

Network Approach for Analyzing and Promoting Equity in Participatory Ecohealth Research

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Abstract: Effective involvement and equity in participation between men and women and the various community groups are likely to influence the equity in the sharing of the development outcomes of any participatory research project. The CARUSO project, a participatory research based on the ecosystem approach to human health, showed that the inhabitants from Brasília Legal, a small village located on the river banks of the Tapajós river in the Brazilian Amazon, are exposed to mercury through fish consumption; a subsequent participatory intervention based on dietary changes was effective in reducing mercury exposure of the population. In the present study, we focus on equity in participation and analyze the discussion network about mercury and health to measure individual and group involvement in the community. Participation in the discussion network is associated with the awareness of the critical information necessary to allow the individual to change dietary habits toward the preferential consumption of the less contaminated fish species. Our network analysis shows that gender, age, religion, education, subsistence activities, and spatial distribution of the houses are key elements affecting the involvement of the population in discussions about mercury and health. Based on these results, we propose strategies for integrating the research results and the knowledge of the villagers in a new cycle of participatory research in order to address the lack of involvement of some groups and to promote equitable participation and benefit sharing.

Key words: Amazon, community, equity, mercury, participatory research, social networks

INTRODUCTION

In recent years, participatory research has become a fervently advocated concept and a tool for many development pro-

grams. Based on a cyclical process of inquiry, reflection, and action, participatory research aims at offering an opportunity for local people to exercise their voice, to interpret their situation and to choose their own way of development through action (Cornwall and Jewkes, 1995; Probst and Haggmann, 2003). The outcome of participatory research is affected by how local people are involved and by whom amongst these people is involved (Cornwall and Jewkes,

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1995; Cornwall, 2003; Parkes and Panelli, 2003). Several studies have shown that participatory research programs that fail to take the sociocultural diversity of the community into account with a view to promoting the effective participation of men, women, and of various social groups affected by the problem may actually increase the inequalities, widening the gap between the elite and lower socioeconomic status groups, although they may have a globally positive impact on the living conditions of the community (Rogers, 1976; Röling et al., 1976; Shingi and Modi, 1976; Mayoux, 1995; Cornwall, 2003). To incorporate the equity dimension in participatory projects, it is essential to develop methods that allow for disaggregated analyses of the data relating to the different social groups and to explore how the barriers to participation faced by some segments of the community might be overcome (Mosse, 1994; Forget and Lebel, 2001; Probst and Hagmann, 2003).

The main goal of the ecosystem approach to human health—ecohealth approach—is to improve human health and well-being while simultaneously maintaining a healthy ecosystem (Forget and Lebel, 2001; Lebel, 2003). Transdisciplinarity, participation, and equity are its three essential methodological components. Here, we address equity in community participation in a ecohealth project on mercury exposure in the Brazilian Amazon. The analysis of the discussion network about mercury and health, that allows for a disaggregated analysis of the involvement of the men, women, and the various social groups in the community, is used to identify the axes of difference that may affect participation. We also propose guidelines for incorporating these results into a cyclical ongoing process of inquiry, reflection, and action to promote equitable participation involving all segments of the community.

Background and Context of the CARUSO Project

Brazilian and Canadian researchers teamed up in 1994 to explore mercury environmental contamination and human exposure of riverside populations in the Tapajós region. The project, called CARUSO, provided a new understanding regarding the environmental dynamics and the health effects of mercury for local communities and allowed the initiation of actions to reduce human exposure and improve well-being. In the present article, we focus on the participatory process involving the inhabitants of Brasília Legal, a small community on the banks of the Tapajós river, where most of the CARUSO studies have been carried out.

Summary of the Modes of Participation in Brasília Legal

From the onset, a participatory approach was chosen by the researchers of the CARUSO project as an appropriate methodology to investigate the complex links between human and environmental factors associated with the mercury contamination of the aquatic ecosystems and with the health and well-being of the communities living on the banks of the Tapajós River. From the first contact with the community in 1994 to the undertaking of a successful pilot project to reduce mercury exposure, the participatory research has gone through a number of stages associated with different types of participation of the villagers, as the researchers recognized the need to integrate local knowledge and experiences in an increasingly collaborative process. Although these stages were not chronologically linear—one beginning as another finishes—but exhibited significant overlap, they follow a trend of progressively deeper involvement of the communities in the participatory process. Table 1 presents the main characteristics of the different phases of the CARUSO project in Brasília Legal, emphasizing the cyclical process of inquiry, reflection, and action. These phases have been distinguished according to the modes of participation of the villagers that in many ways parallel the classification proposed by Biggs (1989).

The previous phases of the CARUSO project, carried out from 1994 to 2000, highlight how approaches with different modes of participation fulfill different tasks, from the generation of scientific knowledge to the adoption of new diet behaviors to reduce mercury exposure. Although the results of the pilot project clearly reveal the emergence of a process of change in the community, they raise two important questions that have been left unanswered: How deep did the process of change spread among community members? Have all the different social groups been equally involved in this process? To answer these questions, a fourth phase of participatory research has been initiated in 2001 and is the subject of the present study (Table 1).

