

Cognitive prototypes in Tzeltal Maya medicinal plant selection

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Research question

It is important to bridge the gap between traditional medicinal plant knowledge and “western” biomedical knowledge if we are to conserve biodiversity, continue to improve human health, and encourage development of sustainable indigenous livelihoods (Balick 1994, Elisabetsky 1986, Masood 1998, Suffness et al. 1995). Linking traditional knowledge with biomedical science is difficult because we often do not understand how or why medicinal plants are selected, conceptualized, and used by indigenous people (Berlin and Berlin 1994, Browner et al. 1988). Here, we propose to conduct research in two Tzeltal Maya communities in Chiapas, Mexico to systematically test what criteria are used to select medicinal plants.

Plant taste, especially bitterness, has been proposed as a universal biochemical cue for medicinal properties of plants (Johns 1990). Other factors that may contribute to plant selection include the distribution of plants within a landscape (Alcorn 1981, Moerman 1998) and cultural interpretations of plant characteristics other than taste (Etkin 1988). Although each of these factors probably contribute to plant selection, none of them, taken individually, can be used to predict which plants are selected by Tzeltal Maya as cures for specific illnesses. A synthetic hypothesis is proposed, in which medicinal plant selection is guided by prototypes drawn from the domains of plants and illnesses.

Prototypical items are those that best express the characteristics that people use to distinguish a set of items from other items not included in the set (Rosch 1978). Research has shown that prototypes serve as powerful guides for organizing complex information (Rosch and Mervis 1975, MacLaurey 1991). The research proposed here represents an innovative attempt to use prototypes to help explain how people organize information that must span more than one domain (i.e., plants and illnesses).

The research will begin by testing whether the explanations for medicinal plant selection proposed by other researchers can predict Tzeltal medicinal plant selection using the following hypotheses:

Hypothesis 1: Tzeltal taste classifications (i.e., bitter, sour, pungent, astringent, sweet, salty, etc.) are correlated with culturally-defined illness categories.

Hypothesis 2: Tzeltal taste classifications are correlated with culturally recognized physiological responses.

Hypothesis 3: more common plants clustered closer to homes are more likely to be known as useful medicinals, and agreement about their use will be higher than for less common plants.

To establish a basis for prototypes, we will identify how Tzeltal participants group medicinal plants, and whether attributes of those groups can be linked to illnesses using the following hypotheses:

Hypothesis 4: Tzeltal participants divide common medicinal plants into statistically significant clusters.

Hypothesis 5: clusters of medicinal plants are correlated with known illness clusters.

Finally, we will attempt to elucidate prototypical items and determine their role in organizing information for guiding medicinal plant selection using these hypotheses:

Hypothesis 6: plant clusters include items that express attributes of the cluster better than other

items within the cluster.

Hypothesis 7: prototypical items are predicted by higher saliency in freelist elicitation.

Hypothesis 8: agreement about naming, use, and taste will be higher for prototypical items.

Hypothesis 9: prototype attributes from the highlands have guided medicinal plant selection by Tzeltal who have migrated to a lowland community with a new flora.

This research will synthesize current partial explanations of medicinal plant selection by providing a framework for elucidating the correlation of plant group attributes with illness classes. This framework can be used to understand medicinal plant selection by cultures other than the Tzeltal. This will contribute to efforts to bridge traditional medicinal knowledge and biomedical knowledge. It will also contribute to theoretical development in cognitive anthropology and ethnobiology by providing a framework for linking classification with behavior.

Rationale

The research proposed here focuses on medicinal plant selection, and is based on the assumption that the most widely-known plants for which there is high consensus about use are the most likely to include chemical compounds that function biologically to result in culturally defined expectations (Trotter and Logan 1986, Browner et al. 1988). Many Maya illnesses are based on natural (non-spiritually interpreted) phenomena with predictable physiological outcomes (Berlin and Berlin 1996). To combat these types of illnesses, Tzeltal Maya, like most people, experiment with the vast reservoir of biochemicals that has resulted from evolutionary interactions among organisms. Because pathogens and flora change, and ideas are shared within and between communities, traditional medicinal systems rely on continuous experimentation with new plants (Barsh 1997, Berlin and Berlin 1996). Knowledge about successful treatments can lead to agreement about a plant's efficacy (Moerman 1998, Trotter and Logan 1986). As a result, selection of medicinal plants is an on-going process and much of the knowledge needed for healing common physical ailments is distributed throughout populations (Caniago and Siebert 1998, Garro 1986, Trotter and Logan 1986).

The taste qualities that humans perceive in plants, especially bitterness, have been proposed as significant clues used in pre-literate societies to detect bioactive compounds (Johns 1990). Species of plants in the sunflower family (Asteraceae), for example, tend to be represented in traditional pharmacopoeia in excess of what would be expected by their occurrence in local environments (Moerman 1989). This has been theorized to result from the correlation between their bitter taste and high levels of alkaloids (Johns 1990, Rodrigues et al. 1976, Schmeda-Hirschmann and Bordas 1990). This hypothesis is supported by observations of chimpanzees using bitter Asteraceae species for treating gastrointestinal disorders (Koshimizu et al. 1993, Wrangham and Goodall 1989). Brett (1994) has argued that taste is the most important variable used by Tzeltal Maya to select medicinal plants. Highland Maya are particularly concerned with gastrointestinal illnesses and often treat these conditions with plants that are bitter (Berlin and Berlin 1996).

