. 2014) - a resource that is acquired, transmitted, and shared through social relations. Within each particular political-economic and cultural context, individuals in privileged social positions more readily access and mobilize knowledge through social learning networks (Ribot and Peluso 2003), leading not only to intracultural variation but also to social hierarchies in related practices and expertise.

Gender is a social identity that confers status and power, where women frequently have less power and lower social status compared with men, although they gain status and prestige within their own (mainly female) social networks (Howard 2003). Gender relations condition how women and men interact with people of the same and opposite sex as well as with the biophysical environment, and are embedded in cosmologies, beliefs, and norms about appropriate behaviors and social power accorded to each sex (Brightman 1996;

Notes

¹Drawing upon Pfeiffer and Butz (2005), we employ a binary view of the terms sex and gender, because a thorough treatment of the multidimensional gender continuum is beyond the scope of our research. We use the terms sex to refer to biological differences between women and men – and the term gender to refer to constructed sociocultural relations and differences between the sexes within a particular culture. We acknowledge the existence of multiple non-dichotomous identities that much more accurately reflect the diversity of human genders.

Howard 2003). Thus, women and men are exposed to diverse environments, skills, and experiences, which help to explain the gendered nature of ethnobiological knowledge and expertise (Pfeiffer and Butz 2005).

Women's and men's social status also differs in relation to the types of social and cultural capital they can access (e.g., domains of expertise and networks). Food procurement and provision have important social significance and symbolism and are means to achieve status (Wiessner and Schiefenhövel 1996). For example, different fishing strategies entail different sets of knowledge and skills, so the ways in which different social groups achieve status is likely to be related to their expertise (see Bird 2007). Heterogeneity in fisher's strategies implies that different fishers have access to different information, which in turn conditions their expertise.

If we acknowledge the significance of social relations in shaping knowledge and expertise intracultural variation, then the issue becomes how to assess those relations. Social Network Analysis (SNA) provides a means to theoretically explain and empirically quantify the structural qualities of social networks to reveal the patterning of positions and connections of the individuals within them (Borgatti et al. 2009). SNA is employed to determine how the connections between individuals in a social structure affect their abilities to access information or resources. Previous research shows that people who have more centrality in the network (are more connected with other people) have greater opportunities to accumulate and control information, which may increase their influence (Burt 1998; 2004). To some extent, an individual's position in social networks defines their ability to perform in the social structure in which the person is embedded, including access to information and resources.

Recently, researchers have begun to use SNA to gain a more holistic view of how human and natural systems interact (Johnson and Griffith 2010; Crona et al. 2011). This body of research has shown the significance of social networks in information flows within and between communities. Sharing information and resources through social networks is largely based on trust and occurs between kin, friends, and acquaintances (Crona and Bodin 2006; Ramirez-Sanchez and Pikerton 2009; Salpeteur et al. 2016). In that sense, an important aspect of social networks research is the principle of *homophily*, or the tendency of individuals to associate with similar others. *Homophily* in social networks has been suggested as a useful concept for the study of the social relations that influence, create, and maintain gender differences (Smith-Lovin and McPherson 1993; McPherson et al. 2001). For example, in a study among the Tsimane', Díaz-Reviriego et al. (2016) found that most exchanges of medicinal knowledge and plant material occur within female networks, suggesting both that women maintain greater plant richness in homegardens than men but also networks are gendered and present homophily. Further research also suggests that the position of an individual in the social network at least partially predicts his/her knowledge or expertise, where people with higher centrality tend to hold more knowledge than less central people (Hopkins 2011; Calvet-Mir et al. 2012). Indeed, location in a social network provides both possibilities and constraints for accessing resources and knowledge through other people in the network given that, in each particular situation, networks either support or constrain access to people.

Drawing on these insights, and based in the assumption that people fishing together share knowledge, here we apply SNA to 1) describe the structure of fishing social networks among the Tsimane' of Amazonian Bolivia and 2) explore the relation between emic perceptions of fishing expertise and fisher's positions in the network. This in turn allows us to explore whether people's choice of fishing partners is related to emic perceptions of fisher's expertise. Our guiding research question is: How does the social network in which a fisher is embedded relate to emic perception of his/her fishing expertise? We hypothesize that (H1) emic perceptions of a fisher's expertise is positively associated with that fisher's position in the network, and (H2) men hold more central positions in fishing networks than women because of their differentiated gender roles, responsibilities, and social expectations related with fishing.