Equity in Participatory Research

Participatory research emerged in the 1970s, but for a long time, perceptions and problems and the differing experiences of women were not taken into consideration (Cornwall and Jewkes, 1995; Mayoux, 1995; de Koning and

Table 1. Phases of Participatory Research in Brasília Legal

Phases of participatory research	Research focus	Modes of participation ^a	Inquiry: main results	Reflection: new research questions	Action
The previous phases					
Phase 1: 1994–1997	Biogeochemical studies of mercury in soil, sediments and water	Contractual: Members of the community were contracted by the researchers to provide services for fieldwork with no decision power	Deforestation causes intensive erosion of soils rich in naturally occurring mercury, contributing significantly to the contamination of waterways ^b	Is the fish-eating population of Brasília Legal exposed to mercury? What are the health impacts of mercury exposure?	Organize a community workshop to discuss mercury contamination with the villagers and invite them to participate in a study about mercury exposure and human health
Phase 2: 1995–1997	Analysis of mercury in fish and evaluation of fish diet, mercury exposure, and health effects	Consultative: Opinions of the villagers were sought as input for research and actions which are under the control of the researchers	The population is exposed to mercury through fish consumption ^c Mercury exposure results in dose-related adverse health effects ^d	How to build solutions to reduce human mercury exposure while maintaining fish consumption?	Long-term collaboration between researchers and the population to search for and implement solutions to reduce human mercury exposure
Phase 3: 1998–2000	Pilot project based on dietary changes to reduce mercury exposure	Collaborative: Villagers participated in all stages of the pilot project and shared some of the responsibilities with the researchers	The participatory intervention based on dietary changes was effective in reducing mercury exposure of the individuals who participated in the pilot project ^e	How deep did the process of change spread among community members? Have all the different social groups been equally involved in this process?	Using a network approach, collaborate with the whole population to analyze community involvement and equity in participation
The present study phase					
Phase 4: 2001–2004	Network study for analyzing equity	Collaborative: Villagers participated in all stages of the network study and shared some of the responsibilities with the researchers	The analysis of the discussion network about mercury and health revealed unequal involvement of social groups in the participatory process	How to promote community involvement and equity in participation?	Using a network participatory intervention, promote community involvement and equity in participation
The next phase					
Phase 5: 2005–	Network participatory intervention for promoting equity	Collegiate: Toward a more collegial mode of participation			

^a Adapted from Biggs (1989), who distinguishes four modes of participation: (1) contractual, where members of the local communities are contracted in the projects of the researchers to take part in their experiments with no decision power; (2) consultative, where local people are asked for their opinions as input for research and actions which are under the control of the researchers; (3) collaborative, where community members work together with researchers to determine priorities but responsibility remains with researchers for directing the process; and (4) collegiate, where local people and researchers share their knowledge to create new understandings and work together to form action plans under the control of local people.

^b Guimarães et al., 2000; Roulet et al., 1999; Roulet et al., 2000.

^c Lebel et al., 1997.

^d Amorim et al., 2000; Lebel et al., 1998.

^e Mergler et al., 2001.

Martin, 1996). As a consequence, women have been largely excluded from many participatory projects where knowledge was both provided and produced by men (Mosse, 1994). Feminist theories and practices have contributed to identify the barriers to women's participation and to address the role of women in community development issues (Frieze et al., 1978; Maguire, 1987; Mayoux, 1995). However, the initial focus on women in development gradually shifted to a greater concern with gender relations and socioeconomic inequality (Cornwall, 2003; Lebel, 2003). Several authors concluded that, in order to promote an equitable development, participatory research projects need to address the issues of differences in terms of an inclusive approach to gender relations, taking into account the heterogeneity both among women and men (de Koning and Martin, 1996; Chant, 2000; Cornwall, 2003).

The most straightforward way to measure the participation of the community members is to build indicators based on their involvement in the various activities carried out during the research. Correlation between participation in research activities and individual social variables can be used to identify the factors that are associated with the degree of involvement of the community members in the participatory process. However, this atomistic approach does not take into consideration the involvement of the community members beyond their direct participation in the activities promoted by the researchers and does not allow the capture of the systemic nature of community development since social interactions between the individuals are not taken in account. Indeed, many studies have highlighted that establishing the usefulness and relevance of the information generated by the participatory process as a basis for action, as well as promoting its diffusion, involves complex negotiations through a rich web of social ties based on relation between all the stakeholders affected by the problem (Rogers and Kincaid, 1981; Valente et al., 1997; Boulay and Valente, 1999; Lebel, 2003; Levy-Storm and Wallace, 2003). As a useful tool for disaggregated analyses of the social interactions between the social groups, in the present study we use social network analysis to inquire into equity in participation at the community level.

Social Network Analysis: A Tool for Analyzing Equity in Participation

Social network analysis studies the interactions between the behavior of the individual at the micro level and the pattern

of relationships between the individuals at the macro level (Wellman, 1988; Wasserman and Faust, 1994). To reach their goal of uncovering the patterns of people's interaction and the structuration emerging from these interactions, social network analysts have created tools and methods for the gathering and analysis of relational data (Wasserman and Faust, 1994). These tools and methods were used for the study of many fields of human communication among which are organizational behavior, social capital, health, social support, small world phenomenon, innovation diffusion, and social inequalities (Saint-Charles and Mongeau, 2005).

Numerous studies have shown that structure of social networks affects the transmission of information and the diffusion of new practices in social groups and communities (Rogers and Kincaid, 1981; Rogers, 1995; Valente, 1995; Valente et al., 1997; Boulay and Valente, 1999; Kincaid, 2000; Watts, 2003). Social network analysis has also allowed for a better understanding of how the most isolated people of a community can be reached (Rogers, 1995; Valente, 1995; Boulay and Valente, 1999; Watts, 2003; Kincaid, 2004; Saint-Charles and Mongeau, 2005) and has been used for targeted health interventions through the identification and involvement of individuals indigenous to a community who are able to promote the diffusion of information and changes in health behavior in their social networks (Ball et al., 1998; Kegler et al., 2003; Valente et al., 2003). Although—to our knowledge—social network analysis has not been used in the context of participative research *per se*, the “actor linkage matrix” proposed by Biggs in his holistic approach for strengthening research and development capabilities in natural resources systems, has strong parallels with social network analysis (Biggs and Matsuert, 1999). The matrix illustrates the relationships and the flows of information between key actors and is used as a tool for project evaluation to promote learning and replanning through the creation of alternative scenarios, action, and interventions.