However, it is difficult to correlate plant selection with illness based on taste alone. Not all plants known by the Tzeltal to be bitter are used as gastrointestinal medicinals and many gastrointestinal conditions are treated with non-bitter plants (Brett 1994). Shepard (1999) has recently shown that two neighboring groups of people in the Amazon use similar plants as medicinals, but one group does not ingest the plants, nor do they use taste in their medicinal plant classification.

Casagrande (Co-PI) has analyzed the Tzeltal medicinal plant database of Berlin and Berlin (1996 and unpubl. data) and found that bitterness was not significantly correlated with any general class of illness. During the summer of 1999, Casagrande conducted a dissertation pilot study among

the Tzeltal, in which plant extracts were used to further test for correlation between tastes and illness classes. Again, no significant correlation was found (Casagrande, unpubl. data). These findings suggest that taste qualities alone are insufficient to guide the selection of medicinal plants.

Moerman (1998) has suggested that some plant families (e.g., Asteraceae) dominate traditional pharmacopoeia because their tendency to grow in disturbed habitats near residential areas makes it easier to share information about them. This proposition leads to the testable hypotheses that common plants clustered closer to homes are more likely to be used as medicinals and that consensus about their use should be greater than for plants located farther from homes. Caniago and Siebert (1998) have shown that residents of a Dayak village in Indonesia were more knowledgeable about medicinal plants found in early successional forests than those of primary forests. Stepp (1998) has suggested that the Tzeltal also rely more on plants from disturbed habitats.

Although these tentative results suggest higher frequency of use, this still does not indicate that there will be higher agreement about use, which we consider a more robust indication of cultural recognition of efficacy (Trotter and Logan 1986). Less common primary forest plants may be important for less common illnesses and may have high cultural value even though they are used less frequently (Caniago and Siebert 1998, Phillips et al. 1994). As part of a NSF Ethnographic Research Training grant, Casagrande studied Tzeltal knowledge of plants in a relatively inaccessible, relict primary forest. The results suggest that medicinal knowledge and agreement about plants was high, even though encounters with plants were very infrequent (Casagrande 1999). It remains to be tested whether agreement about use decreases and knowledge becomes more specialized with distance of plants from homes.

Although it is likely that more common plants are recognized as medicinals by Tzeltal informants, we are also still unable to predict which of the common plants will be associated with particular illnesses. Shepard (1999) has shown that plant use by two neighboring groups of people in the Amazon differed markedly, even though flora and illnesses were nearly identical.

Biological and ecological approaches are insufficient to fully explain medicinal plant selection because they fail to account for human cognition and cultural interpretations (Barsh 1997, Etkin 1988). Tzeltal illnesses are also classified using a dichotomous system (i.e., hot/cold), and only certain plants are appropriate to treat hot or cold illnesses (Berlin and Berlin 1996, Brett 1994). This may result from observations of human physiological response to the ingestion or topical application of medicinal plants (e.g., sweating, heat, abdominal sensation, cessation of symptoms; Brett 1994, Berlin and Berlin 1996). Dichotomous classification may also result from historical contact with the European humoral medicinal plant system (Kidwell 1991, Foster 1994). The point is that conceptualizations of efficacy, whether biologically or culturally based, are not unique to each individual plant, but draw on a knowledge base that spans the medicinal plant domain and must be organized in a meaningful manner.

The Tzeltal regularly use between 200 and 300 plant species for specific illnesses (Berlin and Berlin 1994, 1996). How is it that consensus about the use of plants has been achieved in the absence of written documentation? Preliminary research conducted by Casagrande (unpubl. data) indicates that when Tzeltal interviewees could not name a plant based on taste stimuli only, or could not recall the plant used for an illness from memory, they would often defer to a small subset of plants that appear to serve as prototypical medicinal plants (e.g., *Verbena litoralis*, *Salvia lavanduloides*, *Prunus persica*, *Quercus* spp.).

Prototypes are fundamental cognitive mechanisms for the organization of complex information (Berlin 1992, Boster 1988, Coley et al. 1997, Rosch and Mervis 1975). Complex information must be divided up for processing because of the limits of working memory (Miller 1956). Rosch et al. (1976) proposed that because complexity increases as more items are included in a set, set boundaries

are established in the most cognitively economical way by paying attention to the fewest number of observable attributes that maximize differences between sets of items. In any group of similar items, some are recognized as prototypical because they best represent the characteristics, or attributes, that form the pattern of resemblance within the group (Mervis et al. 1976). For example robins or sparrows are recognized as being more “bird-like” than birds like penguins (Boster 1988). This is because the domain “birds” is bounded by a set of attributes shared by most members (e.g., flight, feathers, wings), but the attributes are not exhibited equally by all members (e.g., penguins have small wings and do not fly). Prototypical members of a domain are those that best express the attributes that define the domain (Rosch 1978). The human tendency to focus on prototypes increases cognitive economy. The concept of prototypes is very powerful when applied to sub-groupings within a domain, such as plants and animals grouped at the genus level (Berlin 1992). Pile sorting experiments and lexical analyses reveal that most folk classifications include prototypical species that are used to define folk genera.

