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Changing Ethnobotanical Knowledge of the Roviana People, Solomon Islands: Quantitative Approaches to its Correlation with Modernization

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Abstract This study examines the acculturation of ethnobotanical knowledge in association with modernization by analyzing similarities and differences within a language group, the Roviana people of the Solomon Islands. Cultural consensus analysis and evaluation of either village-level or individual-level modernity were performed for seven villages. In one modernized and one less modernized village, detailed socioeconomic data at the individual level were collected. Intervillage variation of knowledge correlated with modernity only when the villages were referenced to the less modernized villages, while there was no correlation when the most modernized village was used as the base knowledge. An informant's knowledge in the less modernized village was affected by socioeconomic factors, but this was not observed in the modernized village. From these results, I suggest that modern knowledge is easily integrated into the ethnobotanical knowledge system but is not directly related to the loss of indigenous botanical knowledge.

Keywords Ethnobotany · Modernity score · Acculturation · New Georgia · Melanesia

Introduction

Every society has developed indigenous botanical knowledge (hereafter called ethnobotanical knowledge) through its dynamic interactions with its surrounding environment (Conklin 1972; Berlin et al. 1973; Balick and Cox 1996; Townsend 2000). Such knowledge is valuable not only for the survival of a particular society, but also more generally, since it offers potential uses of genetic resources that are new to other parts of the world. Several reports, however, have indicated that the spread of modernization has reduced such ethnobotanical knowledge (Romanucci-Ross *et al.* 1997; Lewis 2003; Case *et al.* 2005; Reyes-Garcia *et al.* 2007). Factors influencing this loss of knowledge include distance from towns and availability of natural resources (Prance *et al.* 1987; Ladio and Lozada 2004; Reyes-García *et al.* 2005; Case *et al.* 2005), the degree of integration of western goods and market-oriented knowledge (Bennett and Prance 2000; Benz *et al.* 2000; Ragone *et al.* 2001; Zent 2001; Reyes-Garcia *et al.* 2007), and age, gender, and ethnicity (Boster 1986; Atran *et al.* 2002; Caniago and Siebert 1998; Case *et al.* 2005). Cultural consensus analysis and the calculation of cultural competence have been developed as suitable methods for evaluating how much knowledge is similar or dissimilar between or within populations, and to what extent each informant shares knowledge (Romney *et al.* 1986; Atran *et al.* 1999; Romney 1999). When the similarities of knowledge are quantified, statistical analyses can be performed to detect any relationship to differences in modernity.

In Melanesia, contact with Europeans caused rapid socioeconomic, demographic, and cultural changes (Dennett and Connell 1988; Aswani 2004) that taken together reflect degrees of modernity. For instance, modernity, as measured by cash income, occupation, distance to town, and possession of modern goods, was found to be a variable that was correlated with life-style and health related changes (e.g., cardiovascular diseases and obesity; King and Collins 1989; Hodge *et al.* 1995). However, modernity has not been explored as a factor in changing ethnobotanical knowledge.

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The Solomon Islands, like other countries in Melanesia, are comprised of a number of different language populations. The members of each population generally share a similar cultural background and ecological settings (Bennett 2001; Fraenkel 2004). On the other hand, even within a population, the degree of modernization—i.e., the progress of a cash economy, population expansion, availability of modern goods and infrastructure, and exposure to Western culture—varies from one village to another (Hviding and Bayliss-Smith 2000; Aswani 2004). This study is designed to determine the extent to which change in ethnobotanical knowledge is correlated with modernization by analyzing the similarities and differences within a particular language group of the Solomon Islands. Special attention was paid to detecting the factors that affect individual-level ethnobotanical knowledge by using a model that includes variables that are relevant to modernity, ecological settings, and individual characteristics.

Regional Context

The Summer Institute of Linguistics (SIL) identified 70 living languages (Gordon 2005) in the Solomon Islands, most of which are not mutually intelligible. Although the national language has been English since British colonization, and Solomon pidgin (the lingua franca of the Solomon Islands) is recognized as a common language, people still speak their own local languages. Pidgin is used for communication with other language speakers and English is rarely spoken. Migration and exogamic marriage between different language populations have increased recently, but apparently this has not changed the situation.

Roviana is located in the southwestern part of New Georgia Island and the nearby small islets, which extend for 150 km from Konggu Kalena Bay to Parara (Vonavona) Island in the Western Province of the Solomon Islands (Fig. 1). An extensive lowland tropical rain forest and a relatively small swamp forest and mangroves originally covered Roviana (Wall and Hansell 1975). Now, however, subsistence gardens, abandoned second-growth forest, and coconut plantations on the coast have made the landscape a mosaic of various land covers near the settlements. The Roviana people, numbering approximately 12,000 (Solomon Islands Government 2000), are semi-subsistence farmers devoting most of their time to cultivation of tuberous crops and to fishing, although they also spend considerable time earning cash (Furusawa and Ohtsuka 2006), mainly from collecting and selling marine resources in rural waged labor, or managing small retail stores in periurban villages.

