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A. Garong
Faculty of Social and Cultural Studies, Kyushu University

S. Mihara
Shirakawa analysis center, Institute of Accelerator Analysis Ltd.

F. Datar
Anthropology Department, University of the Philippines, Diliman

W. Ronquillo
Archaeology Division, National Museum of the Philippines

他

https://doi.org/10.15017/17109

出版情報：比較社会文化. 16, pp.25-43, 2010-03-20. Graduate School of Social and Cultural Studies, Kyushu University
バージョン：
権利関係：

『比較社会文化』第16巻（2010）25～43頁
Bulletin of the Graduate School of Social and Cultural Studies, Kyushu University
vol.16 (2010), pp.25～43

Article

Carbon and nitrogen stable isotope analysis using human bones and hair from Philippine burial sites

A. GARONG[1], S. MIHARA[2], F. DATAR[3], W. RONQUILLO[4] and H. KOIKE[1]

Recieved 12 November 2009, Acceptecl 12 December 2009

Abstract

In order to understand the diet of the past human population in the Philippines, we analyzed stable isotopic compositions of 61 individuals from five burial sites with different geographical locations, environmental conditions and subsistence strategies. The carbon stable isotope ratio ($\delta^{13}C$) and nitrogen stable isotope ratio ($\delta^{15}N$) of bone collagen and hair were used to estimate dietary protein resources of the population. The Batanes site is located at about 200 km north from the north coast of Luzon and about 150 km south from Taiwan, with the so-called boat-shaped and jar burials (355±70 BP). Results of $\delta^{13}C$ (−16.6±1.3‰) and $\delta^{15}N$ (9.8±1.7‰) values for bone collagen from 21 individuals showed that dietary protein resources had more dependence on marine ecosystems than that on terrestrial resources. The isotopic values vary due to the burial types: both $\delta^{13}C$ and $\delta^{15}N$ values of the specimens from the boat-shaped and jar burials were higher than those from both the primer pit burial. In the Lal-lo site (N=11) of Northern Luzon which is famous for its huge shell midden (3400-1000 years ago), $\delta^{13}C$ and $\delta^{15}N$ values were −19±1.2‰ and 9.7±1.6‰ respectively. Results showed a diet more dependent on terrestrial resources than others, because freshwater shells indicated terrestrial values. Hair samples from the 13th century old mummies (N=3) at Kabayan in Benguet Mountain Province, northwest of Luzon had the average value of −17±1.0‰ for $\delta^{13}C$ and 8.0±1.0‰ for $\delta^{15}N$ reflecting a diet dependent on both terrestrial and aquatic resources. The average value of the Santa Ana site (N=8) in Manila (about 1095 AD) were −15.2±3.3‰ for $\delta^{13}C$ and 10.4±0.7‰ for $\delta^{15}N$ values, suggesting highest dependence on marine ecosystem among the 5 sites. Romblon site (N=18) in Central Philippines (13th-14th centuries) yielded the average $\delta^{13}C$ value of −17.4±2.3‰ and $\delta^{15}N$ value of 10.1±1.1‰ indicating protein resources dependent on both terrestrial and marine ecosystems. In all the sites, the $\delta^{13}C$ and $\delta^{15}N$ values lack gender-based difference.

Keywords: carbon stable isotope, nitrogen stable isotope, burial sites, human bones, hair sample, mummy, Philippines

1 Laboratory of Biodiversity, Department of Environmental Changes, SCS, Kyushu University, 447 Moto-oka, Nishi-ku Fukuoka, Japan
2 Shirakawa analysis center, Institute of Accelerator Analysis Ltd. (IAA) 6-270, Shirasaka, Shirakawa-city, Fukushima pref. 961-0835, Japan
3 Anthropology Department, University of the Philippines, Diliman, Quezon City, Philippines
4 Archaeology Division, National Museum of the Philippines, Manila

Introduction

The Philippine archipelago is composed of 7,107 islands bounded by the Pacific Ocean on the east, the South China Sea on the west and north, and the Celebes Sea on the south. To its north is the southern tip of Taiwan and ending close to northern Borneo on its south. The principal islands comprising the Philippines are the Luzon, the Visayas and the Mindanao Islands.

The Philippines prehistory can be divided into four periods based on technologically-based periodization as reflected through archaeological records. These are the Paleolithic period from about 50,000 to 10,000 BC (Ronquillo 1998), the Neolithic period 10,000 to 500 BC, the Metal age (500 BC-AD 500) and the Age of Contact (AD 500−AD 1400).

The earliest evidence of burial practice in Philippine prehistory was in the Neolithic period (3,100 BC.) where skeletal remain of a man in a fetal position was found in Duyong cave, Quezon Palawan, Southwestern Philippines (Fox, 1970). During the Metal age several burial sites were recorded. The famous site comes from Manunggul cave in Quezon Palawan, Arku cave in Cagayan Valley Northern Philippines and the Ayub cave in southern Mindanao dated about 2000 years ago (Fox 1970; Dizon et al. 1996). Both jar burials and wooden coffins were unearthed in Panhutungan site in Surigao del Norte (Dizon 1998), southern Philippines and in the Banton cave on Romblon Island (Evangelista 1966). In the Age of Contact more burial sites were recovered, for example the Santa Ana primary burial site in Manila, the primary and jar burials in Lal-lo shell middens in Cagayan Valley Northern Philippines.

Archaeological data on burial sites in the Philippines were not thoroughly studied. Diet reconstruction where mostly focused on floral and faunal analyses associated with the burials and also with the shell middens. More often than not, foods recovered were few. This posted limitation to the study on diet reconstruction for Philippine prehistory.

Carbon and nitrogen stable isotopic analysis ($\delta^{13}C$ and $\delta^{15}N$) on human bone collagen is an established technique for paleodietary reconstruction of past population (van der Merwe and Vogel 1978; DeNiro and Epstein 1978; Bender et al. 1981). Collagen values provide information on the type of protein resource in their diet (Krueger and Sullivan 1984). Most isotopic studies made used of collagen since it represents the total average dietary intake of an individual. Hair is also an ideal sample for estimating ancient diets (Macko et al. 1999; Macko et al. 1999; O'Connell et al. 1999) that provide limited time scale information on diet since hair keratin reflects more recent diet limited in months. Hair contained keratin that has mechanical stability dependent on the tight packing of the α-helix and can be degraded by some parasitic and saprotrophic fungi and thermophilic anaerobic bacteria (Bockle et al. 1995; Friedrich and Antranikian 1996). The carbon isotopic values for both bone collagen and hair keratin correlate well with that of total dietary protein with the collagen enriched by about 4.5‰ (Ambrose and Norr 1993).

Atmospheric CO_2 with $\delta^{13}C$ value of −7.0‰ is the major source of carbon for all terrestrial plants. The plant $\delta^{13}C$ values in turn are determined by the isotopic composition of atmospheric CO_2 which is incorporated into the tissues through photosynthesis. There are three photosynthetic pathways that occur among terrestrial plants. These are the Calvin-Benson (C_3), Hatch-Slack (C_4) and Crassulacean Acid Metabolism (CAM) pathways. Since the photosynthetic pathways differ chemically they produce different degrees of isotopic fractionation: an average $\delta^{13}C$ value for the C_3 plants is about −19.5‰, while that for the C_4 species is about −12.5‰ (O'Leary 1981; Smith and Epstain 1971; van der Merwe 1982; Vogel 1978). C_3 plants include mostly the flowering plants, trees, and shrubs, and most of the temperate zone grasses. While C_4 plants are represented in about ten plant families and the majority of species are xeric environment grasses, including maize, some millets, some sorghums, sugar cane and others. The CAM plants are those under arid conditions with $\delta^{13}C$ values usually reflect their habitat.

Marine phytoplankton approximates the C_3 cycle but obtains their carbon from dissolved oceanic carbon which has isotope ratios of about 0‰ (vs PDB; Pee Dee Belemnite) their values average is about −19.5‰ (Sackett et al. 1965; Degen et al. 1968; Brown et al. 1972; Chisholm and Koike 1996). Previous studies have used stable isotope measurements that are enriched in marine food webs and compared with terrestrial food webs, tracing relative contribution of marine versus terrestrial

food webs in diets of contemporary (Hobson 1986, 1991; Hobson and Sealy 1991; Hobson et al. 1997) and prehistoric consumers (Chisholm et al. 1982).