In the present study, we use social network analysis as an alternative method to measure who is involved in the community and to identify equity in participation, in which social interactions as well as key elements in community diversity are taken into account. We analyze the participation in discussions about mercury issues, as an indicator of the effective involvement of men, women, and the various social groups of the Brasília Legal community in the participatory process. Through the analysis of the discussion patterns between the villagers, we identify the axes of difference, such a gender, age, religion, education,

socioeconomic status, subsistence activities, and spatial distribution of the houses, that may facilitate or act as a barrier to the actual involvement of the local population in the discussions about mercury at the level of the entire community.

METHODS

Population

The study was carried out in the village of Brasília Legal, situated on the banks of the Tapajós River, a major tributary of the Amazon River, Brazil. A map of the study region is available on the CARUSO project web site: <http://www.unites.uqam.ca/gmf/caruso/caruso.htm>. In September 2001, a meeting was held in the Brasília Legal community to invite the villagers to participate in the network study. A complete mapping of the community, done in collaboration with the villagers, revealed that the village had a total of 110 households. Data were collected using semi-structured face-to-face interviews that were conducted by the principal investigator privately at the home of the participants in October 2001. The interviews covered standard demographic characteristics, knowledge about mercury accumulation in fish, and network questions. In order to increase the likelihood to find people at home and to maximize the size of our sample, each household was visited several times at different times of the day to invite the household heads (usually a couple) to participate in the interview. If the household heads were repeatedly absent after several visits, another person in the house was interviewed. This strategy allowed us to conduct the interview with a total of 158 persons (89 women and 69 men), from a total of 96 different households. People from the remaining 14 households could not be encountered either because they are not permanent members of the community, had moved recently or were temporarily absent for health or professional reasons.

Variables Used to Differentiate the Villagers

The main variables used in this analysis to reveal axes of difference between the villagers of Brasília Legal were gender, age, socioeconomic status, education, house location, religious affiliation, and subsistence activities. Socioeconomic status was measured as an interval variable that is the sum of the presence in the house of a radio, a television set, a TV parabolic receptor, a well for drinking water, a

sanitary inside the house, and an electric generator. Education level is the number of years attending school. Religious affiliation and subsistence activities were recorded using open-ended questions and categories were defined a posteriori (see Results).

Knowledge about Mercury Accumulation in Fish

The pilot study to reduce mercury exposure of the Brasília Legal population was based on key information: herbivorous fish usually have the lowest mercury levels while the carnivorous fish exhibit the highest (Lebel et al., 1997). To be able to orient their fish consumption to the less contaminated fish species, villagers must be aware of this information. Knowledge about mercury accumulation in fish was measured as a dichotomous variable as whether the respondent was aware of the difference in mercury accumulation between herbivorous and piscivorous fish and able to distinguish between these two groups by identifying correctly at least one species in each category, among the fish living in the Tapajós region.

Discussion Network on Mercury

Interpersonal communication regarding the mercury issue was assessed by asking the respondents to name the individuals with whom they usually discuss mercury issues, whether in the context of health, diet, or fishing. Our intention with the phrasing of the question was to preferentially select network partners with whom the respondent had substantial conversation about mercury (strong ties) and not merely casual talks. From a total of 363 nominations directed at individuals living in the village, 322 (89%) were directed at individuals who had been interviewed and 41 (11%) were directed at individuals who were not included in our sample. From these 322 nominations, 39 were reciprocal. Network ties with individuals who could not be interviewed were dropped from the analysis since no information was available for these network partners. For the purpose of the analysis, two individuals were considered as discussion partners if either person mentioned the other. Accordingly, we obtain a discussion network including 283 reciprocal relationships, giving a total of 566 discussion partners.

Network data were stored as an actor-by-actor matrix using the UCINET software (Borgatti et al., 2002) and then exported to the NetDraw software (Borgatti, 2002) to visualize the structure of the discussion network as pre-

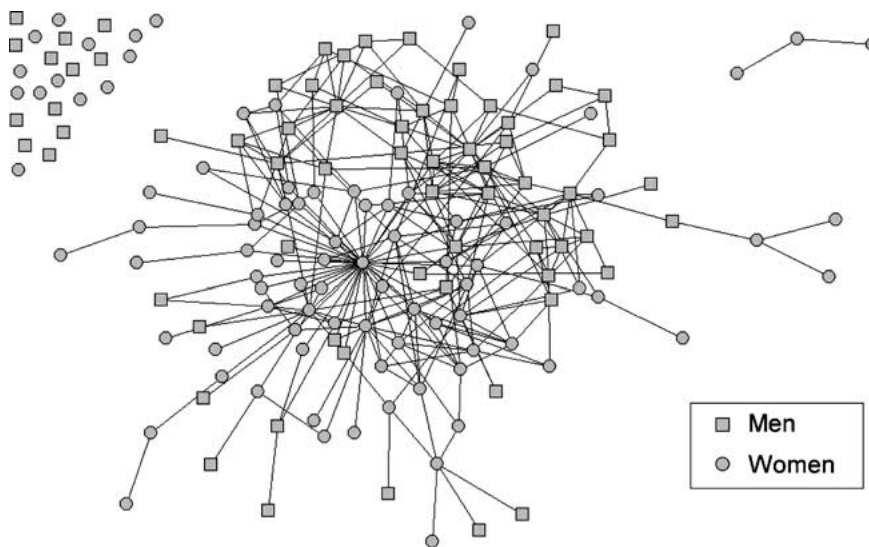


Figure 1. Discussion network on mercury between the villagers of Brasília Legal ($n = 158$).

sented in Figure 1. The grouping of community members sharing selected characteristics was done using the collapse function of the UCINET program, which allows for the calculation of the mean number of discussion partners within and between groups. Significant difference in the mean number of discussion partners between groups was assessed using variance analysis (ANOVA).