Roviana is one of the four languages spoken in New Georgia Island (Fig. 1). Although Roviana and the three

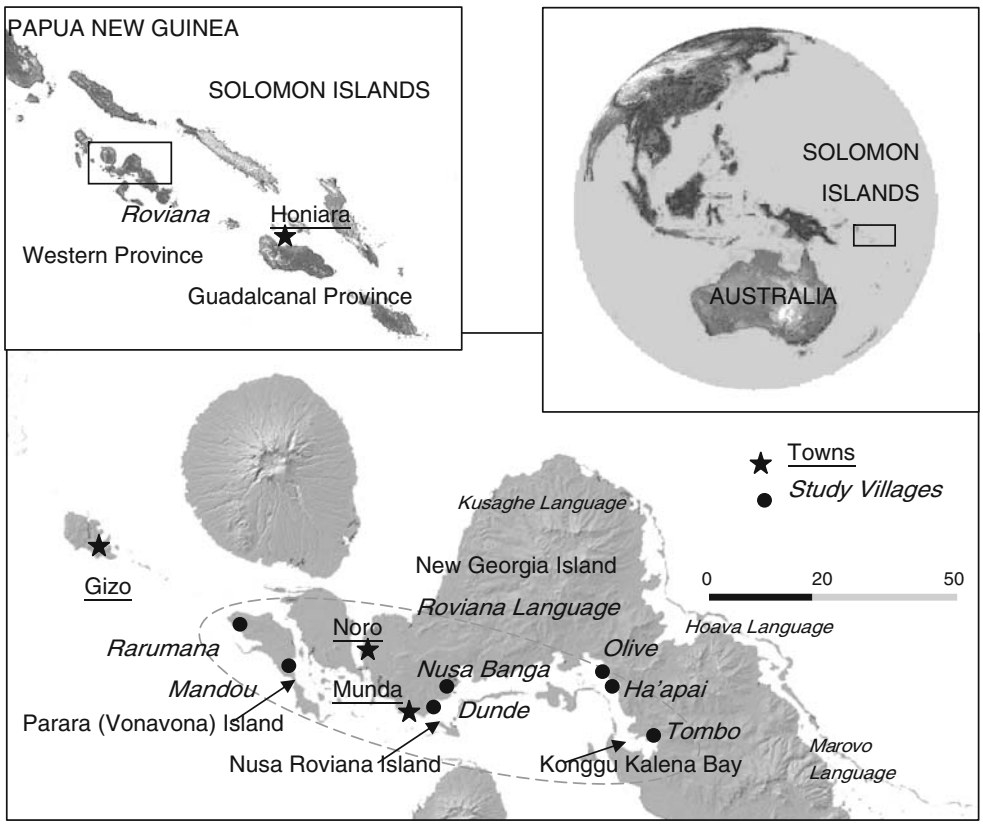


Fig. 1 Locations of the study villages in Roviana, Western Province, Solomon Islands (The map was compiled from data available at GLCF (Global Land Cover Facility, The University of Maryland)

other languages—Kusaghe, Marovo, and Hoava—belong to the West New Georgian language group and exhibit some overlaps in vocabulary and grammar, they are largely mutually unintelligible (Gordon 2005) and the vernacular names of plants differ among them (see Hviding 2005). Oral histories relate that all Roviana clans are descended from one ancestor (Aswani 1999, 2000). Archaeological evidence has revealed that they migrated from Nusa Roviana Island, a small island geographically located in central Roviana, in the nineteenth century (Fig. 1; Sheppard *et al.* 2000).

Although modernization began in the nineteenth century with the first European voyagers, it intensified after the arrival of a Christian mission in Munda in 1902 (Fig. 1). Since then, Munda developed as a township. The addition of an airstrip built during World War II further contributed to the commercialization of this area, resulting in the present population of 3,000. In 1985, an international port was constructed in Noro, 10 km north of Munda. The provincial capital Gizo, 50 km west of Munda is the second largest town in the country. In this study, these three commercial centers are referred to as towns. Villages located near Munda, Noro, or Gizo have generally been more affected by the cash economy and western goods (a majority of these villagers live in western-style permanent houses) than villages in the east in the inner lagoon areas remote from the towns; these villagers generally live in houses made from sago palm leaves (Furusawa 2006; Furusawa and Ohtsuka 2006).

Commercial logging operations by overseas companies began in the western part of Roviana in the 1960s, although most clans in the eastern part disallowed logging until the 1980s. The impact of logging was felt not only on the forest environment but also on the modernization of lifestyles, because such operations provided the villagers with employment, royalty money, and materials for infrastructure such as schools and first-aid stations (Furusawa *et al.* 2004; Furusawa and Ohtsuka 2006). Therefore, the 20 years difference in time of the onset of logging operations increased the differences in modernity between the eastern and western communities, which nevertheless share the same culture and similar ecological settings.

Conceptual Framework

This study is based on a cultural consensus analysis that reveals whether or not a single factor is shared by all informants, and to what extent that factor affects each individual (Romney *et al.* 1986). Romney (1999) assumed that culture is knowledge that is both shared and learned. Cultural consensus theory was thus developed to describe and measure the extent to which the informants share cultural beliefs. The cultural consensus model assumes that the correspondence between the answers of any two respondents is a function of the extent to which each answer is correlated with some truth. It is a mathematical model that shows whether a single underlying factor exists in informants' responses to interview questions, and to what extent each informant has contributed to this factor. The single factor, which is a mathematical product that is virtually referred to as culture, is assumed to exist when the ratio of eigenvectors of the first principal component to the second is markedly large (more than three times), the proportion of the first eigenvector explains most of the variation, and the factor loadings on all questions are positive as a result of the analysis of an adjusted informant-by-informant agreement matrix (Romney *et al.* 1986; Borgatti 1996). The informant's cultural competence is the factor-loading score of the first principal component. The word knowledge refers virtually to the informants' responses to the ethnobotanical questions, but cultural competence, which is the extent to which each informant's knowledge coincides with the culture (single factor), is a good measure because it is a score from which random effects and between-question bias have been removed.

The other quantitative variable is a modernity score, and it is defined as the first principal component of the different kinds of variables that measure modernity (Perz 2003): the intercorrelations among different variables are adjusted by calculating principal components. Several scholars have recognized that modernization in Melanesia is strongly related to the cash economy, population growth (as a result of improved hygiene and nutrition, and the size of the potential economic market), and the availability of modern materials and infrastructures, such as schools, first-aid posts, and radiophones (Dennett and Connell 1988; King and Collins 1989; Hodge *et al.* 1995). In this study, seven villages, which varied in the extent of their modernization, were selected and the modernity score was calculated for each. For instance, Dunde village is located just next to Munda township while Rarumana is near the provincial capital Gizo. Tombo, on the other hand, is less accessible from surrounding townships. The validity of a factor as a proxy of modernity in this study is assumed when all the variables are positively correlated with the first component, and when the factor explains most of the variations. In this study, the modernity score is a first principal component of the variables relevant to demographic and economic expansion, and to the extent to which the community is exposed to western materials and infrastructure.