The Tsimane'

There are some 12,000 Tsimane' people living in 125 villages located primarily along the Maniqui and Quikibey rivers in the department of Beni, Bolivia (Reyes-García et al. 2014). We conducted research in the Tsimane' Indigenous Territory, which includes 55 Tsimane' villages and lies between the eastern foothills of the Andes and the flooded pampas of Moxos (Guèze et al. 2013). San Borja is the primary town of the area, where the *Gran Consejo Tsimane'* (the Tsimane's political organization) is based. Tsimane' villages around San Borja have easy road access to state schools and markets, whereas the more remote villages only have access to the town by river and do not always have access to schools.

The Tsimane' depend mostly on subsistence fishing, hunting, gathering, and swidden agriculture. Their primary sources of income are sales of palm thatch, rice, and, plantain. While some Tsimane' men work as wage laborers for local loggers and ranchers, Tsimane' society continues to be highly self-sufficient.

Tsimane' social organization is largely kinship based (Daillant 2003) and gender relations are one of the central axes of social life and the division of labor. In villages, households are scattered geographically according to clan groups, and social life is embedded in relations revolving around subsistence activities, particularly procuring and sharing food and drink, which strengthen cultural values of solidarity and reciprocity. Boys and girls learn sex-specific subsistence tasks based on observation and direct experience and are acquired by the end of adolescence (Reyes-García et al. 2009). Ethnographers have described Tsimane' gender roles as complementary and as a means of nurturing appropriate and desirable sociality (Ellis 1996). The products of women and men's labor enter different distribution spheres, which define their relative identity and status. The production and distribution of sweet manioc beer is a female domain, and its consumption is an important form of sociality; inter-household food distribution depends on men's capacity to provide fish and meat (Ellis 1996), which confers status on men.

Fishing is practiced for subsistence rather than for income generation and occurs year round, with a peak in the dry season (August to November) when waters are calmer and fish capture is easier. The Tsimane' fish individually or in groups in different fishing settings

such as rivers, streams and ponds, and also employ various traditional (e.g. bow and arrow, plant poisons) and modern (e.g. hook and line, nets) techniques (Pérez-Limache 2001)

Methods

The first and second authors lived in two villages on the Maniqui River where they conducted fieldwork between January 2012 and November 2013. Before beginning, informed consent and permission to live in the villages were obtained both from villagers and from the *Gran Consejo Tsimane'*. One of the villages is in the middle of the Maniqui River (n=37 households), a day's canoe trip from San Borja. The other village (n=22 households) is at the river's source, a three-day canoe trip from San Borja (see Figure 1). All women and men (16 years of age) were invited to participate in the research and equally encouraged to participate. In the mid-river village, men and women were represented nearly equally (n=89, women=43, men=46) while fewer women (n=25) than men (n=33, total n=58) were represented in the upriver village. The participation rate was above 90% in both villages; therefore we consider that the sample captured all potential variability in fishing interactions.

We employed a mixed methods approach that combined participant observation with quantitative data. We shared daily life with the Tsimane', which allowed us to gain interviewees' trust and explore social interactions. Participant observation of fishing expeditions occurred throughout the fieldwork period and helped to contextualize the research and gain a broad overview of the social relations among fishers. We helped set fishing nets, caught live bait, gathered plants used for poison, cleaned and prepared fish, and ate with fishers. This allowed us to observe the distribution of tasks by technique and ultimately interpret our quantitative results. Additional data on informant's age, kinship, and schooling were collected in a census. Data on income were collected through quarterly individual interviews and data on wealth (the monetary equivalent of material possessions that the Tsimane' consider to be signs of modern wealth, i.e. fishing nets, chainsaws, radios, etc.) were collected twice at the beginning and at the end of the study.

Characterizing and analyzing fishing networks

We use a whole network approach that focuses on the interactions of actors within a bounded space (the village) and aims at collecting data about each member of the bounded group and their interactions with all other members. Data on fishing networks were collected over a 15-month period (July 2012-October 2013), allowing us to capture seasonal variation in network composition attributable to the use of different techniques throughout the year. About once every fortnight, on a day chosen at random, we visited each household in the village (for a total of 27 visits/household) and asked all informants about their fishing trips during the two days before the survey. Data collected included fishing location, technique used, and names of accompanying people (adults and children).