RESULTS

Figure 1 presents the discussion network about mercury in the Brasília Legal village. The nodes depicted as square in the graph represent men, while circles represent women. Two nodes are connected by a line if one or both individuals reported discussing with the other about mercury issues. The most striking characteristic of the discussion network is that the majority of the respondents belong to one main and relatively dense component comprising 130 members, including 73 women and 57 men. This observation shows that mercury is a discussion topic between most of the community members. However, a significant portion of villagers seem not to be actively involved in discussion about mercury. The network analysis revealed one small component comprised of 3 women, as well as 25 isolates, 12 men and 13 women. Furthermore, the main component is far from being homogeneous. Some individuals are linked to the main component through only one discussion partner, while others exhibit numerous connections with a wide set of individuals. The individual number of discussion partners ranges between 0 and 40 and is used as a variable to measure the involvement in the

discussions about mercury. The mean number of discussion partners (MNDP) for the whole network is 3.6.

In order to examine if there is an association between personal attributes of the villagers and their involvement in the discussions about mercury, community members sharing selected characteristics were grouped together and MNDPs were analyzed within each group and between them. In Figures 2 to 9, groups are represented by circles whose area is proportional to the number of individuals—indicated within the circle—in the respective groups. The MNDP for each group, with all the other groups including itself, is indicated in the legends of the figures. MNDP within each group is indicated using a reflexive arrow, while MNDP from one group to another is indicated by an arrow directed from the former to the latter. The thickness of an arrow is proportional to the MNDP value. MNDP values within and between groups are available for Figures 2 to 9 in the supporting online material, at http://www.unites.uqam.ca/gmf/fm/data/supporting_online_material_mertens_et_al.htm

Gender

Figure 2 shows how discussion about mercury is distributed within and between men's and women's groups. The MNDP is 3.5 and 3.6, respectively, for women and men. As the thickness of the reflexive arrows indicates, most of the discussion about mercury occurs within same-sex groups. Respectively, 76% of the men and 81% of the women discuss mercury issues with same-sex members. This result prompted us to use gender as an additional grouping variable in the subsequent networks analysis.

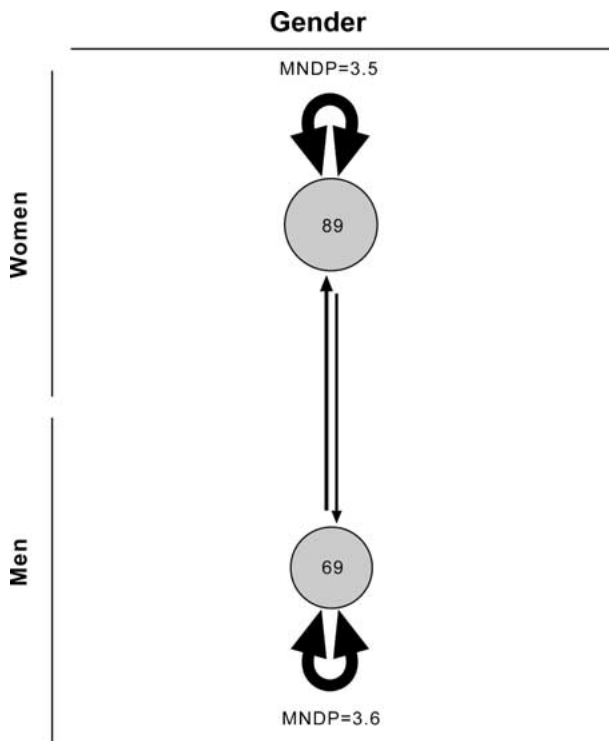


Figure 2. Discussion network on mercury within and between men's and women's groups. MNDP, mean number of discussion partners.

Age

Age of the villagers who participated in the study ranges from 14 to 88 years. The population was divided into three age groups, arbitrarily defined in order to minimize the difference in size between them: 14 to 30, 31 to 50, and 51 to 88 years old (Fig. 3). People who are between 31 and 50 years old have significantly more discussion partners about mercury than people from the two other age groups. This difference is statistically significant for both men and women (ANOVA, $P < 0.05$ and $P < 0.01$ between the 31–50 year olds and the two other groups, respectively, for men and women). Younger men and women have very few discussion partners both among people of their own group and with individuals belonging to the 14 to 30-year-old group of the opposite sex.

Socioeconomic Status

Figure 4 shows that, for both men and women, discussion about mercury is rather evenly spread within and between groups established according to the socioeconomic status of the individual.

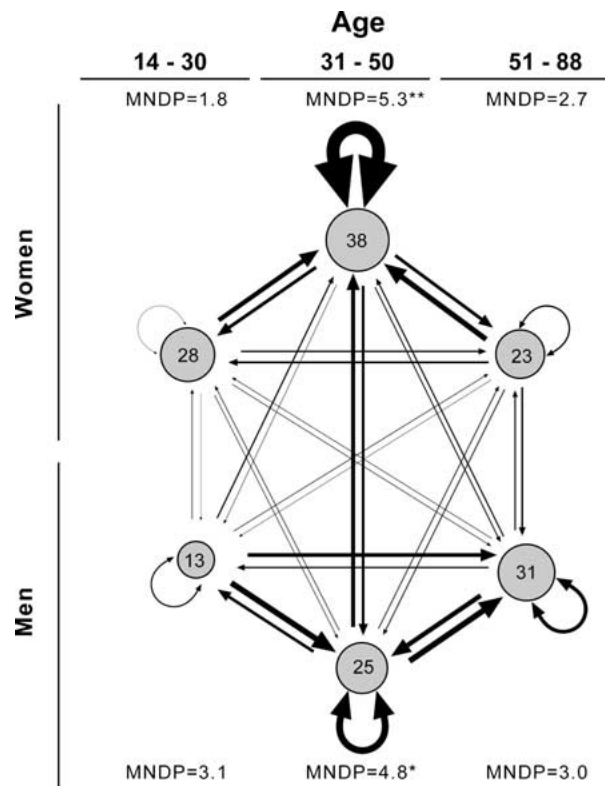


Figure 3. Discussion network on mercury within and between age groups, by gender (* $P < 0.05$, ** $P < 0.01$).