The correlation between extent of ethnobotanical knowledge and degree of modernization is examined through three analyses. I first examine whether there is a shared ethnobotanical culture among the Roviana. The study is based on the assumption that the Roviana people

are from the same cultural origin and have similarly experienced acculturation. Second, the hypothesis that change in ethnobotanical knowledge is caused by modernization is analyzed as the similarities or dissimilarities of knowledge between any two villages correlated with the differences in modernity between them. The average value of the adjusted agreement of answers of all pairs of informants between two villages was used as the measure of knowledge similarities. It should be noted that this is mathematically similar to the average cultural competence of all informants in the paired villages. In addition, differences in estimated modernity scores between two paired villages are used as measures for differences in modernity, so that the correlation between the similarity/dissimilarity of knowledge and that of modernity can be analyzed. Note that the change in knowledge is reflected as the similarity of village informants' knowledge to that of villagers in the least-modernized village. In the cultural consensus analysis, similarities of knowledge are measurable, but villagers' knowledge itself is not measurable unless referenced to a base village.

Third, this study also examines the effects of modernity on ethnobotanical knowledge at the individual level. Individual knowledge is defined as cultural competence (factor loadings of each informant). For this purpose, a model including the following factors was used: (a) individual-level basic variables (e.g., gender , age), (b) household-level life-stage variables (e.g., years since the marriage of the household head and the number of consumers and producers), (c) variables of modernization at household level (e.g., cash income), (d) ecological variables (e.g., vegetation). This model is based on a model proposed by Reyes-Garcia *et al.* (2007, 2005).

In summary, this study examines the following three hypotheses:

Hypothesis 1: Shared ethnobotanical knowledge exists. In the working hypothesis, the answers of all informants are explained by a single underlying factor, which is detected by principal component analysis.

Hypothesis 2: Inter-village variation of knowledge that is not solely explained by shared knowledge is caused by modernization. In the working hypothesis, the similarity of informants' answers among villagers is correlated with the difference in modernity.

Hypothesis 3: Variations of individual knowledge that are not solely explained by village-level shared knowledge are caused by individual-level modernization. In the working hypothesis, cultural competence (individual factor loading) is correlated with individual-level modernity variables when other factors are adjusted.

Methods

This study consisted of two phases of data collection: panel research (from July to November 2003) and cross-sectional research (from December 2003 to February 2004); fieldwork, including collection and identification of plants, had been conducted since 2001.

The panel research was conducted in a modernized village located near Munda township (Dunde Village, 1.4 km to Munda town and 1,065 residents in 202 households in 2003) and a less-modernized village located in the interior eastern part of Roviana Lagoon (Olive Village, 22.3 km to Munda and 357 residents in 65 households). Randomly selected households were invited to participate in the study; 17 households (114 members) and 15 households (112 members) from Dunde and Olive villages, respectively, participated. In the panel research, plant-use behaviors were observed in order to list plants useful to the villagers, in addition to demographic, socioeconomic, and ecological data collection at individual and household levels.

For cross-sectional research, I selected the villages of Tombo, Ha'apai, Nusa Banga, Mandou, and Rarumana, in addition to Dunde and Olive (Fig. 1). These seven villages exhibit different stages of modernization within Roviana (Table 1). From Tombo, a small village with eight households at the eastern end of Roviana (38.7 km to Munda), only six households participated because two households were absent during the study period. Ten households were randomly selected from Ha'apai (32.7 km to Munda, 20 households in January 2004), Nusa Banga (7.7 km to Munda and 64 households), and Rarumana (22.3 km to Gizo and 103 households). In Mandou (11.8 km to Noro and 105 households), 12 households were randomly selected. For each household, if either the male or the female head (e.g., male head or his spouse, widowed female or her first son) was from outside the village, the other was automatically selected as the informant, while if both were from the village, only one was randomly selected. Note that at least one of the heads had to have been born in the village, because, customarily, couples from outside the village do not hold rights to land, and are not allowed to settle in the area. Interviews were conducted in the Roviana language.

Plant List

In the panel research, all food consumed by household members throughout the day was recorded for 1 week in

Table 1 Modernity features of the study villages in 2004

	Dunde	Rarumana	Ha'apai	Mandou	Nusa Banga	Olive	Tombo
Number of households	202	103	20	105	64	65	8
Year of village foundation	1891	1915	1952	1916	1957	1972	1972
Distance to the nearest town (km)[a]	1.39	22.31	32.74	11.78	7.73	31.73	38.71
Number of modern-style houses per HH	0.86	0.74	0.85	0.50	0.30	0.28	0.63
Number of rainwater tanks per HH	0.93	0.96	0.30	0.57	0.36	0.17	0.38
Number of outboard motors per HH	0.33	0.28	0.45	0.17	0.17	0.11	0.25
Number of chainsaws per HH	0.24	0.16	0.10	0.04	0.05	0.05	0.13
Number of generators per HH	0.08	0.07	0.05	0.04	0.03	0.03	0
Number of stores per HH	0.05	0.07	0.05	0.04	0.02	0.03	0
Water line (yes=1; no=0)	1	0	1	0	1	0	0
Aidpost (yes=1; no=0)	1	1	0	0	0	0	0
Primary school (yes=1; no=0)	1	1	1	1	0	1	0
Radiophone (yes=1; no=0)	1	1	1	1	0	0	0
Development project (yes=1; no=0) [b]	1	1	1	0	0	1	0
Modernity score[c]	4.36	2.66	0.35	0.11	−2.09	−2.45	−2.94