To describe fishing networks' structure, we first aggregated the longitudinal data to produce a network that included all fishing events in a village. We then explored the network structure for the most common fishing techniques: bow and arrow, fish poison, hook and line, and net. Instead of assuming that informants' reports on people accompanying fishing

expeditions were always reciprocal (symmetric or undirected data) we used the actual nominations (directed data) that reveal the directionality of connections among fishers. Actual nominations are affected by recall bias, which might reflect perceptions of hierarchical positions and frequency of interaction (Brewer 2001). We calculated five structural measures at a network level for the two villages, which provide insights on the underlying social learning processes and the cohesiveness among different groups of fishers (Crona et al. 2011): 1) *size*, or number of fishers (nodes) involved in each network; 2) *number of components*, or sub-networks, in which individuals are directly or indirectly linked, since the existence of subgroups can have implications for the flow of information and the development of fishing expertise (Crona and Bodin 2006); 3) *density*, or proportion of existing connections in the network relative to the maximum possible number of connections (from 0 to 1), since high density can benefit the spread of information through increased access to information or, in this case, to expert fishers; 4) *mean indegree*, or the average of incoming nominations that people in the network received as fishing partners (Costenbader and Valente 2003), and 5) *reciprocity*, a measure of the tendency for every pair of nodes (fishers) to have mutual connections (Wasserman and Faust 1994), because the extent to which ties are reciprocal may indicate hierarchies.

In order to identify fishers' structural positions, we used the same data to generate two variables that capture a person's centrality in the network. *Indegree*, or number of times a person is reported as a fishing partner, provides an estimate of the extent to which others choose an individual as a fishing partner, as those who are seeking to learn tend to connect to others that they consider experts (Henrich and Broesch 2011). *Betweenness*, or the proportion of times that a person lies on the shortest path between each pair of alters (i.e. other fishers) with whom the person is directly or indirectly connected (Freeman 1979). Betweenness captures the social brokerage capacity of a fisher or the tendency to link other fishers who would otherwise not be linked, providing an indication of the general capacity to steer information flows or resources in the network.

To explore homophily in fishing connections, we tested the matrix of fishing dyadic ties (pairs of people fishing together) according to clan membership and sex. First, we used emic kinship classifications to determine each person's clan membership. We then generated a matrix with all reported dyads. We tested the frequency of inter- and intra- clan dyads using a covariate (*same_clan*) assigned the value 1 if, for each dyad, people were from the same clan, or 0 otherwise. Other matrices were generated that captured whether people in the dyads: 1) were of the same sex (*same_sex*), and 2) shared the same life cycle stage (adults vs. children) (*comp_adult*). We tested whether dyadic fishing interactions were greater than expected by chance within the same clan, sex and life cycle stage with a Multiple Regression Quadratic Assignment Procedure (MRQAP) (Dekker et al. 2007).

Assessing emic perceptions of fisher's expertise

We conducted a peer-rating exercise to develop a proxy for the emic perception of fisher's expertise. Specifically, we followed Reyes-García et al. 2016 and, in each village, first selected people who would rate other villagers' fishing expertise (evaluators). To minimize bias generated by the evaluator–subject relation, we diversified the group of people

evaluating each fisher. We grouped households into groups based on kinship and geographic proximity. We then purposely sampled one or two household heads in each of those affinity groups to form groups of six evaluators. Each group contained three men and three women of different ages. Then, we grouped the names of all adults in the village in lists containing 20 randomly chosen names, and each group of evaluators was assigned one of the lists. We interviewed each evaluator privately. We first asked, “Who are the best fishers in this village?” and assigned four points to the people mentioned. We then read the 20 names on the list and, for each, asked informants to assess whether the person was good at fishing (three points), average at fishing (two points), not specialized in fishing (one point), or didn’t fish (0 points). If one or more informants did not evaluate someone in the list, we asked another informant to do so, so that each person on the list had a total of six scores. Our measure of a person’s fishing expertise is the average rate given by the six evaluators.