Atmospheric N_2 is the main source of nitrogen in the food web (Ambrose 1991). There are different ways in which nitrogen enters the biological domain. The $\delta^{15}N$ value is different between the plants or bacteria that fix nitrogen directly from the air (nitrogen-fixers) and bacterial nodules (azotobacter) and terrestrial plants that incorporate nitrogen source from root as nitrate in the soil from the decomposed organic material (Schoeninger and Moore 1992). Food derived from marine ecosystem such as coral reefs and salt marshes is similar in the $\delta^{15}N$ value with those of terrestrial plants and animals (Schoeninger and Deniro 1984).

Trophic enrichment of $\delta^{13}C$ is small, mostly within 1‰ for each trophic level (DeNiro and Epstein 1981; Minagawa and Wada 1984; Hobson and Welch 1992, Vander Zanden and Rasmoussen 1999) while that of $\delta^{15}N$ is usually large, by 3 to 4‰ (DeNiro and Epstein 1981; Minagawa and Wada 1984). Since the ratio is sensitive to reflect the trophic level, the nitrogen isotope has been used as a food web indicator for animals in various ecosystems (Schoeninger and DeNiro 1984; Wada et al. 1987; Fry 1988; Hobson and Welch 1992). Nitrogen fractionation values for carnivores is lower (3.2‰ ±0.4‰) compared with herbivores which has a value of 2.5‰±2.5‰ (Vander Zanden and Rasmussen 2001).

Considering the $\delta^{13}C$ and $\delta^{15}N$ composition of bone collagen from human skeletal remains, information on the consumption of C_3, C_4 and CAM plants as well as marine versus terrestrial food groups can be obtained (O'Leary 1981; van der Merwe 1982; Schoeninger and DeNiro 1984). Consequently, the stable isotope analyses cannot identify the diet species, however, it can indicate the primary producer and the trophic level in their ecosystem.

The $\delta^{13}C$ and $\delta^{15}N$ analyses in Southeast Asia and the Pacific are limited. In the Marianas Islands, Western Pacific, human skeletal remains from Guam, Rota and Saipan were analyzed for $\delta^{13}C$ and $\delta^{15}N$ using bone collagen and of carbonate in apatite tooth (Ambrose et al. 1997). In Southeast Asia, $\delta^{13}C$ and $\delta^{15}N$ analysis was done in Peninsular Malaysia and Sarawak using human skeletal remains from Niah Cave by Krigbaum (2003) and in Thailand on the skeletal remains from the Ban Chiang site by King and Knorr (2006). Isotopic analysis in the Philippines has not been done until Mihara et al. (2005) who measured bone collagen $\delta^{13}C$ and $\delta^{15}N$ of some human remains from Lal-lo midden sites.

In this paper, $\delta^{13}C$ and $\delta^{15}N$ analysis were applied to estimate paleodiet using the bone collagen obtained from 58 individuals and hair samples from three mummies in the Philippines. Features of these sites were described and individual information such as burial types, sex and age were shown in appendix.

Materials

A total of 61 individuals were sampled for the $\delta^{13}C$ and $\delta^{15}N$ analysis from five burial sites were considered in this study (Fig.1). Bones were collected in most cases with exception with Kabayan site where hair was collected from the mummies. In general, the five sites were categorized into sex groups, male (M), female (F) and unidentified (UI). The specimens were also categorized into age groups. These are juvenile (>9 years), adolescence (>17 years), young adult (<18 but >30 years), adult (<60 year) and mature (>60). Information pertaining to the archaeological site, diet

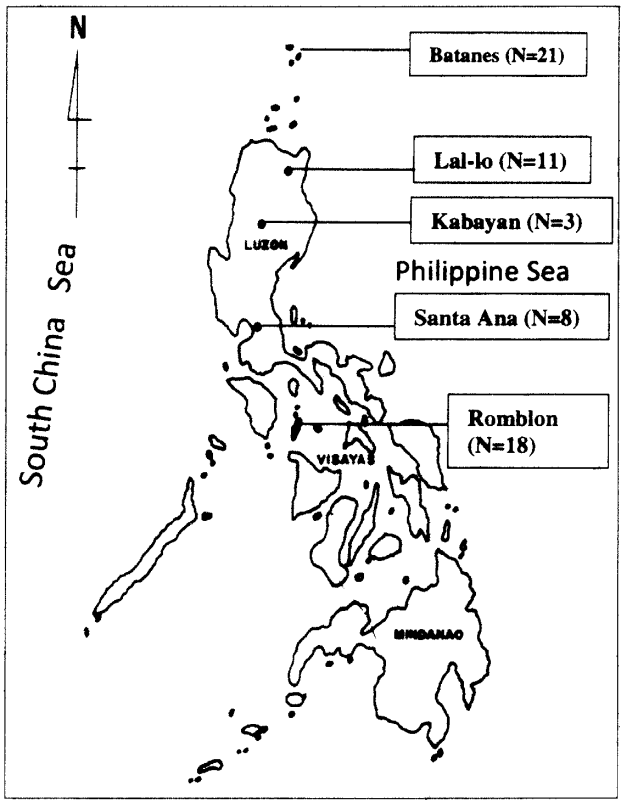

Fig. 1. Map showing the five burial sites in this study

resources and burial description are presented below.

Batanes site

Site description: Batanes, a group of islands and islets, is located in the northernmost part of the Philippines. The Batanes Group of Islands is surrounded by Pacific Ocean to the east, South China Sea to the west, Bashi Channel to the North the Balintang Channel to the South, the Luzon Strait is between Taiwan and Luzon, and connects the Philippine Sea to the South China Sea.

Evidence of the earliest habitation in Batanes was believed to be over 2000 years ago based from preliminary archaeological undertakings done by Kumamoto in 1983 and by a team of geologists headed by Maryannick Richard in 1986. The evidence came from the excavated red-slipped pottery, burnt wood and pottery sherds found under the ash layer deposit caused by the eruption of Mount Iraya in 325 B.C. (Hornedo 2000). The National Museum of the Philippines started the Batanes Archaeological Project in 1994 (Dizon 1995) that resulted in discovering the "castle-like habitation" known as "idjang" and the "stone boat shape burial markers" made of stone arranged in the shape of a boat typical for Batanes. The smallest grave marker discovered was measured 2.3 m in length and 90 cm in width, and the largest was about 5 m in length and 3.5 m in width (Dizon 1998). The ^{14}C date acquired for boat shape burial was 355 $\pm$70 BP or 1595 AD that showed an over 300 years of burial activity in the area. On the other hand the recovered jar burials was of primary type where the complete remains of the dead person were buried inside the jar. No radio-carbon date was obtained for this. But it was believed to have been practiced by the Ivatans (natives of Batanes) between 100 BC to 300 AD and was noted to have been practiced until the late 18th century (Hornedo 2000).

From 1995-2001, the University of the Philippines Anthropology Field School (UPAFS) under the supervision of Dr. Francisco Datar, had continuously performed several excavations in a burial site in Itbud, Uyugan, Batanes exposing about 22 individuals. The burial site was located near the seashore. Sand was the main composition of the soil and this affected the preservation condition of the bones. Two types of burial practices were revealed, these are the primary burials where the body was directly buried on the ground and primary jar burials. In both ways, the individual was placed in a fetal position. Associated with the burials are grave goods such as beads, pot sherds, marine shells where the most common type was the Turbo spp. The site was relatively dated between 16th-17th centuries.

Diet resources: Ethnographic account about Batanes in the 17th-18th centuries (Hornedo 2000) depicted the Ivatan (natives of Batanes) was already engaged in farming and fishing. Yam, sweet potato, bananas and sugarcane were basically grown but not rice or corn. Domestication of goats and pigs was also employed. In the 19th century, corn, millet, cottons and beans were cultivated in the island.

Faunal analysis done by Szabo et al. (2003) in some archaeological sites in Batanes, such as in Naidi and Sunget Top Terrace, the earliest site with ^{14}C dating of 2630$\pm$30 (standardrized with ANU 11693) revealed the presence of labrid, diodontid and scarid fishes and domesticated pig bones. Mavuyok a Ahchip 900 BP), a shell midden site showed variety of marine (56%), land (37%) and freshwater (7%) shells consumed. While mammal remains were scarce, but one pig incisor and two goat bones were identified.