Prototype-based set inclusion has also been proposed as a basis for inductive thinking (Gelman 1988). Humans appear to use attributes of one domain to develop hypotheses about contents of other domains and the relationships between domains (Coley et al. 1997). Studies of childhood learning indicate that living things are particularly good for inductive development because they conform well to children’s expectations about essential attributes of living organisms, and biological domains are the earliest to take form as children develop (Keil 1994, Markman 1989, Stross 1973).

Medicinal plant prototypes may serve as powerful inductive tools helping to structure concepts of disease and illness experiences, which have also been shown to form domains that include prototypes (D’Andrade et al. 1972, Kay 1979, Young 1981). Tzeltal Maya may draw upon a set of plants that are more “medicinal” than others, and extrapolate attributes to other plants and illness experiences. Specific attributes (e.g., taste or cultural interpretations of visual characteristics) may differ from other cultures because concepts of medicinal plants span more than one domain (e.g., botany, illness, inter-personal relationships, and food; Iwu 1986, Johns 1990). By placing medicinal plant prototypes at the juncture between the cognitive domains of plant classification in general and illness experience, a framework is provided for explaining cross-cultural differences and similarities in medicinal interpretations of biological phenomena and cultural interpretations of illness experience.

The research proposed here also provides a link between cultural change and biological-based plant classification. For example, the Maya hot/cold plant classification system has been attributed to contact with the European medical tradition during the early colonial era (Kidwell 1991, Foster 1994). Originally adopted by a few people for political reasons, those aspects of the European system that were eventually accepted on a wide scale likely “fit” well with Mayan prototypical attributes that existed at that time. Maffi (1996) provides an example by arguing that the Tzeltal-Tzotzil lexeme *pox*, currently used to refer to distilled alcohol, derives from an earlier meaning of the root as “powerful medicine.” She argues that the term was originally associated with tobacco (*Nicotiana* spp.), which was a prototypical medicinal plant of the Maya that guided lexemic change.

A more recent example of the role of prototypical medicinal plants and their attributes in cultural constructions of efficacy comes from Casagrande’s collaboration with a Tzeltal herbalist (unpubl. data) who stated that *Verbena litoralis* was a powerful plant because its bitterness acts like penicillin. This herbalist was younger and appeared to be in competition with elder healers who relied on mythic Maya explanations of efficacy. Seizing an opportunity, the younger healer appeared to rely on attributes of the prototypical species, to which he attempted to apply biomedical concepts of efficacy in order to create confidence in his healing abilities, while at the same time differentiating himself from other healers.

Institutional support and qualifications

Two members of Casagrande's (Co-PI) doctoral committee at the University of Georgia (including the PI) are also adjunct faculty at El Colegio de la Frontera Sur (ECOSUR), a graduate research institution in Chiapas where Casagrande has conducted research during the past two summers. Casagrande is fluent in Spanish and speaks basic conversational Tzeltal. He has also developed good working relationships with students and faculty of ECOSUR and Tzeltal Maya collaborators. A letter of institutional support from the director of ECOSUR specifies opportunities for the Co-PI to continue collaboration with Mexican scholars and provides access to ECOSUR's laboratories, herbarium, libraries, and field research resources.

Brent Berlin, Ph.D. (PI) is recognized internationally for his work in ethnobiology, cognitive anthropology, and linguistics. He has worked with Tzeltal communities for over 30 years. Casagrande, M.F.Sci. (Co-PI) has conducted botanical, ethnobotanical, and ecological research in Puerto Rico, Chiapas, Venezuela and the temperate U.S. In addition to extensive coursework in statistics and data analysis, he has published research on quantitative methods (Casagrande and Beissinger 1997, Lewis and Casagrande 1997). During 1995-96 he supervised an interdisciplinary biological and social research project at Yale University. He has conducted ethnographic research in the English, Spanish and Tzeltal languages with such diverse groups as the Maya of Mexico (Casagrande 1999) and urban African-Americans and Hispanics (Casagrande 1996, 1997). He has been conducting ethnoecological and ethnopharmacological research in the Highlands of Chiapas intermittently over the past three years.

Research Plan

The main objective of this research is to systematically test what criteria are used by Tzeltal Maya to select medicinal plants. We will test whether the explanations of taste and plant distribution proposed by other researchers can predict Tzeltal medicinal plant selection, and we will develop a framework for synthesizing these partial explanations using prototype theory. We will identify how Tzeltal participants group medicinal plants, and whether attributes of those groups can be linked to illnesses. We will attempt to elucidate prototypical items and determine their role in organizing information for guiding medicinal plant selection. The overall strategy is to test a series of hypotheses culminating in a comparative study between Highland Tzeltal and Tzeltal who have migrated to the tropical lowlands. The final hypothesis is that prototype attributes developed in the highlands have guided medicinal plant selection by Tzeltal who have migrated to an area with a new flora.