Education

The analysis of the discussion patterns between groups of different education levels, 0 to 3, 4 to 7, or 8 to 11 years of schooling, respectively, reveals that the discussion pattern is markedly different between men and women (Fig. 5). On average, women with 8 to 11 years of schooling discuss mercury issues with 7.2 villagers, in contrast with women with lesser years of schooling who have an average of only 2.2 and 2.7 discussion partners respectively (ANOVA, $P < 0.001$, between the women's group with 8–11 years of schooling and the two other groups). Furthermore, most of the discussion involving women from the group with the highest level of education takes place with members of their own group. A different picture emerges from the analysis of discussion about mercury for men's groups defined according to their education level. Discussions are much more evenly distributed between the three men's groups and there is no significant difference in the MNDPs between them.

Spatial Distribution of the Houses

The 110 houses of Brasília Legal are uniformly spread along the left bank of the Tapajós river, on a North-South axis. A

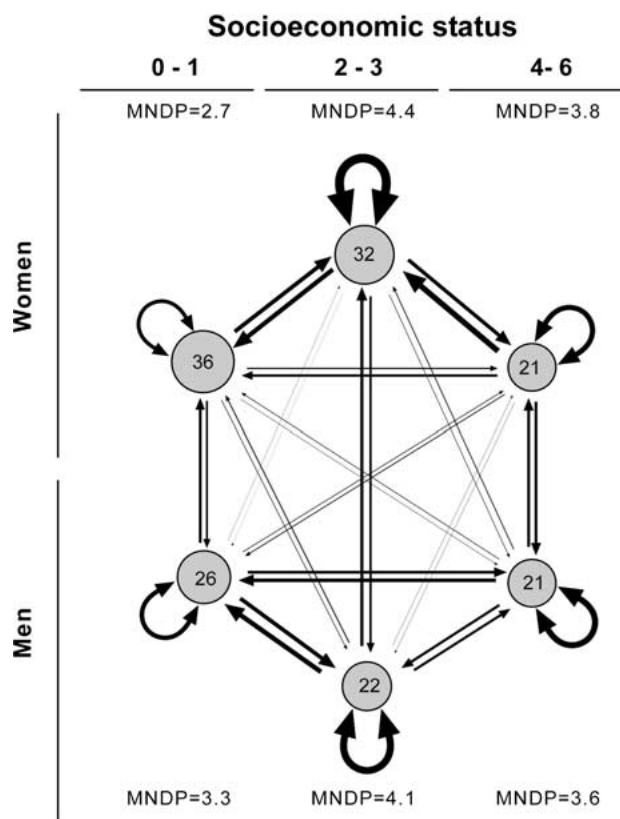


Figure 4. Discussion network on mercury within and between groups defined according to socioeconomic status, by gender.

main line of 56 houses, approximately 800 meters long, fronts straight onto the river. Behind this line, the other houses of the village are distributed into two shorter rows also parallel to the river. Since no clear natural boundary defining distinct neighborhood could be identified, the village was arbitrarily divided into three areas on the North-South axis, with approximately the same number of houses. Although Brasília Legal is a very small community where everybody knows everybody, Figure 6 clearly shows that discussions about mercury are spatially concentrated, occurring preferentially between close neighbors than between people living in distant areas. Respectively, 80, 63, and 64% of the inhabitants of the Southern, Central, and Northern areas of the village discuss mercury with people living in their own area. For both men and women, the intensity of discussion is significantly higher between the inhabitants of the Southern area than between those who live in the other two areas (ANOVA, $P < 0.05$ and $P < 0.01$, respectively, for men and women). Considering men and women together, the MNDPs of the inhabitants decrease from 5.2 in the Southern area to 3.0 and 2.3 in the Central and Northern areas, respectively.

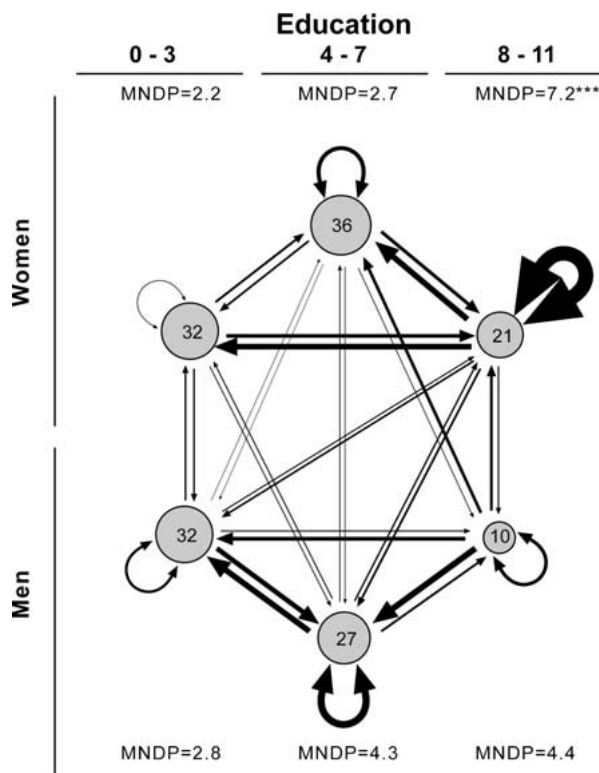


Figure 5. Discussion network on mercury within and between groups defined according to education levels, by gender ($***P < 0.001$).