Human burials analyzed: A total of 21 individuals (07 HM21-08HM69) were sampled (Appendix-1) of whom, seven individuals were identified as male, seven were female and seven individuals have unidentified sex due to missing morphological characteristics. A total of 18 human remains recovered from Itbud, Uyugan (07 HM21-08HM58; 08HM61-08HM66 and 08HM69) site were not in a good preservation condition and most of the bones were broken or fragmented due to disturbances caused by the sand, roots encrustations and intrusions aside from the soil matrix. Despite the condition, the students from the Anthropology Department of the University of the Philippines have tried to fit together the broken parts and done a detailed description and analysis.

The boat-shape burials (08HM67 and 08HM67) were recovered from western coast of Ivuhos Island. The area was a rolling hill covered with pandan vegetation. The Chuhangin stone boat-shaped burial site (Grave No.1) contained a juvenile individual who was

about three years old female at the time of her death (Bautista 1998). While the Mayahao Locality 1 Beach Ridge boat-shape burial contained mature individuals. The bones were well preserved.

The jar burial is of primary type. Sand was also put inside the jar. Bones were mostly in bad preservation and majority of the bone structures was fragmented (Bautista 1998). Two individuals were buried in the jar, 08HM59 and 08HM60. They were recovered from Itbud, Uyugan Batanes site.

Lal-lo site

Site description: Lal-lo, Cagayan Valley in Northern Philippines is known for its huge and extensive shell midden deposit which is considered to be the biggest shell midden deposit in the Philippines and probably in Southeast Asia (Ogawa 2000). Cagayan River, the largest river in the Philippines, runs through the area and flows out to Luzon Strait that connects the Philippines Sea to the South China Sea. Interestingly, these shell middens are mainly composed of freshwater bivalve shells locally known as "kabibe" (*Batissa sp.*). The midden is found usually along the riverbanks, inland and limestone hilly formation.

In 1986, an extensive archaeological exploration was conducted along the lower reaches of Cagayan River in Lal-lo municipality by the Archaeology Division of the National Museum of the Philippines and Japanese archaeologists (Aoyagi et al. 1993). The exploration resulted into identification of 21 shell midden sites. From 1995 to 2005, archaeological undertaking continued resulting into establishment of local chronology based on typological analysis of potteries (Ogawa et al. 2006; Tanaka 2002) and ^{14}C dates (Mihara et al 2002; Mihara 2006). Four pottery assemblages were established. These are: Non-decorated Red-Slipped Pottery assemblage from 3400-3000 cal BP; Decorated Red-slipped pottery assemblage with ^{14}C dating of 2925-2460 cal BP; Decorated Black pottery assemblage with period ranging from 2000-1500 cal BP and Non-decorated black pottery assemblage from 1500-1000 cal BP (Mihara et al. 2002; Mihara 2006).

Mihara (2006) in his doctoral thesis has done isotopic analysis of some of the skeletal remains recovered from the other shell midden sites. The seven individuals from his study were included in this paper.

Diet resources: Aside from the riverine shells and fish, faunal analysis from the different shell middens (Garong 2006) revealed pig (*Sus sp.*) and deer (*Cervus sp.*) bones and were abundantly found in almost all levels/layers of all the shell middens. Deer antlers were mostly modified. Fish bones especially the jaws belongs to Family Labridae (marine fish) were recovered. Bovid bones were mostly carabao. Nagsabaran shell midden site in Alaguia, Lal-lo was excavated by a team from the Archaeology Division of the Philippines and Taiwanese Archaeologists from Academia Sinica, Taiwan that recovered a carabao skull in the silty clay layer below the shell layer. The skull was associated with red-slip pottery, adze and shell bead. It was found with some teeth scattered within the square suggesting that the carabao was probably butchered. The ^{14}C date of the silty clay layer showed a 2240±270 BP (Tsang and Santiago 2001). Also, they recovered a pig mandible in the same clay layer but from a different square. The mandible was associated with red-slipped pottery midden and has a ^{14}C date of 3390±130 BP. The dating of the pig mandible corresponds to the Non-decorated Red pottery assemblage.

Human burials analyzed: In this paper, the burial site were categorized based on the typological analysis of pottery. For Lal-lo site, 11 individuals (08HM28-08 HM31; 08HM04, 00HM07, 00HM04, 01HM24, 03 HM01, 03HM07 and 03HM08) were sampled (Appendix-2). Three of them were identified as male, one was female and the eight samples have unidentified sex. Majority of the skeletal remains from Lal-lo site were found in an open primary pit burial recovered from the shell midden deposit above silty clay layer. The bones were well preserved. There were also burials recovered from the shell layer. However, the burials unearthed from shell layer were mostly disturbed, incomplete and fragmented.

Non-decorated red-slipped pottery (3400-3000 cal BP): Along the eastern side of the Cagayan River, Clemente Irigayen Property Site located in Barangay Sta. Maria revealed many important findings. After excavating six 2 × 2 m squares, the shell midden deposit were not

extensive however, both black pottery and red-slip pottery were found on this site. Layer II of the site consisted of shell deposit and black pottery sherds while Layer III silty clay yielded non-decorated red-slipped pottery sherds (de la Torre 2000). The red pottery assemblage was dated from 3400-3000 cal BP and was associated with primary burial. 08HM28 was a complete male adult skeleton recovered from clay layer.

The Pasqua site at the Fabrica shell midden had a thick shell deposit, however the whole site was disturbed since the shells were being collected for feeds for chicken. Salvage archaeology was done in 2000 and 2001 (de la Torre 2002; Garong, 2002). Red slip pottery sherd and one human mandible (01HM24) was found from layer 1 on the slope (Garong 2002). Calibrated ^{14}C age ranged from 3380 to 3210 BP (Mihara 2006).

In Barangay Nagsabaran, from the silty clay layer above the shell midden, 08HM30, a female individual was recovered.

Decorated black pottery (2000-1500 cal BP): Shell midden deposit was also found in two sites in Camalaniugan, next town after Lal-lo. These were the Leon Ibe and Cortez sites. Both sites were associated with the decorated black pottery phase. Cortez site has a shell midden deposit of almost 2 m thick (Garong 2002). The layer 1 contained skeletal remains but were merely disturbed. The remains consisted of scapula and ribs only. 03HM07 was collected from this burial. In Leon Ibe property, human remains were found in layer 3 which was a shell layer (Garong 2006). The burial was incomplete and contained mixed skull and phalanges (03HM08) belonging to a young individual and teeth of an adult individual

Non-decorated black pottery (1500-1000 cal BP): Two shell midden sites were excavated in Barangay Catayauan (Garong et al. 2000). Both sites are located in the riverbank side. Fausto Sison site has a shell deposit of almost 2 m thick. However, due to some problems encountered, the excavation was limited at exposing 50 cms deep from the surface only. Burial #1 (00HM07) was found associated with carnelian beads (17^{th}-18^{th} centuries) together with black pottery sherds within the midden. Only bone fragments were collected for analysis.

The Conciso site has a 2-m-thick shell midden deposit containing black pottery. One primary burial was recovered from grid N_5E_3 associated with the shell layer. Burial #3 (08HM04) could be a complete skeletal remains but due to time constraints, complete retrieval was not achieved. However, the stature suggested an adolescence individual. Burial #1 (08HM31) was found in grid N_6E_2 below the shell midden deposit and was a complete male skeleton (Garong 2001).

On the western side of the Cagayan River in Catugan, San Lorenzo III, Siriban site was excavated by Tanaka (1998). The site revealed black pottery assemblage with ^{14}C date of 1500-1000 cal BP (Ogawa 2006; Mihara *et al.* 2002; Mihara 2006). Both 08HM29 and 01 HM01 remains were recovered in an open pit burial in the clay layer above the shell midden deposit. Another shell midden was the Dumbrique property excavated in 1997 (Tanaka, 1997). From layer 2 at a 20 to 60 cm depth, human femur (08HM04), humerus and mandible were found without a burial pit.

Kabayan site

Site description: The Kabayan site is located in Benguet province in mountain range in the northern central part of the Philippines. Kabayan is like a bowl-like valley that was surrounded by mountains. It is about 7,000 feet in altitude. The Philippine mummies that can only be found in Kabayan was noted and recognized as early as in 1947. Twenty one caves have been mapped and assessed to contain wooden coffins that have human remains of both mummified and skeletal remains. The mummies were well preserved considering the climate of the area. They were all in fetal or flexed position. Traces of tattoos were visible especially for adult burials, while hairs were still present. The caves were considered sacred by the locals. The mummification in Kabayan was believed to have been in existence since the 13^{th} century (Merino 1989) but was cease as early as Spanish Period (1521) due to conflict in beliefs/religion as well as sanitary and health issues.