[a] Distance to the provincial capital (Gizo), port town (Noro), or airfield (Munda), measured using geo-referenced Landsat ETM+ image

[b] Rural development projects by NGO or foreign governments or scholars (e.g., EU, Taiwan, and UCSB)

[c] Score in first principal component; non-metric variables were transformed using PROC PRINQUAL of SAS software.

order to list the edible plants. If observation was not possible, e.g., when a participant ate food outside the village, the information was obtained though interviews. All the species used for building houses were recorded, and I obtained their vernacular names from the builders by pointing them out. I enquired about illnesses and their treatments every evening for 28 days, in order to record the plants used for treatment. All firewood brought to the participants' homes was recorded every day for 1 week. Informants were asked to describe the morphology and vegetation of each plant they used, and to provide its local name. During this process, participants were informed that their answers would be analyzed anonymously, and that their personal information would remain undisclosed. In total, 198 local vernacular names were listed, of which 98 were used in both villages. Twenty plants used in both villages were randomly selected for structured interviews (Table 2). Every participant in the seven cross-sectional research villages was asked each plant's use or multiple uses for (1) food, (2) building, (3) medicine, (4) tools, (5) magic/ritual, or (6) cash income (Table 2). Plant specimens collected in the field were identified at the Forestry School, Poitete (Mr. Myknee Qusa) and Forestry Station, Munda (Mr. Basile Gua), Ministry of Forest, Environment, and Conservation of the Solomon Islands.

Modernity Variables

For the seven villages in the cross-sectional survey, 14 modernity variables were identified, which were expected to reflect the cash economy, population growth (improved hygiene and nutrition, as well as the size of the potential economic market), and the availability of modern materials and infrastructures. The items (the reasons for the inclusion of the item are in parentheses) were (1) number of households (population size and a control for those variables calculated as a proportion of the total number of household), (2) year of foundation of the village (length of village development), (3) direct distance to the nearest town (Munda, Noro, or Gizo: Fig. 1; kilometers measured on georeferenced LANDSAT ETM + image; accessibility to western materials and commercial centers), (4) proportion of households with western-style permanent houses (e.g., built from timber, and with metal roofs; preference for western lifestyle and possession of western materials), (5) number of rainwater tanks per household (preference for western lifestyle and possession of western materials), (6) number of outboard motors per household (preference for western lifestyle, high economic status, and accessibility to commercial centers; because the study villages were coastal villages without a road connecting to town), (7) number of chainsaws per household (possession of western materials and high economic status), (8) number of generators per household (possession of western materials and high economic status), (9) number of stores divided by number of households (access to western materials and progress of cash economy), (10) existence of water supply (yes=1, no=0; availability of western infrastructure), (11) existence of a first-aid station (yes=1, no=0; availability of western infrastructure), (12) existence of a primary school (yes=1,

Table 2 List of plants used in the interview

Scientific name	English name	Roviana name	Uses observed[a]
Bambusa spp.	Bamboo	Beti	B, T
Pemphis acidula J.R. & G. Forst.		Bobogele	B, T
Calophyllum inophyllum L./*C. kajewskii* A.C.Sm./*C. vitiense* Turill	Alexandrian laurel	Buni	B, T
Citrullus lanatus (Thunb.) Mansf.	Watermelon	Deri	Fd
Averrhoa carambola L.	Star fruit	Opiti	Fd
Cyrtosperma chamissionis (Schott) Merr.	Giant swamp taro	Gohere (gorehe)	Fd
Mentha arvensis L.	Mint	Habe	M, T
Dillenia ingens Burtt		Hebere	B, Fl
Syzygium sp.		Hipahipala	B, Fl
Syzygium malaccense Merr. et Perry	Malay apple	Hipala	Fd
Artocarpus heterophyllus Lamk.	Jack fruit	Beta	Fd
Palaquium erythrospermum Lamk.		Paloto	B, Fl
Ananus comosus (L.) Merr.	Pineapple	Paenapolo	Fd
Cucurbita moschata (Duch. ex Lamk.) Duch. ex. Poir.	Pumpkin	Pamuken	Fd
Pometia pinnata Forst. f.	Taun	Qema	B, Fl, T
Tectona grandis L.	Teak	Tiki	T
Canarium salomonense Burtt		Tovinia	Fo, M
Vitex cofassus Reinw. ex Bl.	Vitex	Vasara	B, Fl, T
Galearia celebica Koord.		Zizito	M
Premna corymbosa (Burm. F.) R. & W.		Zovi	B, M, T

[a] Observation of dietary habits, garden crops, housing styles, treatment for illness, collection of fuels, and tools owned in Dunde and Olive villages
Fd food, *B* building material, *M* medicine, *Fl* fuel, *T* tool

no=0; availability of western infrastructure and access to western eduction system), (13) presence of radios or telephones (yes=1, no=0; availability of western infrastructure), and (14) acceptance of foreign aid projects (i.e., rice cultivation by the Republic of China (Taiwan), seaweed cultivation by the European Union, and resource management and community development by University of California, Santa Barbara (Aswani and Lauer 2006; Aswani *et al.* 2007); yes=1, no=0; availability of western infrastructure and access to western knowledge). These variables reflected modernization events (exposure to market economy, population growth and urbanization, governmental services, contact with modern education) in the Western Solomon Islands, and were chosen based on field interviews and observation (unpublished document of the project "Harmonization of Rural Development and the Community Welfare," led by Ryutaro Ohtsuka). All these variables were transformed and combined into a single scale by principal component analysis.

Household- and Individual-Level Characteristics

In the panel research, male and female household heads were interviewed on individual and household information. Dates of births and marriage were obtained and official birth and marriage certificates were referred to during the interviews.