Based on medicinal plant data collected by Berlin and Berlin (1996 and unpubl. data) over the past 15 years, Casagrande will collect and prepare botanical herbarium vouchers of 60 of the most commonly used medicinal plants in a highland Tzeltal community. A random sample of 20 women and 20 men, stratified by ten-year age classes between 30 and 70, will be drawn from community census data to participate in interviews. Because some community members will decline to participate, random selection of names will continue until all strata are represented evenly. Interviewees will be shown one plant species¹ at a time and they will be asked for the name, medicinal use (including illnesses and preparations), habitat, commonness, hot/cold designation, taste, and known physiological response for each plant. Culturally defined characteristics, such as name and use will be determined for each species using consensus analysis of interview responses (Romney et al. 1986)². Freelists of medicinal plants will also be elicited in order to determine saliency of each species (Borgatti 1996).

Extracts of the 60 species will be prepared as they would be for curing. These extracts will be presented to the 20 women and 20 men who will not know the plants' identities, and they will be asked which illness the extract is appropriate for treating and how they classify the taste. These data will be used to test the first hypothesis: that taste categories (i.e., bitter, sour, pungent, astringent, sweet, salty,

etc.) are not correlated³ with any culturally-defined naturalistic illness categories (i.e., gastrointestinal, respiratory, and dermatological ailments that are named in Tzeltal). A pilot experiment conducted with nine plant extracts and fifteen interviewees indicated that this protocol was feasible, and that concepts could be translated between Spanish and Tzeltal (Casagrande, unpubl. data).

Data from visual and taste stimuli interviews will also be used to test the second hypothesis: that Tzeltal taste classifications are not correlated with expected physiological responses⁴ (e.g., bitter plants are no more likely to be affiliated with reduced abdominal cramping than plants with other tastes).

Distribution and abundance of medicinal plants in various habitats will be sampled by inventorying all plants within 25m² quadrats distributed at 50m intervals along three randomly located 1km transects within the highland Tzeltal community. Preliminary research suggests that between 200-300 species will be encountered. Of these, 60-100 are likely to be known as medicinals. Sixteen men and sixteen women will be randomly selected from the stratified sample to identify medicinal plants in the quadrats and how those plants are used. Specimens of all plants identified by participants will be collected as herbarium vouchers. These surveys will be repeated on three separate occasions in order to account for seasonal variability in the flora. The quadrat locations will be plotted on a map with locations of houses, footpaths, and roads. Plant species will be ranked by the frequency they are encountered, their average proximity to houses, the number of respondents citing a medicinal use and agreement about their use⁵. These variables will be tested for their correlation with each other⁶ to test the third hypothesis: that more common plants clustered closer to homes are more likely to be known as useful medicinals and agreement about their use will be higher.

Research into prototypes will involve the following major aspects: 1) identifying culturally salient groupings of medicinal plants; 2) determining the attributes that are used to define the groups; 3) identifying culturally salient groups of illnesses; 4) determining the relationship of attributes between plant and illness groups; 5) identifying prototypical medicinal plant species; and 6) determining how prototypes influence medicinal plant selection.

To identify culturally salient groupings of medicinal plants, ten men and ten women will participate in triad sorting experiments⁷ using the 25 most commonly used plants as visual stimuli. The triad data will yield proximity values that can be used to perform a cluster analysis (Borgatti 1996). This analysis will indicate grouping, as well as test hypothesis 4: that common medicinal plant clusters are statistically significant (Ludwig and Reynolds 1988, SYSTAT 1996).

Lexical analysis of Tzeltal illness names (Berlin and Berlin 1996) indicates that they are divided into clusters based primarily on anatomical and physiological observations (e.g., diarrheas, coughs, fevers, dermatological conditions). Taxonomic lexical relations will be used to construct a proximity matrix of illness terms. This matrix will be tested for correlation with a plant proximity matrix developed from the triad sort data (Borgatti 1996) to test Hypothesis 5: that clusters of medicinal plants correlate with known illness clusters.

Attributes of medicinal plant groups will be determined by qualitative analysis of multidimensional scaling (MDS) plots derived from the triad tests (D'Andrade et al. 1972, Borgatti 1996). The attributes suggested by the distribution of items in the MDS plots will be cross-checked with attributes obtained from memory recall⁸ of ten men and ten women, and by asking them the question "why does this plant have the power to cure?" The centrality of species in the MDS plots (Borgatti 1994, Romney et al. 1997) will be used to test Hypothesis 6: that plant clusters include items that express cluster attributes in excess of other members.

Potential prototypical species will be ranked by their centrality in MDS plots. Frequency and order of plants within freelists will also be used to compute a list ranked by saliency (Borgatti 1996). The ranked lists will be tested for significant correlation⁹ to test Hypothesis 7: that prototypical items

derived from proximity values are predicted by higher saliency within freelists.

We are ultimately interested in determining whether prototypes enhance sharing of information and guide behavior. A student's t-test (Zar 1996) will be used to test for significant differences in agreement about each plant's name, use, and taste¹⁰ to test Hypothesis 8: that agreement about naming, use, and taste will be higher for plants identified as prototypes.