Since 1968, the National Museum of the Philippineshas been continuously mapping and documenting the different caves and rockshelters that yield mummies and skeletal remains. Conservation, on the other hand, is in a continuous endeavor up to now by the Conserva-

tion Laboratory of the museum. The project involved conservation of the mummies and safeguarding of the caves and rockshelters (Abinion 2003).

Diet resources: Both hunting and gathering were noted as the main source of subsistence in early times. Hunting wild animals included deer, wild boar, civet cats, birds and fowl. While food gathering involved mostly root crops. Kabayan is famous for its farming producing the red rice. No archaeological undertakings were done or recorded.

Human burials analyzed: For this study, three mummies (07HM01, 07HM33 and 08HM34) were considered (Appendix-3). The hair samples were collected from Timbac 2 (N=1) and Kangal (N=1) caves and from the mummy displayed in the National Museum branch office (N=1) in Poblacion; two males and one female.

There were several mummies interred in Timbac 2 where 07HM01 hair sample was taken and were all inside the wooden coffins and well preserved. Mummy from Kangal cave (08HM34) was deteriorating due to the highly unstable conditions of the cave, insect and rat infestations. The mummy displayed in the museum was in good preservation condition (07HM33).

Santa Ana site

Site description: Santa Ana site is situated on the southeast of Manila, the capital of the Philippines. It is located at the southeast banks of the Pasig River. The whole river and most portions of its tributaries lie entirely within Metro Manila. During the Spanish period the location of the site was ideal for trading activity. The site is only 300 m away from the river which was an important transport route at that time.

The site was actually a churchyard. The church itself was built in 1578 by Spanish missionary, thus named as Santa Ana church. Stratigraphic profile of the site revealed that signature of Spanish refuse occurs in the upper layer but not in the lower layer, and shell midden consisted of brackish shells, animal bones, pottery, trade wares ceramics and iron slag (Fox *et al.* 1977). The site was believed to have been occupied, as early as 11th century based on the trade ware ceramics that were mostly blue-and-white and late Sung Dynasty porcelain. The period from 12th-13th century AD was the beginning of an extensive trading with Chinese who brought with them metals, cloth and highly fired porcelains and stonewares. The site has a ^{14}C dating of 1095 A.D.

Diet resources: In the 16th century, the main staple food crop was rice though root crops such as taro, yam sweet potato were also common but considered second choice (Scott 1994). Both hunting of deer and wild pig and fishing utilizing both coastal and inland waters were exploited and employed.

Faunal remains recovered from the pre-Spanish layer included a thick shell midden deposit containing brackish water shells mostly oyster, bones of pig, deer and water buffalo (Fox *et al.* 1977).

Human burials analyzed: A total of 71 human graves were recovered from this site (Fox *et al.* 1977). The remains were buried in extended position with funerary offerings. The skeletal remains from this site had been long curated in museum. The storage condition was indeed poor that affected the poor preservation of the skeletal remains. Also, most of the skeletal remains were not complete that posted problem for sex identification. The analyzed eight individuals (08HM11-08 HM13, 08HM16-08HM18 and 08HM22-08HM23) from Santa Ana site (Appendix-4) consisted of male (N=3), female (N=2) and unidentified sex (N=3).

Romblon site

Site description: Romblon is an island province that forms part of the Southern Tagalog islands and part of the Visayan islands of the Philippines which is 346 km south of Manila. The province consists of numerous islands situated in the Sibuyan Sea. The cave burial site was actually located in Banton which is known for its rocky island surrounded by bodies of water.

Romblon site was discovered in 1937 but it was only in 1966 that the National Museum started an expedition to recover the remains from this reported secondary burial cave using wooden coffin (Evangelista 1966). A total of thirty-four human remains were retrieved. The site was dated late 13th or 14th century based on the associated Chinese and Siamese jars, gold ornaments,

carnelian beads, turtle shell combs, coconut shells and bamboo flute (Evangelista 1966). The specimens were presently stored in the Archaeology Division's storage room of the National Museum.

Diet resources: Staple foods for the Central Philippine island in the 16th century were rice, millet, taro yams, sago palm (lumbia) and bananas (Scott 1994). Root crops were common all year round. Bananas and plantains (cooking banana) were also staple foods and like rice, yams when still unripe were being boiled. They also hunted deer, civet cat and pig. Fishing was most commonly done since the Visayan waters abound with fish. Seafood was the main source of protein in their diet. However, they also domesticated animals such as pig.

Human burials analyzed: The human remains were well preserved when they were recovered from the site. However, the skeletal remains were mixed and piled together inside the coffin (Evangelista 1966). One reason for this disturbance could be attributed to the fact that the site was looted by antique collectors prior to the retrieval of the National Museum. The skulls were all deformed and were believed to be deliberately done. Eighteen individuals (08 HM 01-08 HM 10 and 08HM13-08HM20), male (N=7); female (N=2) and unidentifed sex (N=9) from Romblon site were considered for this study (Appendix-5).

Methods

For this study, bone and hair samples were used for $\delta^{13}C$ and $\delta^{15}N$ measurements.

Preparation of bone samples for collagen extraction: Surface of each bone sample was cleaned. Using a dental drill, 200 mg powdered sample was extracted and cleaned by sonication in double distilled water (DDW). Then, alkaline treatment with 0.1N NaOH to remove soil acids followed. This step was repeated until the solutions became colorless. The samples were then washed with DDW and placed in cellulose dialysis tubes for acid treatment to remove inorganic carbon. Each sample tube was placed in a beaker containing 0.1 N HCl with a stirrer (Horai *et al.* 1989). The HCl solutions were changed daily for 5 days to achieve complete dissolution. The organic residues were centrifuged to pellets, and rinsed with DDW three times. The samples were again washed with 0.01N NaOH and then rinsed with DDW and centrifuged to pellets. The pellets were frozen and then freeze-dried over night using an Eyela freeze dryer (Tokyo-Rika, FDU 506). Aliquots of 0.8 ±0.05 mg of each sample were placed in tin capsules (two capsules per sample) for isotopic measurement.

Preparation of hair samples: About 40 strands of hair from each mummy were sorted out from root to tip and for the skin tissue, and the hair sample was cut into small pieces (less than 1 × 1 mm). The samples were cleaned by sonication in double distilled water (DDW). Lipid removal follows by soaking it with 5-10 times volume of lipid extraction solution: chloroform methanol 2 : 1, then subject the sample for ultrasonication process for about five minutes. After removing the supernatant liquid, this process was repeated until the solution became colorless and clear. After complete drying in the draft chamber for a couple of hours, the samples were cut by 1 cm interval since hair grows at a rate of about 1 cm/month (O'Connell et al. 1999). Aliquots of 0.8±0.05 mg of each sample were placed in tin capsules (two capsules per sample) for isotopic measurement.

$\delta^{13}C$ and $\delta^{15}N$ measurements

The $\delta^{13}C$ and $\delta^{15}N$ values were analyzed twice for each sample using a continuous-flow mass-spectrometer (ANCA-mass 20-20, Europa Scientific Instruments, UK). Repeated measurements of a running standard (glycine) produced measurement errors of less than 0.1 ‰ for $\delta^{13}C$ and 0.3‰ for $\delta^{15}N$. If the difference in results between the two analyses per sample was larger than the expected error, that sample was re-measured.

Analytical results are expressed as delta values, in parts per mil (‰), as follows:

$$\delta(‰) = [R_{sample}/R_{standard}-1]\times 1000$$

where R is ($^{13}C/^{12}C$) or ($^{15}N/^{14}N$). Conventional standards for carbon and nitrogen are PDB (Pee Dee Belemnite) and the atmospheric N_2, respectively.

Results

%C and %N Values

C/N which is the ratio of %C and %N was obtained from ^{12}C and ^{14}N counts by the ANCA-MASS. Extracted collagen samples from the 59 individual had reasonable carbon and nitrogen contents, yielding a C/N ratio between 2.8-3.1, which is comparable with the ratio observed from modern hair samples (3.0-3.8; O'Connel 1996). The reasonable range of the obtained C/N ratio showed that the collagen was uncontaminated and that no further gelatination treatment is not needed.