Religious Affiliation

Five churches are present in the Brasília Legal community. The majority of the villagers interviewed reported attending the Catholic church (58 and 65% of men and women, respectively). Only 7% of the women did not attend any church, against 28% of the men. Church attendance of the remaining population is distributed between four evangelical churches (Assembly of God, Presbyterian, Baptist, and Christian Congregation). Since there were very few members in each of the evangelical affiliation groups, individuals were pooled into one evangelical group to allow comparison with the Catholic affiliation group and with the group of people who do not attend any church. Results presented in Figure 7 show that discussion about mercury between the villagers is associated with their religious affiliation. A similar pattern, showing a deep involvement of the Catholic community in discussion about mercury, is observed for men and women. Men and women attending the Catholic church have on average significantly more discussion partners than men and women with evangelical or no religious affiliation, respectively (ANOVA, $P < 0.05$, between the

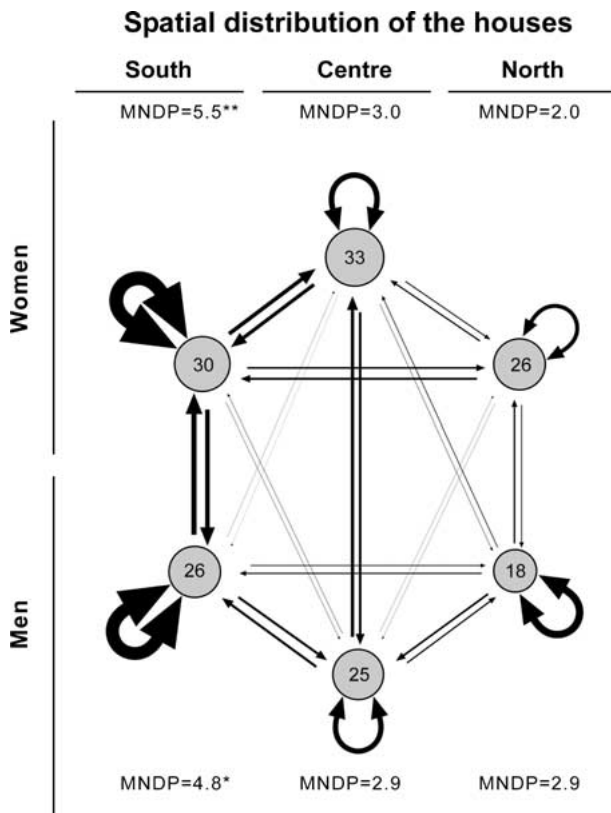


Figure 6. Discussion network on mercury within and between groups defined according to the spatial distribution of the house, by gender (* $P < 0.05$ and ** $P < 0.01$).

Catholics and the other two groups). Furthermore, the thickness of the reflexive arrows for both Catholic groups indicates that men and women discuss mercury issues much more frequently within their own religious group than with individuals with evangelical or no religious affiliation.

Subsistence Activities

In Figure 8, villagers were aggregated into groups according to their main subsistence activities. The housewives group consist of 70 women whose main activities are to take care of children, prepare the meals for the family, and clean the house. However, many of them add to these daily task other activities like working with their husband in fishing or agricultural activities, taking care of a vegetable garden, or producing and selling handcraft. Seven men who worked in boat transportation, four as public servants, five in small grocery stores, and two in house construction, as well as two women who worked as domestic servants and two as public servants, were included in the service group. Agriculture was the main subsistence activity for 20 men. Among men, 18 reported to be professional fishermen. Seven teachers (six

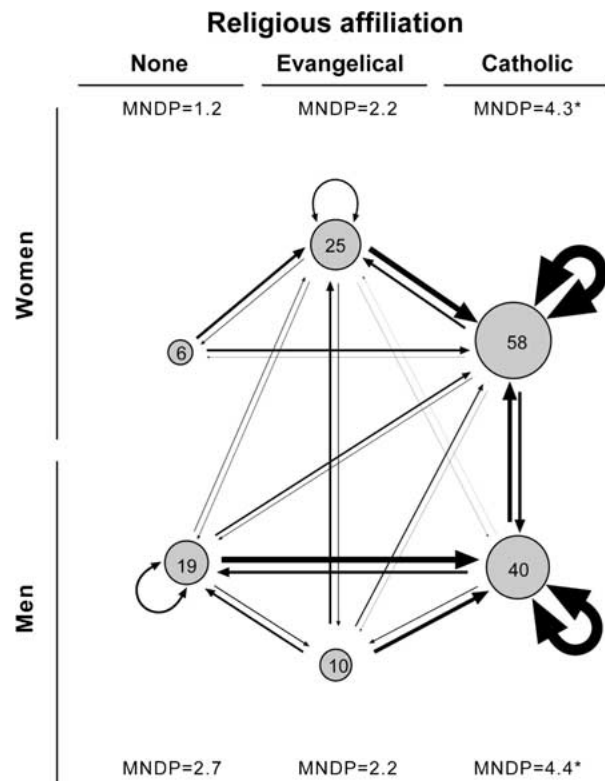


Figure 7. Discussion network on mercury within and between groups defined according to religious affiliation, by gender (* $P < 0.05$).

women and one man) and four public servants (three women and one man) were working at the local public school. Five persons were working in the health sector: three men (one was selling pharmaceuticals, one was the community health worker, and one is a nurse assistant) and two women (a midwife and a nurse). Four female students and eight retired men were not considered for this analysis, to avoid cluttering the diagram with too many groups.