Testing the relation between fishers’ expertise and their positions in the fishing network

To examine the associations between fisher’s peer rated expertise and centrality in networks (H1) and sex (H2), we ran a set of multivariate Ordinary Least Square (OLS) regressions. In a first model, we explored the association between fishers’ ratings, centrality in fishing networks, and sex, controlling for age and schooling. In a second model, we added fishing related variables (e.g. number of adults joining in fishing expeditions or company) and the person’s level of integration into the market economy (e.g. income, wealth). We also added a term capturing the interaction between the centrality measures and sex, so to examine whether the effect of the centrality measures on fishing ratings (outcome variable) differs by sex. As we can only include a limited number of controls in each model, the two regressions models reported here only include the explanatory variables showing an association with the outcome variable. Since the household is the primary unit where fishing competences are shared, we used clustered robust standard errors by household for all of the models. The option “cluster” relaxes the assumption that observations from people belonging to the same household are independent.

Social network data were analyzed with UCINET6-Netdraw (Borgatti et al. 2002) and network visualizations were designed with Gephi (Bastian et al. 2009) using the Force Atlas algorithm. Stata 13 was used for statistical analysis.

Contemporary Tsimane’ fishing strategies

In the mid-river village, 16% of women reported participating in fishing expeditions in the two days prior to the survey compared to nine percent in the upriver village. In both villages, men reported fishing more often than women (33% mid-river vs. 62 % upriver). Men and women fish mainly in the river (women: 42% mid-river and 76% upriver; men: 49% mid-river and 85% upriver), although women living in the mid-river village regularly fish in streams (46%).

Women’s and men’s frequency of use of different fishing techniques differed. Only men fish with bow and arrow (10% of the expeditions in the mid-river village and 21% in the upriver village) and craft these fishing implements. Bow and arrow fishing occurs both day and

night in rivers, streams, and ponds, where men usually fish alone or in groups of two to three along the banks or from canoes.

Men, women and children fish year-round with hook and line in rivers and streams, either individually or in small groups. Hook and line are frequently used in both villages (women: 38% mid-river and 55% upriver; men: 27% mid-river and 32% upriver). The size of the hook depends on the size of the target fish. Men's hooks are larger than women's and children's, allowing them to capture larger fish.

Men mainly fish with nets (44% mid-river and 39% upriver) in streams, ponds, or in rivers when the water level is low, and when fish migrate upstream to spawn. Nets are obtained from merchants and are usually owned by men. At least two people are needed to set up the nets, so it is common to see groups of men and boys net fishing together.

The Tsimane' also carry out collective fishing expeditions that can involve all members of a household or several households from a village. During these events, shallow areas of rivers or streams are temporarily blocked and ichthyotoxic plants are placed upstream so that toxins diffuse downstream, paralyzing fish and making them float so they are easier to capture. Fish poisons are mostly used in the dry season when the current is slower and yields are higher. Amerindians have practiced this technique for centuries (Carod-Artal 2012).

The division of tasks in fish poisoning is strongly gendered. Women and children typically gather *chito* from homegardens and agricultural plots (*Tephrosia vogelii* or *T. toxica*) and prepare the poison. Men collect a tree resin known as *conoifoto* (*Hura crepitans*) and a vine, *vashi* (*Serjania tenuifolia*), which are found in the forest or close to rivers and streams. Men and women together block the water flow and men distribute the poison. As the fish begin to surface, men and young boys use bows and arrows to capture them, often from canoes. Women and young girls use knives, machetes, and their hands to catch fish from the riverbanks or while standing in shallow water. Elderly people and women with infants stay on shore to clean and cook some of the fish immediately after capture. Part of the catch is consumed on the spot, but large amounts are taken back to the village where some are redistributed. In the two study villages, women practice fish poisoning (48% mid-river and 37% upriver village) more than men (18% mid-river and 7% upriver).

Findings

Structure of fishing networks

Overall, the studied networks have low densities (Table 1, column 4) and are fragmented, i.e. have several sub-networks corresponding to different groups of fishers. The number of fishers (or 'nodes') (total = 115) varies greatly in the mid-river village sub-networks (9 to 66). Node composition in the upriver village (total = 69) is smaller (23 to 47) (Table 1). In the upriver village, there was greater reciprocity, meaning that people named each other as fishing partners, and a higher mean indegree, meaning that people nominated more people in their fishing expeditions (Table 1, columns 5 and 6).