$\delta^{13}C$ and $\delta^{15}N$ values for the bone collagen samples

The average and standard deviation of $\delta^{13}C$ and $\delta^{15}N$ values for each of the five burial sites are shown in Fig. 2. Data separated based on sex, age, burial type, locality and period were shown for Batanes, La l-lo, Santa Ana and Romblon sites (Fig. 3).

Batanes site: The average and standard deviation (1s) of the collagen $\delta^{13}C$ and $\delta^{15}N$ values obtained from the Batanes site (N=21) are -16.6 ± 1.3‰ and 9.8 ± 1.7‰, respectively. For sex categories (Fig. 3A), males (N=7) have $\delta^{13}C$ values of -16.6 ± 1.3‰ in average, ranging from -19.0 to -14.3‰ and $\delta^{15}N$ values of 9.4 ± 1.1 ‰ in average, ranging from 14.5 to 7.6‰. For female samples (N=7), $\delta^{13}C$ was -16.7 ± 1.3‰ in average ranging from -18.5 to -14.7‰, and $\delta^{15}N$ was 9.9 ± 1.4 ‰ in average, ranging from 11.7 to 8.0‰. Individuals with unidentified sex (N=7) recorded $\delta^{13}C$ and $\delta^{15}N$ values that were -16.4 ± 1.6‰ with a range from -18.1 to -14.4‰ and 9.5 ± 2.2‰ with a range from 11.8 to 6.6‰, respectively. No significant difference was found among the sex categories. However, the difference in $\delta^{13}C$ values was recognized using the burial type categories, individuals buried in primary position (N=17) were -16.9 ± 1.3‰ (ranging from -19.1 to -14.4‰) while individuals with boat shaped burial (N=2) were -14.5 ± 0.3‰ (ranging from -14.3 to -14.1‰). Probablity using t-test was 0.0203 ($p<0.05$) showing a significant difference between the two burial categories. Individual buried using jars (N=2) had no significant difference with the other two categories. Thedifference in $\delta^{15}N$ values among the three categories was not statistically significant ($p>0.05$). For the age categories, both $\delta^{13}C$ and $\delta^{15}N$ values yielded no significant difference.

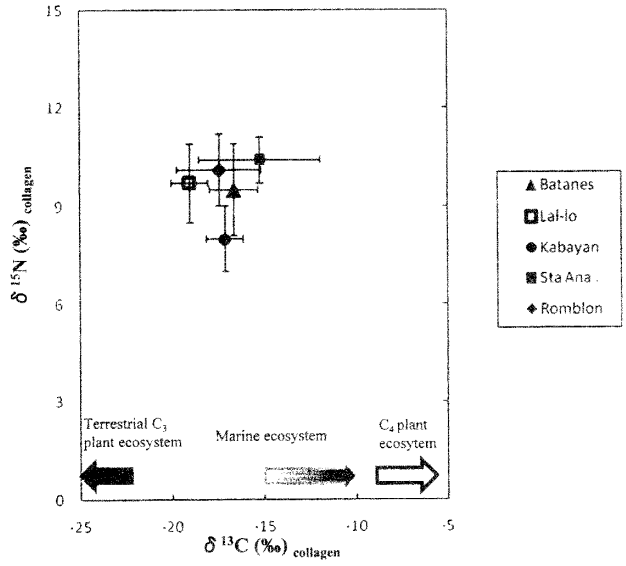

Fig. 2. The average value and standard deviation of $\delta^{13}C$ and $\delta^{15}N$ of human bones and hair at the five study sites. The $\delta^{13}C$ response to the ecosystem type of the diet is shown as estimated collagen values.

Lal-lo site: The $\delta^{13}C$ values for Lal-lo site (N=11) were higher than other burial sites (Fig. 2). The values were between -21.3 to -18.4‰ with an average of -19.4 ± 1.2‰. The $\delta^{15}N$ values were between 10.8 to 6.8‰ yielding the average value of 9.6 ± 1.6‰. For male individuals (N=3), $\delta^{13}C$ value was -19.5 ± 1.5‰ in average, ranging from -21.3 to -18.5‰ and $\delta^{15}N$ value was 8.9 ± 1.9‰ in average, ranging from 10.5 to 6.8‰. A female sample (N=1) recorded $\delta^{13}C$ value of -18.4‰ and $\delta^{15}N$ value of 10.8‰. Individuals with unidentified sex (N=7) showed $\delta^{13}C$ value of -19.0 ± 1.0‰ in average and ranging from -20.0 to -17.7 ‰, and $\delta^{15}N$ value of 10.0 ± 1.0‰ in average and ranging between 11.0 to 9.2‰. Comparison between male and UI sex revealed no significant difference in both $\delta^{13}C$ and $\delta^{15}N$ values. Correlation among the different localities of shell midden burial sites also showed no significant difference in the average collagen $\delta^{13}C$ and $\delta^{15}N$ values; Catayauan (-19.5 ± 0.7‰; 9.0 ± 1.6‰), Dugo (-19.0 ± 1‰; 10‰) and San Lorenzo (-19.9 ± 1.9 ‰; 10.2 ± 1.1‰).

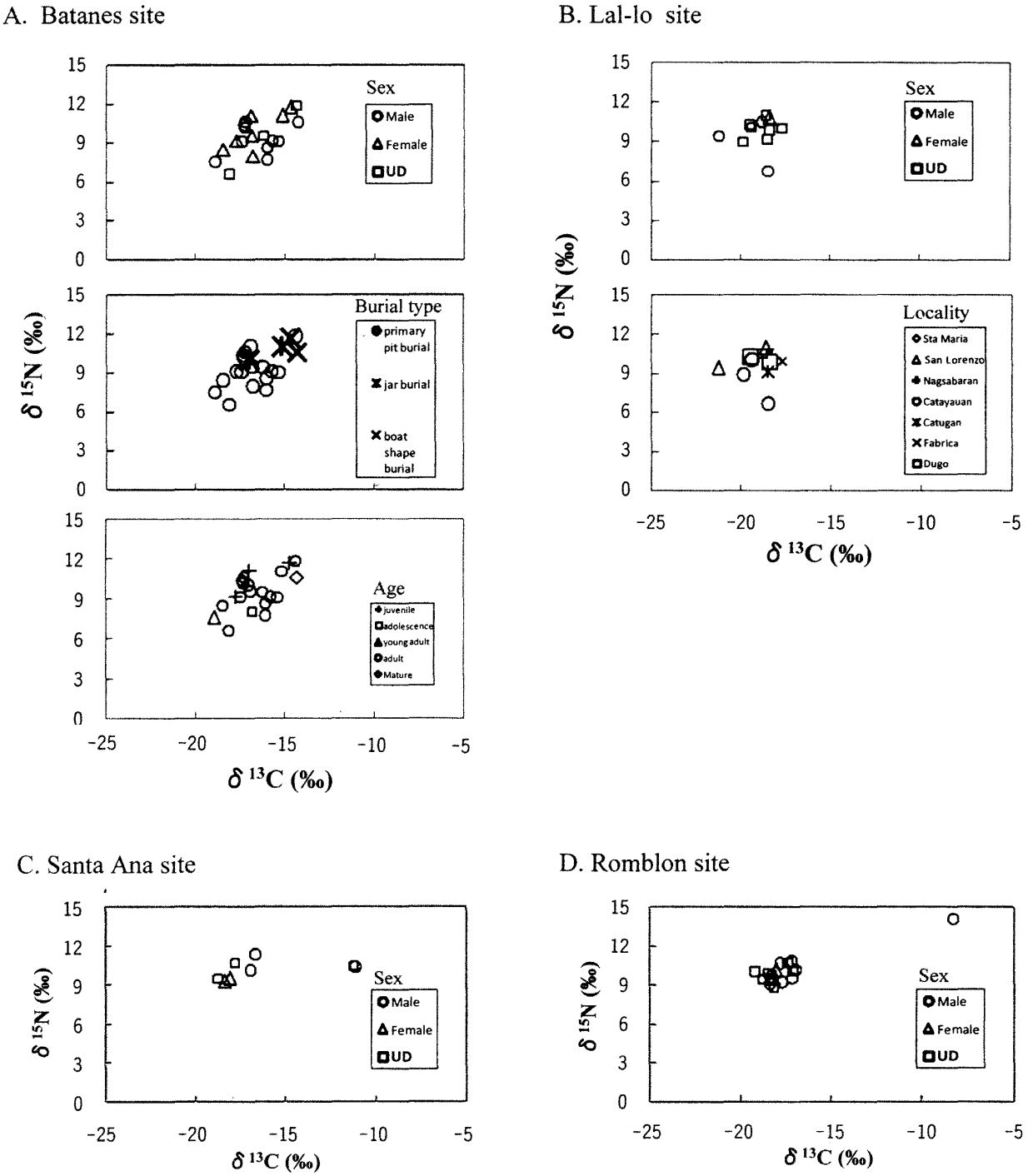

Fig. 3. Cross-plotting of $\delta^{13}C$ and $\delta^{15}N$ values by categories. (A) Batanes site by sex, burial type and age: (B) La l-lo site by sex and shell midden site; (C) Santa Ana and (D) Romblon sites by sex