The intensity of involvement in discussion about mercury as well as the structure of the discussion network differs markedly between groups with different subsistence activities (ANOVA, $P < 0.001$, between the six groups). The health workers’ group is the one with the highest MNDP. On average, each member of the group discusses mercury issues with 13.2 villagers in our sample. Their involvement in these discussions is clearly directed to the other groups of the community with strong variations in intensity depending on the group involved. Their MNDP with the other groups ranges from only 0.6 with the farmers’ group to as much as 7.2 with the housewives’ group. The local school workers’ group discuss mercury issues with 6.5 villagers on average. In sharp contrast with the health work-

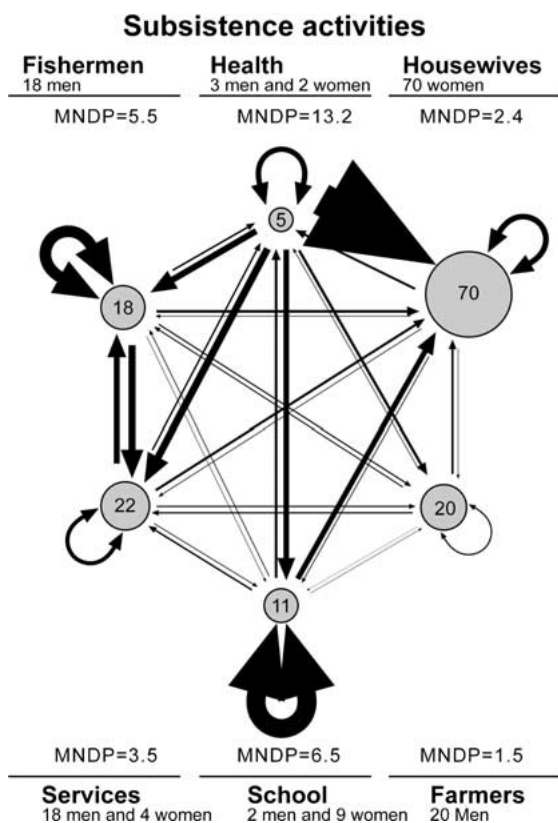


Figure 8. Discussion network on mercury within and between groups defined according to subsistence activities.

ers' group, most of their discussion occurs with members of their own group with very little involvement with the other groups, except with the housewives group. Fishermen have a MNDP of 5.5. Their discussion partners belong mostly to their own group and to the service group, composed predominantly of men. Members of the service group have an average of 3.5 discussion partners and direct most of their discussion to individuals belonging to their own group or to the fishermen's group. Each housewife discusses mercury issues with only 2.4 persons on average and most of their discussion partner are women of their own group or health workers. The participation of the farmers in discussions about mercury is the lowest among all groups, with a MNDP of only 1.5.

Knowledge about Mercury Accumulation in Fish

The analysis presented in Figure 9 addresses the possible link between discussion about mercury and the diffusion of the critical information necessary to allow the individual to change dietary habits toward the preferential consumption of the less contaminated fish species. Results show that both men and women who know the difference in mercury

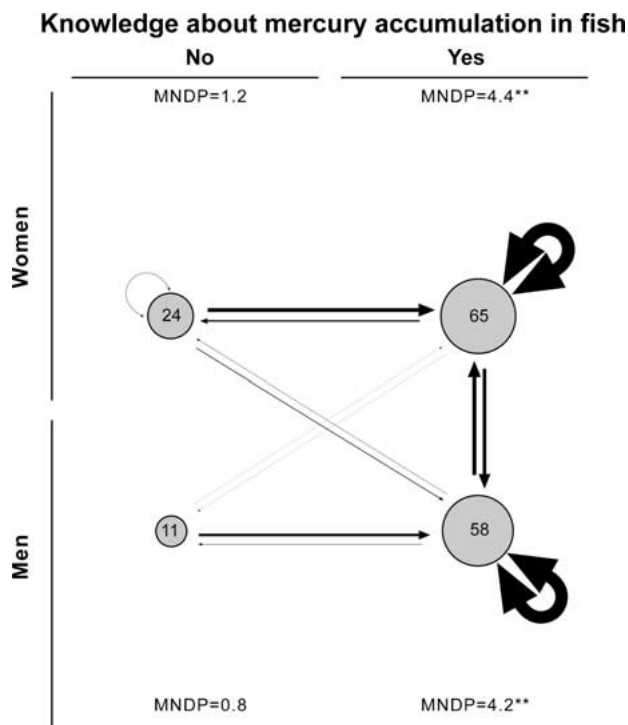


Figure 9. Discussion network on mercury within and between groups defined according to knowledge about mercury accumulation in fish, by gender (** $P < 0.01$).

accumulation between herbivorous and piscivorous fish discuss mercury issues with a much higher number of partners on average than people who are not aware of this information (ANOVA, $P < 0.01$ between the two groups, for both women and men).

DISCUSSION

The analysis of the discussion network on mercury illustrates how the problem of mercury contamination is now an important issue for the members of the Brasília Legal community. Association between discussion about mercury and knowledge of the critical information necessary to effectively reduce mercury exposure, while maintaining fish consumption, highlights the role of interpersonal communication between the villagers as one of the essential components in the process of change toward improved health. However, a causal relationship cannot be assumed from these results and at least two alternative possibilities may contribute to the strong association between discussion about mercury and awareness. Discussion about mercury might be an efficient interpersonal channel for information

exchange, contributing to awareness and extending the reach of the information about mercury issues beyond the individuals who were directly involved in the participatory process. Alternatively, it is also possible that people who are aware of the difference in mercury accumulation between herbivorous and piscivorous fish are more motivated to get involved in discussion about mercury.

Results show that the community is not an homogeneous entity and that the degree of participation in the discussions is highly variable between the villagers. Gender was shown to be only one of the dimensions of difference associated with discussion about mercury, indicating that the participation of particular men or women in the discussion should not be taken as representative of men or women in general in the community. The factors which may facilitate or constrain the involvement of the villagers in the discussion about mercury were best revealed by performing analyses of disaggregated network data using gender combined with other axes of difference. We built on these results, which have been discussed with the villagers in a community workshop held in October 2004, to propose strategies for targeting excluded groups and for stimulating new roles of key actors in the community. These strategies are intended to provide guidance in a new cycle of participatory research (Table 1: Phase 5).