The analyses of pairs of people fishing together (dyads) suggest that fishing interactions are shaped by kinship, age stage, and gender relations. Results of the MRQAP test for dyadic interactions show that ties between fishers (i.e. the selection of fishing partners) were greater than expected by chance among fishers of the same clan (mid-river: $\text{coef} = 0.519$; $p < 0.001$; upriver: $\text{coef} = 0.395$; $p < 0.001$), same life stage or adults (mid-river: $\text{coef} = 0.226$; $p < 0.001$; upriver: $\text{coef} = 0.204$; $p < 0.001$), and gender (mid-river: $\text{coef} = 0.16$; $p < 0.001$; upriver: $\text{coef} = 0.218$; $p < 0.001$). This means that, for their fishing expeditions, adults tend to select partners that are of their same clan, sex, and generally adults.

Fishers' rating and centrality in the fishing network

Women's average rating for fishing expertise was considerably lower than men's (1.19 vs. 2.28) (Table 2). Average indegree was also lower for women, meaning that, on average, men were more often chosen as fishing partners than women. The average value of the variable betweenness was also considerably lower for women, although, this variable displays greater variation for men (Table 2), suggesting that some men have a much stronger connecting role than others, especially in the upriver village (Figure 2, a1 and b1).

When exploring the link between a person's fishing rating and her centrality in the fishing network we found that a person's indegree is not associated with her fishing rating (Table 3, Model [A]). However, a person's betweenness is positively associated in a statistically significant way with the person's fishing rating (Table 3, Model [B]; $\text{coef} = 0.002$; $p = 0.003$). We also found that being male is associated with higher ratings. Moreover, in Model [B] there is a statistically significant association between the interaction term (the sex of a person and her betweenness in the network) and fishing ratings. Specifically, people with more betweenness have higher ratings and this relation is more striking for women than for men.

Discussion

We applied SNA 1) to describe the structure of social networks in fishing expeditions among the Tsimane' of Amazonian Bolivia, and 2) to explore the relation between emic perceptions of fishing expertise and fishers' positions in the network. We organize the discussion around these two main research aims.

Structure of Tsimane' fishing networks

In both Tsimane' villages, fishing networks display low density of interactions and high fragmentation (fishers are joined in different disconnected groups). This low density finding fits well with our ethnographic research, where the Tsimane' were found to mostly fish alone or in small groups, often adopting different fishing strategies. As women and men use different techniques and choose different ecological settings and partners for their expeditions, it is not surprising that these groups present low density of interactions.

While gendered strategies for subsistence activities have been previously reported (see e.g. Koster et al. 2016 for hunting), the network perspective used here allows us to disentangle variations in social organization. Specifically, SNA allows us to understand the role of gender relations in defining who has access to which knowledge and expertise, and the

cultural frame of reference regarding who it is that people chose to learn from (or with whom they fish). For example, the Tsimane' believe that only men should craft and use bows and arrows and that women cannot be involved with fish poisons while pregnant, since this reduces the poisons' effectiveness (Chicchón 1992). These gendered norms and beliefs shape women's access, preferences, and skills in relation to fishing techniques and their status as fishers, explaining the dissimilar perceived abilities of women and men with regard to fishing. Fishers' socio-demographic identities and especially their sex contribute to the establishment of fishing routines, which in turn shape fishing networks. Such differences may affect not only men's and women's overall levels of expertise but may also result in different types of expertise or gendered knowledge as reported in other settings (Kleiber et al. 2015).

We only found one case with higher network density: fish poisoning in the upriver village. This technique traditionally involved the collaboration between several people from different households. While this apparently continues to be the case in the upriver village (Figure 2, b3) where there is a group of densely connected fishers, it differs in the mid-river village where there is a tightly connected fishers' group but also many other smaller groups of women fishing with children. Low densities of ties probably relate to the second commonality of the networks studied: fragmentation, or the existence of different fishing groups. Although levels of fragmentation found vary from one village to another and are higher for some techniques (hook) than others (net), overall network fragmentation is high. One factor that might help explain this is homophily. The analysis of dyadic ties suggests that kinship and gender relations mediate fishing partner selection and thus are significant in the social organization of fishing. As people select others of the same sex and clan, the fishing network is necessarily fragmented. This fragmentation is important not simply because it structures fishing events, but also because it conditions the transmission of information (McPherson et al. 2001) and thus shapes the distribution of knowledge and expertise.