The consumer unit (CU) was defined as the sum of each individual's energy requirements based on body weight (Umezaki *et al.* 2000; FAO/WHO/UNU 2004); the CU of an adult male with average body weight (66.5 kg) was defined as 1.0, and the value for each individual was calculated on the basis of relative energy requirements taking gender, age, body weight, and reproductive status into account. Food energy requirements of lactating or pregnant women were assumed to be 2,100, or 850 kJ higher than those of non-lactating and non-pregnant women of the same age and body weight. The producer unit (PU) was defined as the number of adults (18 years of age or older) in the household. Every evening for 28 days participating households were visited, and all members were asked to report all cash income and its source for the previous 24 h; this interview was conducted after obtaining informed consent that included the provision that all personal information would be anonymous and not available to the public. Net income was calculated based on the amounts earned and expended for necessities. Every day for 14 days, the participating households were visited every 1 to 2 h from 6 A.M. to 10 P.M. All crop yields brought to the households were measured, and the total energy obtained per day was calculated in MJ. During the same period, the gardens cultivated by each household were visited and measured using a tape measure and clinometer. For more

detailed descriptions of the methods, please refer to Furusawa and Ohtsuka (2006).

Based on these data, the following variables were used in this study:

(a) Individual-level basic characteristics: (a1) gender, (a2) age (years)
(b) Household-level basic characteristics: (b1) duration of marriage (years), (b2) CU/PU
(c) Modernity: (c1) total amount of cash income (logarithm of SI$), (c2) proportion of income from wage labor or commercial activities (%), (c3) occupation (regular occupation=1, others=0), (c4) housing style (western-style permanent house=1, others=0), (c5) owning outboard motors (yes=1, no=0), (c6) individual level education (education higher than primary=1, primary school or none=0); attendance at primary school is very high and varies little, whereas secondary or higher education varied both between and within villages.
(d) Ecological settings: (d1) village (Dunde=1, Olive=0), (d2) agricultural production (MJ), (d3) agricultural production per garden area (MJ/ha)

Statistical Analysis

Cultural consensus analyses were performed according to standard procedures (Romney *et al.* 1986; Borgatti 1996) for each village, each pair of villages, and for the total of all villages. The similarities of knowledge between two villages were defined as the average of the adjusted value of coincident responses. The cultural competences of informants in panel-research villages were calculated from all the three analyses listed as follows: competence in each village's culture, in culture shared by both villages, and in culture shared by all Roviana informants.

In calculating the modernity score, categorical variables were transformed and then used as variables for principal component analysis. The first eigenvector was defined as the modernity score in the case that the first eigenvector was large and positive to all modernization variables but negative to the distance to the nearest town. Spearman's correlation coefficients were calculated between the differences in the modernity score and the similarities of knowledge between two villages. When differences between two villages are calculated, I refer to one village as the "reference" village and the other as the "base" village.

For comparing the number of plants known to be useful for specific purposes, a Tukey's multiple comparison was performed. The relation of the number of plants and modernity were tested by Spearman's correlation.

Multiple regression analyses were performed, after stepwise selection, to determine which individual and household characteristics affect individual cultural competence. Both significant level of entry (SLE) and significant level of staying (SLS) were fixed at 0.15. For the multiple regression analyses three kinds of cultural competence values were used. Model 1 indicated the cultural competence of an individual compared to the knowledge shared by all Roviana informants. Model 2 compared the cultural competence of an individual to the knowledge shared by informants in the panel-survey villages (Dunde and Olive). Finally, model 3 compared the cultural competence of an individual compared to the knowledge shared by informants of the village where the individual lived.

All cultural consensus analyses were performed using ANTHROPAC 4.0 (Analytic Technologies). The other statistical analyses were performed using SAS 9.1 (SAS Institute Inc.). The PROC PRINQUAL procedure was used for transformation of categorical variables. Statistical significance was assumed when the p-value was less than 0.05.

Results

Modernization variables for each village are shown in Table 1. The principal component analyses showed that the first eigenvector explained 58.1% of the variations and was positive for all variables (negative to distance); this factor is hereafter called "modernity score," and is shown in the last row of Table 1.

As shown in Table 3, a cultural consensus was observed in each of the seven participating villages, in each pair of villages, and for all informants. The first eigenvector explained more than 80% of the variations and was positive for all informants. The degree of consensus varied among villages (from 6.0 for Nusa Banga to 21.8 for Olive) and among pairs of villages (from 6.9 for Dunde–Tombo to 16.9 for Olive–Tombo). Table 3 also shows the averages and ranges of individual cultural competences varying from 0.75 to 0.83.

Figure 2 shows the relationships between the similarities of knowledge and the differences in modernity. In Fig. 2a, Dunde, the most-modernized village, was set as the base village. Other reference villages were projected on their relative similarity or difference from Dunde. In this case, the correlation was weak and not significant ($r=-0.36$). On the other hand, Fig. 2b, where all villages were referenced to the base value of Tombo (the least-modernized village), shows a clear negative correlation between knowledge and modernity ($r=-0.095$, $p=0.0032$). These results suggest that when the least-modernized village was the base, knowledge changes occurred in correlation with the progress of modernity. Knowledge did not correlate positively with modernity, as shown when the most modernized village was used as the base (Fig. 2b).