Comparative research will also be conducted in a community of Tzeltal who have migrated within the past 25 years from the highlands to the tropical lowlands where they have had to experiment with new plants to find cures¹¹. A random sample of 16 women and 16 men, stratified by ten-year age classes between 30 and 70, will be drawn from community census data to participate in interviews. Medicinal plant saliency in the lowland community will be determined by eliciting free lists of medicinal plant names. The 25 most salient species will be collected and prepared as herbarium vouchers and to use for triad and memory recall experiments with six women and 6 men as described above. Prototypical attributes will be determined by memory recall and multidimensional scaling of triads. Ranked correlation analysis of attributes from lowland and highland prototypes will be used to test hypothesis 9: that prototype attributes from the highlands have guided medicinal plant selection from the new flora. An alternative hypothesis is that sharing of knowledge with the original lowland inhabitants has led to new prototypical attributes.

Research Schedule (1 year)

Sept. 2000 Efforts during this month will include obtaining proper visas and permission to conduct research from communities and collecting and mounting the 60 most common medicinal plants of the highland community¹². Previous research (Berlin et al. 1974; Casagrande, unpubl. data) indicates that approximately 15 working days will be required to collect the specimens. Seven days will be allocated for decontamination, determination, and mounting vouchers at the ECOSUR herbarium.

Oct. 2000 The first highland plant transect survey will be conducted. Each walking of the three transects with an informant will require 1/2 day, indicating 16 person-days will be required for 32 participants. Thirty-one days are allocated to account for weather, "missed" interviews, and considerations for personal schedules of participants.

Nov. 2000 – Jan. 2001 These months will include extract preparation, free list elicitation, taste and visual stimuli interviews, and triad experiments in the highland community, as well as iterative data analysis. The 100 half-day interviews (including 20 triad sorts) will require approximately 70 days to complete. Twenty days are reserved for iterative data analysis.

Feb. - March 2001 Research will begin in the lowland community with freelist elicitation and collecting plants. Fifty days are allocated for obtaining permission to conduct research and 32 half-day interviews. Forty days are allocated for botanical collecting, and decontamination, determination, and mounting of vouchers at the ECOSUR herbarium.

April 2001 The second highland plant transect survey will be conducted.

May 2001 Triad tests in lowland community will be conducted. Fifteen days are allocated for the 12 triad sort experiments, and 15 for preliminary data analysis.

June 2001 The third highland plant transect survey will be conducted.

July – Aug. 2001 The final months will be dedicated to final curation of herbarium vouchers, preliminary data analysis, and writing of preliminary results. It is our ethical position that in addition to financial compensation for time, all research results are to be disseminated to participating communities. The Co-PI will present all final results at community meetings, as well as leave reports written in three languages (English, Spanish, and Tzeltal) with each participating community (cf. Casagrande and Guzmán 1998).

Research site

This research will be conducted among the Tzeltal Maya because they possess an extensive and well documented pharmacopoeia (Berlin and Berlin 1996) and most communities are relatively accessible. Migration from the highlands to lowlands within the past 25 years also provides a unique opportunity for comparative research and rigorous hypothesis testing.

Extensive research conducted on Tzeltal Maya medicinals (Berlin et al. 1974, Berlin and Berlin 1996, Brett 1994, Maffi 1996, Metzger and Williams 1964) provides an outstanding opportunity for advancing theoretical concepts by building on well documented and verified empirical observations. The current NIH-funded ICBG program *Drug Discovery and Biodiversity Among the Maya of Mexico*, a joint research project including the University of Georgia and ECOSUR, provides financial opportunities (see budget justification), as well as an intellectual atmosphere, for conducting doctoral dissertation research in collaboration with other researchers. In particular, several doctoral students will be in the field simultaneously, which will allow for healthy cross-fertilization of ideas and logistical cooperation. Finally, the library, office, computer, and herbarium facilities provided at ECOSUR represent important resources located close to the field research sites.

Conclusion

The relationships between current theories about medicinal plant selection, such as taste, proximity of plants to households, and cultural notions of efficacy need to be clarified. This proposal uses the concepts of domains and prototypes to understand how the biological and cultural aspects of plant selection interact with each other. We establish a methodological framework based on the analysis of plant attributes for research into Tzeltal Maya medicinal plant selection that can also be applied to other cultures. Because attributes are used to link multiple cognitive domains, both biological and cultural-based attributes can be accommodated in this approach. This will contribute significantly to cognitive theory regarding how biological and cultural domains are combined into behavioral processes.

Traditional pharmacopoeia reflect centuries of observations about plant ecology and the physiological effects of plants on humans (Schultes and von Reis 1995). Unfortunately, modern science and technology have devalued such knowledge (Etkin 1988, Lozoya 1994). Alternatively, the marketing of herbal remedies and international medicinal plant research that compensates indigenous people for their knowledge and long-term plant production may provide economic opportunities while promoting biological and cultural diversity (Balick 1994, Holmstedt 1995, Masood 1998, Suffness et al. 1995). Medicinal plant research also provides the biomedical community with the opportunity to return information to indigenous people so that they may improve their health practices (Elisabetsky 1986). In addition to theoretical development, the research proposed here is intended to help develop the framework needed to enhance conservation and human health programs that seek to break the link between poverty and the loss of biological and cultural diversity.