Strategies for Targeting Excluded Groups in the New Phase of Participatory Research

The data presented here allowed us to identify the groups of men and women who have significantly fewer discussion partners than the other groups according to specific axes of difference and who can be targeted for adapted participatory approaches to promote their effective involvement around mercury issues. For instance, farmers may be less involved in discussion about mercury issues because they frequently leave the village for several days for farm work in remote locations and may not feel much concerned by a problem centered around fishing practices and fish consumption. Promotion of their involvement in discussion about mercury issues should take into account the barriers specific to this group and the results of both health studies which have shown that farmers are among the community members with the highest hair mercury level [Passos, unpublished data], and biogeochemical studies which have highlighted the important relationships between slash-and-burn farming practices and mercury contamination of the ecosystems (Roulet et al., 1999).

Furthermore, the analysis of network structure allows going beyond the identification of less involved people and may contribute to achieving a deeper understanding about how the various axes of difference may affect the involvement in discussion about mercury. Three examples illustrate how to take advantage of this understanding to promote participation in the next phase of the project.

The most obvious characteristics of the discussion network is that men discuss preferentially with other men and women with other women. The low level of discussion across gender may have some implications because men and women share responsibilities in family nutrition that may influence mercury exposure of the whole family. The choice of fish for family consumption might be the subject of negotiation between men and women since it depends both on how men (in Brasília Legal, more than 80% of the adult men fish for family consumption) orient their fishing activities and choose the fish to be brought home and on how housewives select the fish to be included in the preparation of the daily meals. Consequently, the future phase of participatory research in Brasília Legal should simulate discussion between spouses as a strategy to promote family-level consensus allowing for the preferential consumption of the less contaminated fish.

Discussion patterns involving men's and women's groups attending the evangelical churches show that they discuss very little about mercury issues with other people of the same religious affiliation. This observation suggests that the evangelical churches do not provide an arena for debate and information exchange about mercury in Brasília Legal. To increase the degree of involvement of the evangelical church leaders in the CARUSO activities could be a significant step to put mercury higher on the agenda of these groups.

A striking characteristic of the discussion pattern between age groups is the very low level of interaction between the people 30 years old or younger. This observation calls for a specific approach with younger people because most of the pregnancies are likely to occur within this age group and it is well-known that the health of fetuses and young children is especially at risk in relation to mercury exposure (Grandjean et al., 1997, 1999).

Strategies for Stimulating New Roles of Key Actors in the Participatory Research

Up to now, we have mainly focused on strategies for targeting groups relatively isolated in the discussion network

about mercury. However, researchers should also take advantage of potentially influential groups who are highly involved in discussion about mercury and may play a critical role regarding health and development issues in the community. People working at the local school is one of these groups. Teachers and local school public servants are among the people with the highest level of education in Brasília Legal and are recognized as well-informed people and as a source of advice by many of the inhabitants of the village. They participated actively in CARUSO health studies and are keenly aware of the many aspects of the mercury problem in the Tapajós region. They have organized classroom activities about mercury issues with their pupils that are important for the future of the community. However, it remains to be assessed whether these initiatives have been able to promote discussion on mercury at the family level and whether they have had an impact on diet behaviors. Although it is one of the most active groups in the debates about mercury, the analysis of the discussion network structure revealed that schoolworkers limit most of their interaction to members of their own group. Given their social position, if they broaden their range of discussion partners outside of their group, schoolworkers could greatly contribute to the diffusion of the information and recommendations which are critical to allow the villagers to lower their exposure to mercury. Consequently, researchers could stimulate schoolworkers to share their knowledge more broadly within the community.

Study Limitations and Implications for Future Research

Our study is based on a snapshot of the discussion network and does not reveal how the involvement of the villagers in the CARUSO project has changed through time and how social interactions have contributed to the process that allowed mercury to gradually become an issue on the agenda of the community. In order to capture the evolution of the participation of the various groups in the discussion network regarding mercury issues, a follow-up network study will be conducted in the next phase of participatory research.

By using the MNDPs to assess groups' involvement in the discussion about mercury, we do not take into consideration the intra-group variability. This limitation is partially overcome by disaggregating the network data according to several axes of difference, which allowed us to build and compare a wide range of different groups.

However, another limitation of our study is that the variables used to disaggregate the discussion network data were externally defined and may fail to match with other dimensions of difference, based on the community power structures, which may contribute to shape interpersonal relations between the villagers. In the next phase of participatory research, we will involve the villagers in the definition of the variables to be used to measure the dimensions of difference in order to build social categories which are relevant to them and better reflect local diversity. We could also use *blockmodeling* techniques (Wasserman and Faust, 1994) in order to look for groups sharing similar patterns of interaction within the network.

CONCLUSIONS: NETWORK PARTICIPATORY INTERVENTION FOR PROMOTING EQUITY

In the next phase of participatory research in Brasília Legal (Table 1: Phase 5), targeted activities involving farmers, people 30 years old or younger, people attending evangelical churches, and school teachers will be organized to promote debates centered around the specific role of each group in the building of solutions to reduce the environmental and social impact of mercury contamination. These activities will provide an opportunity for the participants to discuss their specific preoccupations, and to formulate recommendations which may not have emerged before in the participatory process and will be included in the new cycle of inquiry, reflection, and action. By involving previously excluded social groups and by stimulating new roles for key actors of the community, we believe that the integration of the network approach in the cycle of the participatory research in Brasília Legal will result in a significantly stronger role for the villagers in the guidance of the research project, which provides an important step toward collegial participation.

The present study suggests that social network analysis is a useful approach to take into consideration how men, women, and the various social groups differ in their involvement with environmental and health issues, according to their respective role in the community. Although this network approach is presented in the specific context of the CARUSO study, it has a much more general appeal, and we believe it may be applied to integrate community participation and equity in the research framework of the ecosystem approach to human health, in a broad range of projects.

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