We found two other important differences in the structure of fishing networks in the studied villages. Overall, the upriver network displays higher reciprocity and mean indegree than the mid-river network, meaning that fishers in the upriver village reported more mutual connections and a higher average number of fishing partners. We do not have a clear explanation for this difference, although it might relate to other structural changes (i.e., market integration and adoption of new livelihood strategies) that affect social life and cohesion in the two villages. For example, mid-river villagers rely more on purchased goods than upriver villagers, where people continue to practice fishing in a more traditional collective manner. Regardless of the plausibility of this explanation, the fact that there are more reciprocal ties and greater mean indegree in the upriver village network may indicate less hierarchy and more cohesiveness.

Fishing expertise and network centrality

With regard to the relation between emic perceptions of fishing expertise and fishers' positions in the network, we found that one of the two centrality measures tested, betweenness, is statistically positively associated with fishers' expertise ratings. The

explanation found in the social network literature is that actors who have a mediating role in a network can connect or disconnect parts of the network by passing accurate, ambiguous, or distorted information between otherwise unconnected nodes, highlighting their role in information exchange (Burt 2004). Previous studies have also demonstrated the importance of an actor's performance or status in relation to their position in networks (Reyes-García et al. 2013; Kawa et al. 2013).

However, if this is the case, why is only one of our two measures of centrality (i.e., betweenness) positively associated with fishing expertise? Acquiring status based on fishing expertise is a complex social process through which fishers interact with many others over a long period of time. Betweenness centrality might reflect a structural position created over time that allows a person to gain access to many pieces of group-specific information and expertise. In contrast, indegree centrality captures the number of direct contacts between people, but does not necessarily indicate how well connected a person is in the overall network structure. Thus, a person with many connections (high indegree), but low brokerage (low betweenness), might only be able to access information that is restricted to her/his subnetwork, and not be able to access that which is available in other subnetworks.

The gendered social network puzzle

Our results show a final puzzling finding: the association between fishers' ratings and betweenness is more striking for women than for men. The association is puzzling because, among the Tsimane', fishing is considered as a predominantly male activity. Moreover, the fact that women are not generally perceived as *good fishers* was evident in men's higher expertise ratings. Why, then, when including the interaction of the level of betweenness with sex in the regression, do we find that betweenness is a better predictor of women's fishing rating?

We argue that to explain this requires recognizing that the study of gender relations and expertise also must contemplate the intersection of gender identities with other identities (e.g. age, kinship, class, religion) (Banerjee and Bell 2007) and how these shape the acquisition, transmission, and distribution knowledge and expertise. Among the Tsimane', women generally lack legitimacy as fishers. However, the handful of women who were observed to fish more frequently (middle-aged women who can leave children with elder siblings, or elderly women who can still fish) seem to have more opportunities to access fishing knowledge, skills, and grounds and to interact with several groups, which in turn may increase their competence, legitimacy, and perceived fishing expertise. Women who can bridge relations between different individuals might acquire more knowledge and skills through these connections, which provides them with information that may be new and valuable and which increases their status as fishers proportionately more than the same information will increase men's status as fishers, thus explaining the gender difference in brokerage positions.

We would like to end by acknowledging a potential limitation of our study. Our results suggest a bias towards selecting males as fishing partners. This finding should be interpreted with caution due to possible measurement errors. In the field we realized that women often fish with children. However, since children were not included in the sample, women might

have received proportionately fewer nominations compared with men. This highlights the importance of considering children's involvement in subsistence-related activities in small-scale contemporary societies (Gallois et al. 2015).

Conclusion

A network perspective proves useful for uncovering the pattern of gendered relationships amongst Tsimane' fishers and how this is related to the choice of fishing partners. It broadens our understanding of how social relations shape the opportunities and constraints for accessing knowledge and gaining status and expertise, and therefore for using natural resources, by adding a dimension not directly observable and that extends beyond informants' testimonies: the social structures that emerge in a particular context around a specific cultural domain. Furthermore, SNA provides means not only to uncover the social structures within which people are embedded but as well to investigate how differences in performance at the individual level (centrality measures) can explain the functioning of that social structure.