Literature Cited

- Alcorn, J. B. 1981. Huastec noncrop resource management: Implications for prehistoric rain forest management. *Human Ecology* 9(4): 395-417.
- Balick, M. J. 1994. Ethnobotany, drug development and biodiversity conservation: Exploring the linkages. Pp. 4-18 in *Ethnobotany and the Search for New Drugs*, G. Prance (ed.), Ciba Foundation Symposium No. 185. John Wiley and Sons, New York.
- Barsh, R. 1997. The epistemology of traditional healing systems. *Human Organization* 56(1):28-37.
- Berlin, B. 1992. *Ethnobiological classification: Principles of categorization of plants and animals in traditional*

- societies*. Princeton University Press, Princeton NJ.
- Berlin, B. and E.A. Berlin. 1994. Anthropological Issues in Medical Anthropology. Pp. 240-258 in *Ethnobotany and the Search for New Drugs*, G. Prance (ed.), Ciba Foundation Symposium No. 185. John Wiley and Sons, New York.
- Berlin, B., D. E. Breedlove and P. H. Raven. 1974. *Principles of Tzeltal plant classification*. Academic Press, New York.
- Berlin, E. A. and B. Berlin. 1996. *Medical ethnobiology of the Highland Maya of Chiapas, Mexico: The gastrointestinal diseases*. Princeton University Press, Princeton NJ.
- Borgatti, S. P. 1994. Cultural domain analysis. *Journal of Quantitative Anthropology* 4:261-278.
- Borgatti, S. P. 1996. *ANTHROPAC 4.0 methods guide*. Analytic Technologies, Natick MA.
- Boster, J. S. 1988. Natural sources of internal category structure: Typicality, familiarity, and similarity of birds. *Memory and Cognition* 16(3):258-270.
- Breedlove, D. E. 1981. *Part I: Introduction to the flora of Chiapas*. California Academy of Sciences, San Francisco.
- Brett, J. A. 1994. *Medical plant selection criteria among the Tzeltal Maya of highland Chiapas, Mexico*. Ph.D. Dissertation, San Francisco, Univ. California.
- Browner, C. H., B. R. Ortiz de Montellano, and A. J. Rubel. 1988. A methodology for cross-cultural ethnomedical research. *Current Anthropology* 29(5):681-702.
- Burton, M. and S. B. Nerlove. 1976. Balanced designs for triad tests: Two examples from English. *Social Science Research* 5:247-267.
- Caceres, A., O. Cano, B. Samayoa and L. Aguilar. 1990. Plants used in Guatemala for the treatment of gastrointestinal disorders. 1. Screening of 84 plants against enterobacteria. *J. Ethnopharmacology* 30:55-73.
- Caniago, I. and S. Siebert. 1998. Medicinal plant ecology, knowledge and conservation in Kalimantan, Indonesia. *Economic Botany* 52(3):229-250.
- Casagrande, D. G. 1996. A value based policy approach: The case of urban salt marsh restoration. *Coastal Management* 24:327-337.
- Casagrande, D. G. 1997. Values, perceptions and restoration goals. In *Restoration of an urban salt marsh: An interdisciplinary approach*, D. Casagrande (ed.), Bulletin No. 100, Yale School of Forestry and Environmental Studies, New Haven CT.
- Casagrande, D. 1999. Tzeltal knowledge of relict primary-forest: Implications for conservation. Paper presented at the Annual Meeting of the Society for Applied Anthropology, Tucson AZ.
- Casagrande, D. G. and A. M. Guzmán. 1998. *Wamaletik ja te ta witsetik ta Matsam (Plants and birds of the summits of Matsam)*. Report submitted to the Matsam Comité Escolar and the Municipality of Tenejapa, Chiapas, Mexico.
- Casagrande, D. G. and S. R. Beissinger. 1997. Evaluation of four methods for estimating parrot population size. *Condor* 99:445-457.
- Coley, J. D., D. L. Medin and S. Atran. 1997. Does rank have its privilege? Inductive inferences within folkbiological taxonomies. *Cognition* 64:73-112.
- D'Andrade, R., N. Quinn, S. Nerlove, and A. K. Romney. 1972. Categories of disease in American-English and Mexican-Spanish. In *Multidimensional Scaling*, Vol 2. A.K. Romney, R. Shepard, and S. B. Nerlove, (eds.). Seminar Press, New York.
- Elisabetsky, E. 1986. New directions in ethnopharmacology. *Journal of Ethnobiology* 6(1): 121-128.
- Etkin, N. L. 1988. Cultural constructions of efficacy. Pp. 299-326 in *The context of medicines in developing countries*. Geest, S. v. d. and R. Whyte (eds.), Kluwer Academic Publishers.
- Foster, G. M. 1994. *Hippocrates' Latin American legacy: Humoral medicine in the New World*. Gordon and Breach, Langhorne PA.
- Garro, L. C. 1986. Intracultural variation in folk medical knowledge: A comparison between curers and noncurers. *American Anthropologist* 88:351-370.
- Gelman, S. A. 1988. The development of induction within natural kind and artifact category. *Cognitive*