Kabayan site: Hair from three mummies was analyzed for seasonal changed reflecting the diet during the entire hair growth until the death of the individual (Fig 4). Results of the $\delta^{13}C$ and $\delta^{15}N$ values average was $-17.0 \pm 1‰$ and $8.0 \pm 1‰$ respectively. Male mummies (N=2) recorded $\delta^{13}C$ values of $-17.0 \pm 1‰$ in average and ranging from -17.3 to $-15.7‰$, and $\delta^{15}N$ value of $9.0 \pm 2‰$ in average and ranging from 9.7 to 7.5‰. For a female mummy (N=1) the average $\delta^{13}C$ and $\delta^{15}N$ values were $-17.2‰$ and 8.3‰, respectively and showed some temporal change in $\delta^{13}C$ values. The two male mummies showed higher values of $\delta^{15}N$.

Santa Ana site: The collagen $\delta^{13}C$ value recorded the

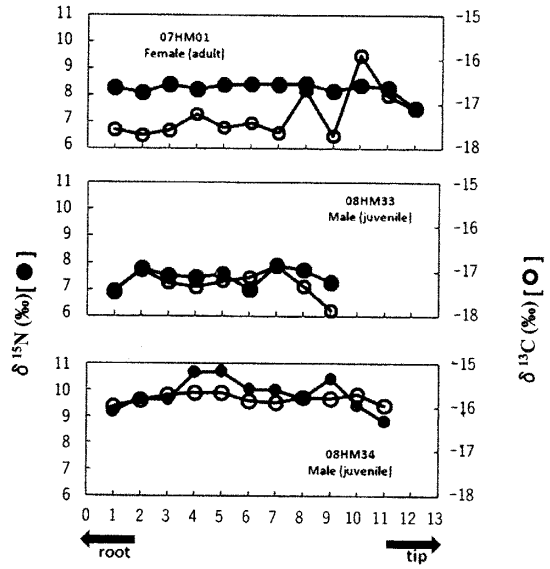

Fig. 4. $\delta^{13}C$ and $\delta^{15}N$ values of the hair from mummies in Kabayan site.

average and standard deviation of -15.2 ± 3.3‰, and ranged from -18.4 to -11.1‰. The $\delta^{15}N$ values were 10.4 ± 0.7‰ in average and ranged from 11.4 to 9.3‰. Using sex category (Fig. 3C) difference in the average $\delta^{13}C$ values between -14.9 ± 3.3‰ for males (N=3) and -18.2 ± 0.2‰ for females is largely attributed to a single male individual that recorded a distinctly high $\delta^{13}C$ value. The average $\delta^{15}N$ values for male and female (10.6 ± 0.6‰ and 9.4 ± 0.2‰) are quite comparable. Three individuals with unidentified sex recorded the $\delta^{13}C$ of -20.6 ± 3.1‰ in average and ranging from -17.7 to -11.2‰, and the $\delta^{15}N$ values of 10.2 ± 0.7‰ in average and ranging from 10.7 to 9.5‰.

Romblon site: The collagen isotopic data were clustered around -18‰ in $\delta^{13}C$ and 10‰ in $\delta^{15}N$, except for one outlier (07HM19). The average values are -17.4 ± 2.3‰ in $\delta^{13}C$, and 10.1 ± 1.1‰ in $\delta^{15}N$. Sex category (Fig. 3D) showed no significant difference between male (N=3) and female (N=2) and unidentified sex individuals (N=3) on both $\delta^{13}C$ and $\delta^{15}N$ values.

Discussion

The recognized large variation in $\delta^{13}C$ values ranging from -21.3 to -8.4‰ suggests variation in dietary resources. The $\delta^{13}C$ values as well as $\delta^{15}N$ values are highly variable among plants and animals. Terrestrial C_3 plants analyzed from Batanes site showed $\delta^{13}C$ value range from -32.2 to -25.2‰ and $\delta^{15}N$ value range from 10.6 to -0.7‰. For C_4 plants consisting of corn, sugarcane and millet, $\delta^{13}C$ and $\delta^{15}N$ values ranges were between -12.6 to -11.2‰ and 3.2 to -2.0‰, respectively. The $\delta^{13}C$ and $\delta^{15}N$ values of medium size marine fish range from -16.1 to -16.4‰ and from 12.1 to 6.3‰, and those of shellfish are -14.7 to -7.1‰ and 8.3 to 2.9‰ for shellfish. One terrestrial herbivore was analyzed and showed $\delta^{13}C$ and $\delta^{15}N$ values of -25.1‰ and 6.8‰, respectively. River mollusks from Cagayan River were analyzed by Mihara (2006) and yielded $\delta^{13}C$ and $\delta^{15}N$ values range between -30.2 to -27.0‰ and 8.1 to 6.0‰, respectively. Likewise, river fish $\delta^{13}C$ value ranges between -27.4 to -18.3‰ and the $\delta^{15}N$ values were from and 13.9 to 5.6‰.

In general, C_3 plants dominate the Philippine staple food such as root crops like taro and yams in earlier peroids and later on rice, however, millets (C_4) were also cultivated in the Central Philippines in the 16th century. While sweet potato which was first introduced by the Spaniards in the 16th century and corn that was introduced in the 17th century (Scott 1994) became also staple food.

The wide range of $\delta^{15}N$ values from 14.1 to 7.5‰ reflects variation in food; e. g. rerative importance of terrestrial versus aquatic resources. Hunting was common especially in the mountainous area while fishing and shellfish gathering are normally employed in areas where ocean or river is available. The variation is normally insignificant in terms of sex difference, as in the case of the $\delta^{13}C$ and $\delta^{14}N$ analysis of the bone collagen and apatite from the human remains (N=33) of Ban Chiang site northeast Thailand about 4000-1800 cal BP, showing that the $\delta^{13}C$ values obtained from collagen showed ranged from -20.5 to 18.0‰ reflecting C_3 plants (King and Norr 2006). On the other hand, this case study showed that $\delta^{14}N$ values suggested increased consumption of aquatic resources or carnivorous terrestrial animals over time.

Batanes site showed reliance on both terrestrial and marine resources that confirms most ethnographic accounts wherein, root crops and cereals were the staple food and aquatic resources from the ocean were considered as the main source of protein (Hornedo 2000).

From the archaeological finding, marine fish bones and shellfish were believed to have been exploited although the numbers are small. Terrestrial snail also appeared in some sites and was believed to have also played a major role in protein resources in Batanes (Szabo *et al.* 2003). However, the results of $\delta^{13}C$ ($-16.6\pm1.3‰$) and $\delta^{15}N$ ($9.8\pm1.7‰$) measurement were inconsistent with pure terrestrial protein resources.

The Lal-lo site $\delta^{13}C$ and $\delta^{15}N$ values average ($-19.4\pm1.2‰$ and $9.6\pm1.6‰$) showed a diet more dependent on terrestrial resources. The Cagayan river runs through Lal-lo municipality and since prehistoric time to present, the river was the source of protein for the inhabitants. Considering the presence of deer and wild pig bones from archaeological sites (Tanaka 1997; de la Torre 2000; Garong 2000, 2001, 2002 and 2006), it is evident that hunting wild animals also contributed to the diet of the individuals. Recent food items (freshwater fish and mollusks) measured for $\delta^{13}C$ and $\delta^{15}N$ from Lal-lo (Mihara 2006) reflects the values obtained from the collagen.