Table 3 Intravillage and intervillage cultural consensus [mean and range in block parentheses (minimum, maximum) are shown]

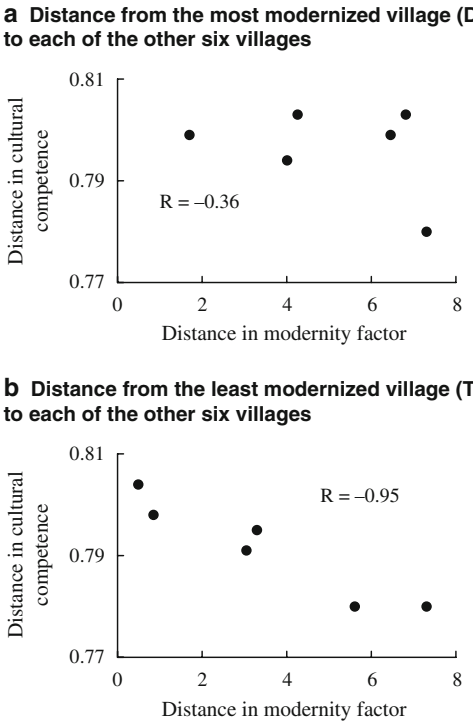
	N	Ratio first/second component	Consensus (% explained by first component)	Average informants' competence [a]	SD of informants' competence
Intravillage	7	13.2 (6.0, 21.8)	89.5 (83.3, 95.6)	0.81 (0.75, 0.83)	0.04 (0.04, 0.05)
Intervillage	21	11.8 (6.9, 16.9)	88.2 (84.6, 91.0)	0.81 (0.78, 0.83)	0.05 (0.03, 0.07)]
Overall	1	11.4	88.8	0.80	0.05

[a] Informant's cultural competence is the factor loading score of the first principal component

Table 4 shows all the correlation coefficients between the similarities of knowledge and differences of modernity. As shown in the left column, a significant correlation was observed only in the case in which Tombo was used as the base village. However, as shown in the right column, if the coefficients were calculated only for the correlation of villages with modernity scores higher than the base village, significance was observed in all cases of $N>3$. For instance, when Nusa Banga was used as the base, the correlations between knowledge similarities and modernity differences were significant for Mandou, Ha'apai, Rarumana, and Dunde ($r=-0.99$, $p=0.0055$), but were not significant when Olive and Tombo were added. Although not shown in the table, a significant correlation was not observed when the analyses were performed only for villages with lower modernity scores.

Table 5 shows the number of plants cited for each of the seven use categories. Villages were sorted in the order of their modernity scores. For all uses other than cash income, the modernity score of the village did not correlate with the number of plants. For instance, in Ha'apai, the village with the third-highest modernity score, villagers mentioned a greater number of medicinal plants (7.5 out of 20 plants on average) than other villages. Villagers in Rarumana, with the second-highest modernity score, knew a greater number of tool plants (10.5 in average) than those in the less-modernized Nusa Banga (7.0). However, the number of plants cited as cash income sources did correlate with village modernity score ($r=0.85$, $p<0.05$).

Figure 3 shows the difference in cultural competence of all informants in cross-sectional surveys in association with age and gender. Neither age nor gender was associated with an individual's competence, suggesting other factors should be included. From the results of a multiple regression analysis (Table 6), the cultural competences of the panel-survey villages (Dunde and Olive) were explained only by the cash income of the household, when competence was calculated as the knowledge shared by all Roviana informants (model 1). In analyses using competence for



Note: cultural competence is the average of individual competences ranging from 0 to 1.

Fig. 2 Correlation between distance in modernity factor and distance in cultural competence

Table 4 Spearman's correlation coefficients between intervillage competence values and intervillage distance of modernity

Baseline village	Original coefficient (*N*)	Coefficient of correlation only with higher-modernity villages (*N*)
Dunde	−0.36 (6)	N.A. (0)
Rarumana	−0.32 (6)	N.A. (1)
Ha'apai	−0.48 (6)	N.A. (2)
Mandou	−0.38 (6)	−0.54 (3)
Nusa Banga	−0.52 (6)	−0.99 (4) $p=0.0055$
Olive	−0.40 (6)	−0.93 (5) $p=0.0203$
Tombo	−0.95 (6) $p=0.0032$	−0.95 (6) $p=0.0032$

Table 5 Number of plants known to be useful for each of the seven use categories (mean±SE), categorized by village

	N	Food	Building	Medicine	Fuel	Traditional	Tool	Cash
Dunde	17	9.4±1.1	8.5±3.4	5.5±3.4	11.4±2.5[b]	4.9±3.0	9.0±2.5	16.4±2.1
Rarumana	10	9.6±1.3	9.1±3.3	6.1±2.4	12.1±1.9	6.5±2.1	10.5±2.8[a]	16.2±2.3
Ha'apai	10	9.7±1.3	8.2±2.5	7.5±2.5[a]	12.7±1.6	5.7±2.2	10.3±2.6[a]	16.2±1.9
Mandou	12	9.8±0.8	8.7±2.2	4.0±1.5[b]	12.8±1.9	4.0±2.1	9.2±2.3	15.7±2.2
Nusa Banga	10	8.5±0.5	7.6±2.7	6.1±1.4	12.2±2.0	3.6±1.8	7.0±2.4[b]	14.8±1.3
Olive	15	9.1±1.4	10.2±2.3	6.3±2.1	13.9±1.1[a]	5.1±2.6	10.1±1.7[a]	15.5±2.1
Tombo	6	8.7±0.5	7.3±3.0	7.0±3.6	11.0±3.6	6.0±2.6	9.2±3.1	15.3±2.1

The villages were sorted in the order of decreasing modernity score (see Table I). See Table I for modernity score of each village. Modernity score and the average number of useful plants positively correlated with the use category of cash income (r=0.85, p=0.015) but not for other categories (r ranges from −0.29 to 0.64, p>0.12).

[a] Larger than p<0.05 level, as evaluated by Tukey's multiple comparison for intervillage differences

[b] At p<0.05 level, as evaluated by Tukey's multiple comparison for intervillage differences

knowledge shared by informants in Dunde and Olive but not other villages (model 2), the village, duration of the marriages of the household heads, housing style, and informant's age were the detected factors. Informants in Olive, in younger households, older informants, and those who lived in western-style permanent houses had higher cultural competence. In models 3-1 and 3-2, the cultural competences of Olive and Dunde informants' knowledge shared by them, respectively, were used as dependent variables. It was found that age and living in a western-style permanent house were positive factors for higher competences in Olive, but no significant factor was observed for Dunde.