- Psychology* 20:65-95.
- Holmstedt, B. R. 1995. Historical perspective and future of ethnopharmacology. Pp. 320-337 in *Ethnobotany: Evolution of a discipline*, R. E. Schultes and S. v. Reis (eds.). Dioscorides Press, Portland OR.
- Hunn, E. 1982. The utilitarian factor in folk biological classification. *American Anthropologist* 84:830-847.
- Iwu, M. M. 1986. Empirical investigations of dietary plants used in Igbo ethnomedicine. Pp. 131-150 in *Plants in indigenous medicine & diet: Biobehavioral approaches*, Etkin, N. L. (ed.), Redgrave Publishing Co., Bedford Hills NY.
- Johns, T. 1990. *With bitter herbs they shall eat it: Chemical ecology and the origins of human diet and medicine*. University of Arizona Press, Tucson AZ.
- Kay, M. 1979. Lexemic change and semantic shift in disease names. *Culture, Medicine and Psychiatry* 3:73-94.
- Keil, F. C. 1994. The birth and nurturance of concepts by domains: The origins of concepts of living things. Pp. 234-254 in *Mapping the mind: Domain specificity in cognition and culture*, Hirschfeld, L. A. and S. A. Gelman (eds.), Cambridge University Press, New York.
- Kidwell, C. S. 1991. Aztec and European medicine in the New World, 1521-1600. Pp. 20-31 in *The anthropology of medicine*, Romanucci-Ross, L., D. E. Moerman and L. R. Tancredi (eds.), Bergin and Garvey, New York.
- Koshimizu, K., H. Ohigashi, M. A. Huffman, T. Nishida and H. Takasaki. 1993. Physiological activities and the active constituents of potentially medicinal plants used by wild chimpanzees of the Mahale Mountains, Tanzania. *International Journal of Primatology* 14(2):345-356.
- Lewis, C. and D. G. Casagrande. 1997. Using avian communities to assess salt marsh restoration. In *Restoration of an urban salt marsh: An interdisciplinary approach*, D. Casagrande (ed.), Bulletin No. 100, Yale School of Forestry and Environmental Studies, New Haven, CT.
- Lozoya, X. 1994. Two decades of Mexican ethnobotany and research on plant derived drugs. Pp. 130-163 in *Ethnobotany and the search for new drugs*. D. J. Chadwick and J. Marsh. Chichester (eds.), John Wiley and Sons, UK.
- Ludwig, J. A. and J. F. Reynolds. 1988. *Statistical Ecology*. John Wiley and Sons, New York.
- MacLaurey, R. E. 1991. Prototypes revisited. *Annual Review of Anthropology* 20:55-74.
- Maffi, L. 1996. Liquor and Medicine: A Mayan case study in diachronic semantics. *Journal of Linguistic Anthropology* 6(1):27-46.
- Markman, E. M. 1989. *Categorization and naming in children*. MIT Press, Cambridge MA.
- Masood, E. 1998. A formula for indigenous involvement. *Nature* 392: 539.
- Mervis, C. B., J. Catlin and E. Rosch. 1976. Relationships among goodness-of-example, category norms, and word frequency. *Bulletin of the Psychonomic Society* (73):283-284.
- Metzger, D., and G. Williams. 1963. Tenejapa medicine I: The curer. *Southwestern Journal of Anthropology* 19: 216-234.
- Miller, G. A. 1956. The magical number seven, plus or minus two: some limits on our capacity for processing information. *The Psychological Review* 63(2):81-97.
- Moerman, D. E. 1989. Poisoned apples and honeysuckles: The medicinal plants of native America. *Medical Anthropology Quarterly* 3: 52-61.
- Moerman, D. E. 1998. *What native American people knew about medicinal plants and why*. Paper presented at the Annual Meeting of the American Anthropological Association, Philadelphia PA.
- Phillips, O., A. H. Gentry, C. Reynel, P. Wilkin and C. Gálvez-Durand. 1994. Quantitative ethnobotany and amazonian conservation. *Conservation Biology* 8(1):225-248.
- Rodrigues, E., G., H. N. Towers, and J. C. Mitchell. 1976. Biological activities of sesquiterpene lactones. *Phytochemistry* 15: 1573-1580.
- Romney, A. K., C. C. Moore, and C. D. Rusch. 1997. Cultural universals: Measuring the semantic structure of emotion terms in English and Japanese. *Proceedings of the National Academy of Sciences of The United States of America* 94(10):5489-5494.
- Romney, A. K., S. C. Weller and W. H. Batchelder. 1986. Culture as consensus: A theory of culture and informant accuracy. *American Anthropologist* 88:313-338.