The $\delta^{13}C$ values average ($-17.0\pm1‰$) of the mummies from Kabayan site showed dependence on both terrestrial C_3 plant and aquatic ecosystems. Considering the topographical location, animals from river and streams were the possible sources of protein. The hair samples showed lower average $\delta^{15}N$ values ($8.0\pm1‰$) compared with the other four sites. It is assumed that a low-meat diet would produce lower $\delta^{15}N$ values in the body proteins and meat diet would produce higher $\delta^{15}N$ values (Schoeninger and De Niro 1984). C_3 plants or vegetables could have possibly influenced the diet.

In general, the $\delta^{13}C$ ($-15.2\pm3.3‰$) value of Sta. Ana site showed protein resources more dependent on aquatic ecosystem. However, three individuals showed lower $\delta^{13}C$ values between -11.5 to $-11.1‰$ that was different from other individuals depending on C_3 plant ecosystem. The shell midden unearthed from the excavation was mainly brackish shellfish which were believed to have been collected from the nearby river or bodies of water. The Pasig River that runs through the site is actually a tidal estuary and played a major role as one of the trade route during the Age of Contact in Philippine prehistory between AD500 - AD1400. It is difficult to know exactly the type of the plant and to identify C_4 plants, since no plant remains were found in the excavation aside from recent food items.

In Romblon site, the $\delta^{13}C$ and $\delta^{15}N$ values ($-17.4\pm2.3‰$ and $10.1\pm1.1‰$ in average) are concentrated in a small range and do not show so much variations. Generally, the diet reflects dependence on both terrestrial resources and marine ecosystems. Both sea and at the same time, hunting and possible domestication of animals might have been introduced at that time. But there was one male outlier that showed lower $\delta^{13}C$ and $\delta^{15}N$ value of $-8.4‰$ and $14.1‰$ suggesting a diet dependent on coral fish, of which $\delta^{13}C$ value was about $-13‰$ or seaweeds with $\delta^{13}C$ value between -13.2 to $-4.0‰$ (Fry et al. 1982).

The earliest evidence of protein resources in the Philippines was from Palawan in Tabon cave ($47,000\pm11,000$ BP) where shellfish, fish and bats remains were recovered (Ronquillo 1998). Towards the end of the Neolithic period with the introduction of rice cultivation, it became evident that domestication of crops and animals were being employed. The five sites used in this study were mostly in the Age of Contact period and even later. The results of the $\delta^{13}C$ and $\delta^{15}N$ analysis from the 61 individuals had largely terrestrial plant-based diet and consumed both terrestrial and aquatic protein that could be either marine or riverine, depending on the topographical location and environment. Exception are the Lal-lo site that suggest protein resources more on terrestrial-based ecosystem and the Santa Ana site that showed large reliance on marine-based ecosystem. Higher $\delta^{15}N$ value for some individuals suggests consumption of large amounts of marine fish. It is difficult to determine whether there was an increase in animal domestication since most of the sites relied mostly on aquatic resources aside from not so much faunal remains.

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Appendix 1. List of human remains from Batanes site

Lab. No.	Accession No. and/or Site Code	Locality	Burial Type	Period	Grid	Feature	Sex	Age	%C	%N	C/N	$\delta^{13}C$	$\delta^{15}N$
07HM21	UPAM-IUB-96-211-010	Itbud Uyugan	primary pit burial	16th-17th centuries	S20W87	Nikki	UI	juvenile	43.4	14.8	2.9	-16.9	11.1
07HM22	UPAM-IUB-96-211-014	Itbud Uyugan	primary pit burial	16th-17th centuries	S38W87	Feature L2	UI	young adult	44.2	15.2	2.9	-15.8	9.2
07HM23	UPAM-IUB-96-211-007	Itbud Uyugan	primary pit burial	16th-17th centuries	S14W87	Bart	F	young adult	43.1	13.9	3.1	-16.9	9.6
07HM24	UPAM-IUB-96-211-023	Itbud Uyugan	primary pit burial	16th-17th centuries	S38W87	Feature L2	M	young adult	38.2	13.0	2.9	-14.4	11.8
07HM25	II-95-J	Itbud Uyugan	primary pit burial	16th-17th centuries	S14W87	Bad Trip	M	adult	40.0	13.4	3.0	-17.3	10.2
08HM54	II-2001-Y	Itbud Uyugan	primary pit burial	16th-17th centuries	S18W52 & S18W53	Feature H	F	adolescence	40.8	13.9	2.9	-16.8	8.0
08HM55	II-2001-Y	Itbud Uyugan	primary pit burial	16th-17th centuries	S20W53	Hermione	F	adolescence	43.6	14.9	2.9	-17.7	9.1
08HM56	UPAM-IUB96-211.026	Itbud Uyugan	primary pit burial	16th-17th centuries		Kaka	UI	adult	40.0	12.9	3.0	-17.4	10.4
08HM57	II-95-J	Itbud Uyugan	primary pit burial	16th-17th centuries	S38W87	K2	UI	adult	48.9	17.1	2.9	-16.2	9.5
08HM58	II-95-J	Itbud Uyugan	primary pit burial	16th-17th centuries	S6W46	Feature E	UI	adult	46.3	16.1	2.9	-18.1	6.6
08HM59	No accession	Itbud Uyugan	jar burial	16th-17th centuries	S10W93	Unwanted	M	adult	45.7	15.5	2.9	-17.0	10.0
08HM60	UPAM-IUB96-211-001	Itbud Uyugan	jar burial	16th-17th centuries	S33W87	Winona	F	adult	44.1	14.6	3.0	-15.2	11.1
08HM61	II-95-J-469	Itbud Uyugan	primary pit burial	16th-17th centuries	S09W46	Feature L	M	young adult	46.4	16.2	2.9	-19.0	7.6
08HM62	II-95-J	Itbud Uyugan	primary pit burial	16th-17th centuries	S35W75	Chochoyoc	F	adolescence	40.5	13.8	2.9	-16.0	8.7
08HM63	II-95-J	Itbud Uyugan	primary pit burial	16th-17th centuries	S14W87	Taruga	F	mature	41.1	13.9	2.9	-17.5	9.1
08HM64	UPAM-IUB96-211.009	Itbud Uyugan	primary pit burial	16th-17th centuries	S20W87	Marahet	M	adult	43.5	15.1	2.9	-18.5	8.5
08HM65	II-95-J	Itbud Uyugan	primary pit burial	16th-17th centuries	S4W13	Sabtang Fellow	UI	adult	44.5	15.7	2.8	-16.0	7.8
08HM66	UPAM-IUB96-211.002	Itbud Uyugan	primary pit burial	16th-17th centuries	S33W87	Jonmark	UI	juvenille	43.2	14.7	2.9	-17.3	10.6
08HM67	II-1995-S	Chuhangin Site, Ivuhos	boat shape burial	355±70 BP		Grave #1	F	juvenile	44.2	14.2	3.1	-14.7	11.7
08HM68	II-1996-O2	Mayahao Beach Ridge, Ivuhos	boat shape burial	355±70 BP		Grave #1	M	mature	47.0	16.0	2.9	-14.3	10.6
08HM69	No accession	Ivana, Basco	primary pit burial	16th-17th centuries			M	adult	42.2	14.8	2.9	-15.4	9.1

Appendix 2. List of human remains from Lal-lo site

Lab. No.	Accession No.	Locality	Burial Type	Grid	Feature	Sex	Age	%C	%N	C/N	$\delta^{13}C$	$\delta^{15}N$
08HM28	II-95-O-9596	Sta Maria	primary pit burial	N_6W_7	Burial 1	M	adult	38.5	12.7	3.0	-18.8	10.5
08HM29	II-96-U2-7114	San Lorenzo	primary pit burial	$N_{24}E_{22}$	Burial 1	M	adolescence	41.9	14.2	3.0	-21.3	9.5
08HM30	No accession	Nagsabaran	primary pit burial	-	Burial 1	F	adolescence	41.5	14.7	2.8	-18.4	10.8
08HM31	II-96-V_2-6354	Catayauan Conciso	primary pit burial	N_6E_2	Burial 1	M	adult	45.5	15.3	3.0	-18.5	6.8
08HM04*	II-96-V2-6355	Catayauan Conciso	primary pit burial	N_5E_3	Burial 3	UI	adolescence	39.2	13.8	2.8	-19.9	9.0
00HM04*	II-96-Q4-12	Catugan	primary pit burial	-	-	UI	UI	40.3	14.4	2.8	-18.5	9.2
00HM07*	II-95-P-212	Catayauan Sison	primary pit burial	N_5W_3	Burial 1	UI	UI	43.1	14.5	3.0	-19.4	10.1
01HM24*	II-2000-Q351	Fabrica	primary pit burial	-	-	UI	UI	42.8	14.9	2.9	-17.7	10.0
03HM01*	II-96-U2-104592	San Lorenzo	Jar burial	-	-	UI	juvenile	41.8	15.0	2.8	-18.6	11.0
03HM07*	II-80-J-8211	Cortez site	primary pit burial	S_1W_2	-	UI	UI	40.5	13.8	2.9	-18.4	9.9
03HM08*	II-01-P2-3322	Leon Ibe	primary pit burial	N_2E_1	-	UI	UI	34.7	12.0	2.9	-19.5	10.3