Discussion

This study examined whether (1) Roviana communities shared similar ethnobotanical knowledge, (2) whether there was clear variation however small in knowledge among villages, in addition to shared knowledge, (3) whether the variation was explained by modernity, and (4) whether individual knowledge variation was explained by personal characteristics. Cultural consensus analyses suggested the existence of shared knowledge. All the Roviana inhabitants descend from a population that had migrated in the nineteenth century from the small island of Nusa Roviana—only 150 km from east to west (Fig. 1; Aswani 2000; Sheppard *et al.* 2000). This shared historical background and environment no doubt contributed to their high degree of shared ethnobotanical knowledge. It is also noteworthy that the cultural consensus was much larger than found in other societies. For example, the ratio of first to second eigenvectors had rarely exceeded 10 in previous studies on ethnobotanical knowledge (Atran *et al.* 1999, 2002; Case *et al.* 2006; Reyes-Garcia *et al.* 2006, 2007). Although further study is necessary, this strong consensus is likely due to the short time since migration, the great similarity in ecological settings, and the delayed modernization of the area.

However, the results shown in Table 2 suggest that, in addition to shared knowledge, there are also variations in ethnobotanical knowledge between villages. I examined the effect of modernity on this variation (hypothesis 2). The results relevant to hypothesis 2, in which the differences in knowledge between the villages correlated with modernity, are complex, as follows. The change in knowledge correlated with modernity when the villages were referenced to the least modernized village (Fig. 2b). This did not occur, contrary to my expectations, when villages were referenced to the village with the highest modernity score (Fig. 2a). In addition, the correlation was observed only for villages referenced to less-modernized villages, but not when the observation was in the opposite direction (Table 4). From these results, it was assumed that ethnobotanical knowledge was changing in the same direction as the progress of modernization, although the

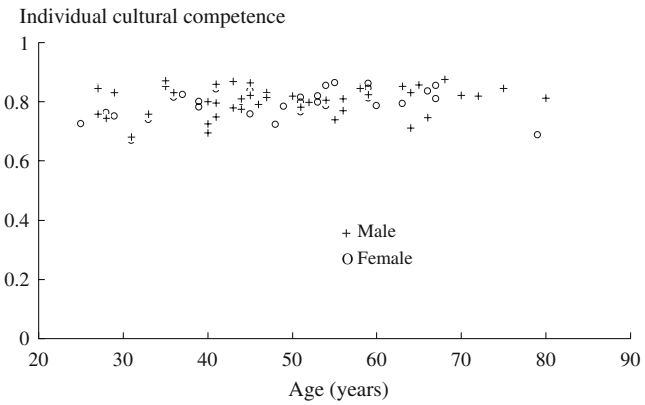


Fig. 3 Effects of age and sex on cultural competence

Table 6 Factors determining an individual's cultural competence

Model (dependent variable)	Explanatory variables[a]	Parameter (SE)	*P*-value
Model 1 (competence to knowledge shared by informants of all seven Roviana villages)			
(*N*=32)	Cash income (log)	−0.015 (0.006)	0.0205
	Intercept	0.890 (0.036)	<0.0001
Model adjusted R^2	0.172		0.0205
Model 2 (competence to knowledge shared by informants of both Dunde and Olive)			
(*N*=32)	Village	−0.1001 (0.0263)	0.0008
	Duration of marriage	−0.0046 (0.0013)	0.0021
	Housing type	0.0602 (0.0260)	0.0291
	Age	0.0013 (0.0078)	0.0841
	Intercept	0.8045 (0.0468)	<0.0001
Model adjusted R^2	0.4578		0.0024
Model 3-1 (competence to knowledge shared by informants within Olive)			
(*N*=15)	Gender	0.0495 (0.0225)	0.0478
	Housing type	0.0483 (0.0275)	0.1049
	Intercept	0.7912 (0.0180)	<0.0001
Model adjusted R^2	0.4146		0.0402
Model 3-2 (competence to knowledge shared by informants within Dunde)			
(*N*=17)	N.A.[b]		

[a] Explanatory variables were selected by stepwise method from the following variables:

Individual characteristics: age (years), gender (male=1, female=0)

Life-stage of household: duration of marriage (years), consumption unit per production unit (total food energy required for household members divided by the number of laborers in household)

Modernity: household-level cash income (monthly; logarithm), proportion of income from employment/business, occupation (any member employed as waged laborer=1, others=0), housing style (permanent=1, traditional leaf=0), whether owning outboard motor (yes=1, no=0), and individual-level education (education higher than primary=1, primary school or none=0)

Ecological characteristics: village (Dunde=1, Olive=0), crop yield of household (MJ), and crop yield per cultivation land area of household (MJ/ha).

[b] No matched model was found at SLE=0.15

knowledge differed from one village to another, in addition to shared knowledge, before it was influenced by modernization. This interpretation requires two further clarifications: (1) the cause of the variation before modernization and (2) the cause of the linear effects of modernization on the knowledge. On the first point, this study quantified only the modernization, and so the cause of variations other than in modernity remains unclarified. However, it is reasonable to assume that each village society had developed unique and indigenous ethnobotanical knowledge that was adaptive to each village's social and natural environmental factors. The social factors potentially include migration and communication from the neighboring linguistic populations, while the natural environmental factors include plant species abundant in the forest surrounding each village. Further studies are necessary to reveal the effects of these factors, but previous studies have suggested that intermarriage between different linguistic populations has existed since the nineteenth century (Aswani 1999; Sheppard *et al.* 2000), and that the availability of each plant species differed slightly from one village to another, even with the same vegetation, as a result of distance to mountains, coast, or rivers, and/or the land use of earlier generations (Bayliss-Smith *et al.* 2003).