- Rosch, E. 1978. Principles of categorization. Pp. 28-49 *Cognition and categorization*, in E. Rosch and B. Lloyd (eds.), Lawrence Erlbaum Assoc., Hillsdale NJ.
- Rosch, E. and C. B. Mervis. 1975. Family resemblances: Studies in the internal structure of categories. *Cognitive Psychology* 7:573-605.
- Rosch, E., C. B. Mervis, W. D. Gray, D. M. Johnson and P. Boyes-Braem. 1976. Basic objects in natural categories. *Cognitive Psychology* 8:382-439.
- Schmeda-Hirschmann, G. and E. Bordas. 1990. Paraguayan Medicinal Compositae. *J. Ethnopharmacology* 28:163-171.
- Schultes and V. Reis (eds.). 1995. *Ethnobotany: Evolution of discipline*. Dioscorides Press, Portland, OR.
- Shepard, G. H. 1999. *Pharmacognosy and the senses in two Amazonian societies*. Ph.D. Dissertation, Berkeley, University of California.
- Stepp, John R. 1998. Ethnobiología en los altos de Chiapas: Una revisión de la distribución de las plantas medicinales. Poceedings of the conference *Geografía aplicada y desarrollo*, Quito, Ecuador, Centro Panamerica de Estudios e Investigaciones Geográficas.
- Stross, B. 1973. Aquisition of botanical terminology by Tzeltal children. Pp. 107-141 in *Meaning in Mayan languages*, Edmonson, M. S. (ed.), Mouton, The Hague, Netherlands.
- Suffness, M, G.M. Cragg. M.R. Grever, F.J. Grifo, G. Johnson, J. A. Mead, S. A. Schepartz, J.M. Venditti, and M. Wolpert. 1995. The National-Cooperative-Natural-Products-Drug-Discovery-Group (NCNPDDG) and International-Cooperative-Biodiversity-Group (ICBG) programs. *International Journal Of Pharmacognosy* 33:5-16.
- SYSTAT. 1996. *SYSTAT 6.0 Statistics Manual*. SPSS Inc., Chicago IL.
- Trotter, R. T. and M. H. Logan. 1986. Informant consensus: A new approach for identifying potentially effective medicinal plants. Pp. 91-112 in *Plants in indigenous medicine and diet: Biobehavioral approaches*, Etkin, N. L. (ed.), Redgrave Publishing Co., Bedford Hills NY.
- Wrangham, R. W. and J. Goodall. 1989. Chimpanzee use of medicinal leaves. Pp. 22-37 in *Understanding Chimpanzees*, Murquardt, P. G. H. a. L. A. (ed.), Harvard University Press, Cambridge MA.
- Young, A. 1981. When rational men fall sick: an inquiry into some assumptions made by medical anthropologists. *Culture, medicine and psychiatry* 5:317-335.
- Zar, J. H. 1996. *Biostatistical Analysis*. Prentice Hall, Upper Saddle River NJ.

(Footnotes)

- ¹ The dried and pressed herbarium specimens will be used for interviews because previous studies have shown that they convey as much information to interviewees as fresh specimens while providing significant logistic advantages (Berlin et al. 1974, Berlin and Berlin 1996).
- ² Preliminary research has shown that consensus about medicinal plant use can be established with as few as 15 participants for common medicinal plants.
- ³ Presence vs. absence of plant characteristics will be obtained from each interviewee for each plant. This will yield dichotomous nominal-scale data (Zar 1996). The Pearson coefficient will be used to compute correlation between characters (SYSTAT 1996), such as presence of bitterness or illness class associated with the plant by the interviewee.
- ⁴ Using the Pearson coefficient of correlation.
- ⁵ Here we are more interested in agreement than the culturally correct answer. In this case, the Shannon Index of Information (Ludwig and Reynolds 1988) can serve as a more parsimonious metric of agreement than Romney et al.'s (1986) consensus analysis, because the Shannon Index does not weight responses by informant expertise.
- ⁶ A Spearman-ranked correlation matrix will be used since these will be ordinal data (Zar 1996).
- ⁷ In this experiment, participants are normally presented with all possible combinations of stimuli in sets of three and are asked to judge which of the three is different. We will use a Lambda two balanced-incomplete-block design (Burton and Nerlove 1976), which reduces the number of triads presented to a participant to 200 for 25 items.
- ⁸ Rosch et al. 1976 found that simply asking interviewees to recall from memory why an item was a good example of the set yielded a reliable list of prototypical attributes.
- ⁹ Using Spearman-ranked correlation.
- ¹⁰ Calculated using the Shannon index of information (Ludwig and Reynolds 1988).
- ¹¹ During the summer of 1999 Casagrande visited two communities in the lowland rainforest that were settled by highland Tzeltal Maya approximately 25 years ago during a government program of incentives to colonize the southern frontier. Residents were very interested in this research and the flora was sufficiently different to enable the experiment proposed here. Breedlove (1981)

has noted a nearly complete difference in the flora between the temperate highlands and tropical lowlands of Chiapas.

¹² Many of these species have already been collected for this purpose. Effort will be made to find additional specimens in flower, but this is not essential because most Tzeltal people can recognize the common medicinal plants in sterile condition (Casagrande, unpubl. data).