Gender blindness has often led researchers and policy makers to neglect the gendered nature of ethnobiological expertise and knowledge (Howard 2003; Pfeiffer and Butz 2005). Environmental policies incorporating insights from local knowledge systems should consider the patterned distribution of expertise, specifically, the distinctive strategies of women and men with regard to the environment, their differential access to technologies and to ecological resources. Furthermore, ethnobiological research should recognize that the study of gender relations and expertise also includes the intersection of gender identities with other identities (e.g. kinship, age, class) and how these shape the acquisition, transmission, and distribution of ethnobiological knowledge and expertise.

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Figure 1.
Map of the study area

Figure 2.

Fishing networks by village. Village a) mid-river, b) upriver. Nodes size shows *betweenness* centrality; colors show women (purple), men (green) fishing perceived knowledge with gradient from lighter to darker with greater knowledge. Yellow nodes represent children. The color of the ties represents the color of the target node. Numbers show networks for the different fishing techniques 1) all fishing events, 2) bow and arrow, 3) fish poison, 4) nets and 5) hooks.

Table 1

Fishing networks' structure by technique and village.

Village	Network	Nodes (n)	Density	Components	Max. nodes in a component	Reciprocity	Mean Indegree	SD
Mid-river								
	All events	115	0.023	3	109	0.313	3.82	3.69
	Bow&arrow	9	0.069	4	3	0.000	0.55	0.49
	Fish poison	73	0.026	10	37	0.241	2.32	2.37
	Hook	60	0.016	15	11	0.132	1.40	1.26
	Net	66	0.033	6	45	0.464	2.53	2.50
Upriver								
	All events	69	0.049	2	52	0.535	5.68	5.78
	Bow&arrow	23	0.047	7	5	0.333	1.60	1.68
	Fish poison	26	0.175	5	14	0.652	6.15	5.68
	Hook	47	0.030	10	19	0.416	1.76	1.57
	Net	39	0.053	3	28	0.519	2.87	2.75

Table 2

Definition and summary statistics of the variables used in multivariate analysis by sex.

		Women (N=50)					Men (n=59)				
Variable	Definition	N	Mean	S.D.	Min.	Max.	N	Mean	S.D.	Min.	Max.
<i>Outcome variable</i>											
Fishers' ratings	Average score in rating survey (from 0 to 4)	50	1.19	0.63	0	3.16	59	2.28	0.69	1	4
<i>Explanatory variables</i>											
Indegree	Nominations in the fishing network	50	2.26	2.24	0	11	67	4.25	3.28	0	12
Betweenness	Brokerage among people where each person is directly and indirectly connected	50	56.88	97.80	0	418.1	67	143.5	251.6	0	1392.5
		N		%			N		%		
Male	Dummy variable that captures the sex of the person, 1=male, 0=female	50		45.87			59		54.13		
<i>Control variables</i>											
Age	Age of the person, in years	50	36.02	18.20	14	88	59	38.01	19.53	14	91
Age2	Squared term to control for nonlinearity in the relation of age with fishing knowledge										
Wealth	Individual wealth in dollars purchasing power parity (ppp). In regressions enter as 1.000.	49	167.7	271.8	0	1058.8	59	1717.79	1750	0	10011.7
Company	Average number of adults joining in fishing expeditions.	48	0.34	0.34	0	1.58	59	0.54	0.43	0	1.88
		N		%			N		%		
Village	Dummy variable for village of residence										
	mid-river	34		68			32		54.24		
	upriver	16		32			27		45.76		

Table 3

Results of multiple OLS regression models.

	Fisher's ratings	
	[A]	[B]
	Indegree_Model	Betweenness_Model
Number of obs (n)	106	106
Male	0.832 (0.245) **	0.910 (0.200) ***
Indegree	0.079 (0.062)	^
Betweenness	^	0.002(0.000) **
Interaction (male * centrality measure selected)	-0.026 (0.056)	-0.002(0.000) **
Mid-river village	0.325 (0.163)	0.345 (0.149) **
Age	0.019 (0.013)	0.018 (0.014)
Age2	-0.000 (0.000)	-0.000 (0.000)
Company	-0.077 (0.295)	0.122 (0.151)
Wealth	0.095 (0.057)	0.140 (0.062)
R²	0.49	0.62

Note: For definition of variables see Table 3.

Robust standard errors in parenthesis. *, **, and *** significant at the 10%, 5% and 1% level. ^ variable intentionally omitted.