For the second point, the other analyses of this study provided suggestions on the effects of modernity on ethnobotanical knowledge change. The villages that had access to commercial markets were thought to have developed knowledge of the cash values of plants, whereas in remote villages such knowledge was less valuable, and indeed this study found a significant correlation between modernity and the number of known plants useful for cash income (Table 5). However, in the same table, the modernity score did not affect plants cited for use as foods, building materials, medicine, traditional uses, and tools (Romanucci-Ross *et al.* 1997; Case *et al.* 2005). Thus, even though ethnobotanical knowledge was diversified, and local experience affected the uniqueness of knowledge, only recognition of cash income constantly affected this knowledge, because cash was the only stable value in modernization.

The analyses of hypothesis 3 also showed the complicated nature of the effects of modernization on ethnobotanical knowledge, even at the individual level. The effects of cash income on the competences of informants in the pool of all Roviana knowledge were reasonable, as an effect of the modernization described above. Exposure to a cash economy might affect the economic domain of botanical knowledge. The effects of the village when only the competence in the pooled knowledge of Dunde and Olive was used as the dependent variable were also reasonable, because villages represent different ecological settings and modernization levels. For instance, Olive has primary and secondary forests near the settlement and is less influenced by modernization, whereas Dunde is located on coastal flatland with a disturbed forest, a densely populated settlement, and a township. Shortly after the marriage of the household head, households were faced with the necessity of cultivating gardens, collecting house-building materials, and engaging in other activities for increasing household-level production. The effects of age were also included in the model, but were not significant: since elders are the source of knowledge for other household heads, it is thus natural that this variable is a factor for cultural competence. Living in western-style permanent houses also had a positive effect. This was caused by complicated social settings. People living in such houses did not necessarily have high cash income, but they were high in social class, e.g., chiefs and elders, because the foreign logging companies provided such people with permanent houses. These villagers were usually sources of knowledge, and, in addition, they had access to information because a variety of people gathered at their houses. Interestingly, education was not a significant factor. This suggests that the source of new knowledge was not limited to the schools, but was also available on other occasions, or through other social networks.

The most important finding from the multiple regression analysis was that individual- or household-level characteristics, such as gender and housing style, affected competence only in Olive (model 3-1 in Table 6), whereas in Dunde (model 3-2) the analysis found no effect. This difference between villages is thought to be related to social organization. In Olive, decisions are made communally—villagers usually consult other villagers (elders and relatives) in cultivating gardens, building houses, treating illnesses, etc., and decisions are made based on the communal discussions of village leaders. This communication partly helps to increase competence and the similarities of individual knowledge within the village. At the same time, this communication suggests that individuals do not need to learn all the necessary knowledge, because they can consult an elder for professional knowledge whenever they require it. In other words, in Olive, individuals have their own professional knowledge and consult each other as required. In contrast, Dunde is an urbanized and more individualistic society, and land and settlement are separated into small plots and owned by individuals, not communally (Schneider 1998). Here, villagers need to collect all the materials from their own territory by themselves, and are not allowed to trespass on the land of others. The villagers are thus less likely to consult other villagers and to share knowledge with them. This situation makes it necessary for villagers to possess the knowledge necessary for survival, but no additional knowledge. Thus, the interindividual variation is high but it is not related to specific individual features. Therefore, in the quantitative analyses, individual-level modernity and social variables predict individual knowledge significantly in a less modernized village, but just the opposite in a modernized village.

This study is subject to some limitations in the analytical models and explanatory variables. The cultural consensus model oversimplified the concept of the culture of ethnobotanical knowledge system in order to understand the change in knowledge, since it did not explore the insights of the various domains of culture, but treated the shared ethnobotanical knowledge as a single whole. In this regard, the inter-village variation may have been affected by subcultures, but the contents of the relations of each subculture with the mainstream culture of the Roviana remain unexplored. In addition, it was difficult to judge which plants were wild species, when and how certain plants had been introduced, and how relevant knowledge had arrived in this area. Also, the effects of the familial and social network of each informant with the people from outside the village were not considered in this study. However, although these limitations restrict the interpretation of the results, there were robust findings that the correlation coefficients were very high in the village-level comparison of knowledge referenced to the higher-modernity village (r ranged from −0.99 to −0.93), and the multivariable adjusted R^2 were also high for individual-level factors in model 2 and model 3-1.

Finally, although many matters remain to be clarified, the findings of this study are summarized below: (1) the village-level variation in ethnobotanical knowledge was correlated with modernity, as a first principal component of variables including the demographic and cash economic aspects and contact with western goods, when villages were referenced to the least-modernized village; (2) but the variation in knowledge was not correlated with the modernity when villages were referenced to the village with the highest modernity score; (3) the number of plants that the informants know are useful for cash earning was correlated with the village-level modernity; (4) the number of useful plants was not correlated with modernity for purposes other than cash earning (i.e., food, building, medicine, fuel, traditional, and tool); (5) household-level cash income, village location, housing-type, the duration

from the household outset, and gender were predictors of the individual-level ethnobotanical knowledge; and (6) individual or household level variables predict individual knowledge only in less modernized villages, but not in modernized and individualized villages. From these findings, especially the first and second points, I suggest that the change in ethnobotanical knowledge had two or more domains, one of which was strongly affected by modernity, while the others were never explained by it. Similar findings were reported by Reyes-Gracia *et al.* (2007), who found that theoretical ethnobotanical knowledge and practical skills using plants were not strongly correlated, and that their association with modernity variables differed from each other. Although indispensable indigenous knowledge has been reported to be at risk of being lost (Prance *et al.* 1987; Balick and Cox 1996; Townsend 2000; Atran *et al.* 2002; Aswani and Lauer 2006), this study suggests that modernization was directly related to increase of introduced botanical knowledge such as cash values of plants, but was not to the loss of indigenous botanical knowledge because of the shared knowledge and diversity which had been formed independently of modernization.

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