* Mihara 2006

Appendix 3. List of human remains from Kabayan site

Lab.No.	Locality	Burial Type	Sex	Age	Tissue	%C	%N	C/N	$\delta^{13}C$	$\delta^{15}N$
07HM01	Timbac cave 2	Mummy Cave Coffin Burial	F	adult	hair	43.2	13.3	3.2	-17.2	8.3
07HM33	National Museum Kabayan Branch	Mummy Cave Coffin Burial	M	juvenile	hair	53.4	17.0	3.1	-17.3	7.5
08HM34	Kangal Cave Bangao Gusaran	Mummy Cave Coffin Burial	M	juvenile	hair	47.0	14.9	3.2	-15.7	9.7

Appendix 4. List of human remains from Santa Ana site

Lab. No.	Accession No.	Locality	Burial Type	Sex	Age	%C	%N	C/N	$\delta^{13}C$	$\delta^{15}N$
08HM11	Box SA66 7	Old Lamayan road	primary pit burial	M	Adult	44.1	14.7	3.0	-16.7	11.4
08HM12	BL G-R-23	Old Lamayan road	associated with Sung, Yuan/early Ming dynasteis tradewares	F	adolescence	45.1	16.2	2.8	-18.4	9.5
08HM13	No accession	Old Lamayan road		UI	unknown	48.4	16.8	2.9	-11.5	11.0
08HM16	Sta Ana 1968 Man 13	Old Lamayan road		UI	unknown	46.1	15.6	3.0	-17.8	10.7
08HM17	Sta Ana Man 5	Old Lamayan road		M	adult	45.9	16.6	2.8	-16.9	10.2
08HM18	Sta Ana Man 12	Old Lamayan road		M	adult	47.8	17.0	2.8	-11.1	10.4
08HM22	No accession	Old Lamayan road		F	adult	45.0	16.0	2.8	-18.1	9.3
08HM23	Sta Ana 1966 Man 6	Old Lamayan road		UI	Young Adult	45.5	16.2	2.8	-11.2	10.5

Appendix 5. List of human remains from Romblon site

Lab. No.	Accession No.	Locality	Burial Type	Sex	Age	%C	%N	C/N	$\delta^{13}C$	$\delta^{15}N$
08HM01	Banton Is GN I	Guyungan cave, Banton	secondary burial using wooden coffin	M	adult	44.7	15.7	2.9	-18.4	9.1
08HM02	Banton 30 GN I	Guyungan cave, Banton	associated with Sung, Yuan and Ming China wares	UI	young adult	47.1	16.4	2.9	-18.1	8.8
08HM03	IV-66-H-78	Guyungan cave, Banton		UI	adult	47.2	17.0	2.8	-17.1	10.1
08HM04	IV-66-H-79	Guyungan cave, Banton		UI	adolescence	44.4	14.1	3.1	-18.3	9.8
08HM05	IV-66-H-81	Guyungan cave, Banton		UI	adult	46.6	16.3	2.9	-18.2	9.5
08HM06	IV-66-H-82	Guyungan cave, Banton		UI	adult	43.7	15.4	2.8	-17.4	10.7
08HM07	IV-66-H-83	Guyungan cave, Banton		UI	adult	38.2	16.9	2.3	-19.2	10.0
08HM08	IV-66-H-84	Guyungan cave, Banton		UI	adolescence	45.1	16.2	2.8	-18.4	9.5
08HM09	IV-66-H-85	Guyungan cave, Banton		UI	adult	52.6	18.5	2.9	-18.7	9.5
08HM10	IV-66-H-87	Guyungan cave, Banton		UI	mature	44.4	15.5	2.9	-18.5	9.9
07HM13	5570	Guyungan cave, Banton		M	young adult	43.9	15.5	2.8	-17.7	9.2
07HM14	IV-66-H-72	Guyungan cave, Banton		M	adult	45.9	16.3	2.8	-17.1	9.5
07HM15	IV-66-H-68	Guyungan cave, Banton		M	adult	45.9	16.6	2.8	-16.9	10.2
07HM16	IV-66-H-54	Guyungan cave, Banton		M	adult	46.1	15.6	3.0	-17.8	10.7
07HM17	IV-66-H-66	Guyungan cave, Banton		F	adolescence	46.7	16.4	2.9	-18.0	10.1
07HM18	D	Guyungan cave, Banton		F	young adult	46.7	16.5	2.8	-18.2	9.5
07HM19	IV-66-H-59	Guyungan cave, Banton		M	adult	50.1	17.9	2.8	-8.4	14.1
07HM20	IV-66-H-63	Guyungan cave, Banton		M	adult	50.0	17.5	2.9	-17.2	10.8

Appendix

フィリピン埋葬遺跡出土人骨コラーゲンを用いた炭素・窒素安定同位体分析

A. GARONG[1], F. DATAR[2], W. RONQUILLO[3], 小池　裕子[1]

要　旨

フィリピンにおける古代人の食性を調べるため、それぞれ異なった地理的位置・環境条件・生業戦略をもつ5箇所の遺跡から出土した61個体の炭素・窒素安定同位体比（$\delta^{13}C$ and $\delta^{15}N$）を分析した。Batanes諸島はLuzon島北端から約200km、台湾から150kmに位置し、いわゆる船型埋葬と甕棺埋葬（355±70 B.P.）が知られている。21個体の人骨コラーゲン分析の結果、$\delta^{13}C$値は−16.6±1.3‰、$\delta^{15}N$値は9.8±1.7‰で、食料中の蛋白源がやや海洋生態系に依存していることを示した。同位体比は埋葬形式で異なり、船型埋葬と甕棺埋葬の人骨の$\delta^{13}C$・$\delta^{15}N$はともに土坑墓のものよりも高かった。一方、Luzon島北部に位置するLal-lo貝塚遺跡群（1000 BP）から出土した11個体では、$\delta^{13}C$値が−19.4±1.2‰、$\delta^{15}N$値が9.6±1.6‰で、より陸上生態系に依存すること示し、貝塚を構成する淡水貝が陸上生態系に属する値をもつことと整合的であった。北西Luzon島のBenguet山地にあるKabayan遺跡は13世紀のミイラを産出する遺跡で、3体のミイラの毛髪は$\delta^{13}C$値が−17.0±1.0‰、$\delta^{15}N$値が8.0±1.0‰で、陸上と内水面生態系の両者を利用していたことを示唆した。マニラ郊外のSanta Ana遺跡（about 1095 AD）の8個体では、$\delta^{13}C$値が−15.2±3.3‰、$\delta^{15}N$値が10.4±0.7‰で、5つの遺跡中、最も海洋生態系に依存していた。フィリピン中央部のRomblon島遺跡（13th-14th centuries）の18体の骨コラーゲンは$\delta^{13}C$値が−17.4±2.3‰、$\delta^{15}N$値が10.1±1.1‰で陸上と内水面生態系の両者を利用していたことを示唆した。またこれらの5遺跡において、$\delta^{13}C$・$\delta^{15}N$値の性差はいずれもみとめられなかった。

キーワード：炭素安定同位体、窒素安定同位体、埋葬遺跡、人骨、ミイラ、骨コラーゲン、毛髪、フィリピン

1　九州大学大学院比較社会文化研究院、環境変動部門、生物多様性講座
2　フィリピン大学、人類学研究室、ケソン市，フィリピン
3　フィリピン国立博物館、考古部門、マニラ、フィリピン