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Editor

James D. Paterson
Department of Anthropology
The University of Calgary
2500 University Drive Northwest
Calgary, Alberta, Canada
T2N 1N4

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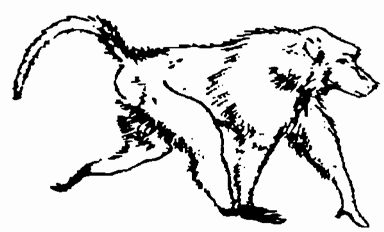
The Review/Revue is published by the Canadian Association for Physical Anthropology / L'Association pour L'Anthropologie Physique au Canada. This is the last issue to be published. The journal has ceased to exist, and will be replaced with a Newsletter. For further information, membership, and/or subscription to the Newsletter, please contact:

Dr Shelley R. Saunders
Department of Anthropology
McMaster University
1280 Main Street West
Hamilton, Ontario
Canada, L8S 4L9

FROM THE EDITOR'S WORKSTATION



Welcome to the last issue of the CRPA / RCAP. While the last year has proven to be an extremely "interesting" one in my personal and academic life, it has not been so for the Review. I have no doubt that many of our international readers will be saddened not to be receiving any further volumes in this series, but the facts of the logistics of attempting to produce a quality journal in Canada for physical anthropology have finally made their impact evident. While I, as your current editor have attempted browbeating and cajolery to bring manuscripts into the Review, I have always been scraping to find enough material to fill an issue. In some ways I will find it to be an enormous relief to be able to put the preparation and production of the Review behind me.

I have in a very personal way learned an enormous amount about editing, writing, and the intricacies of type faces, points, leading, and the other facets of printing, to the extent that if I ever lose my academic position, I will be able to step into any modern print shop and be up to speed in short order. Such are the fringe benefits of the editorial life.

This issue has been prepared in a somewhat less complicated manner than the previous volumes. It has been prepared as electronic manuscript in Microsoft Word 3.01 from a collection of material submitted as IBM Wordstar files, raw manuscript, Bitnet downloads, and in the case of my own submission, naturally composed on a Macintosh. All of this mass of material was eventually fed into Ready,Set,Go,(the newest version 4.0a) and printed out on our old reliable original LaserWriter. All of the graphics were inserted by the printer rather than being done on the Mac since some of the material would have been nearly impossible to adequately digitize.

The masters were printed out on legal size paper in an 8.5inch by 12.5 inch format, and reduced to 70% in the final printing process. This yields an effective 400 dots per inch of printing resolution with an effective type size of 10 point.

The papers and short notes which make up this issue, have, very surprisingly, turned up in the last two and one half months, rather than been waiting for a year. The major contribution is the co-winning student paper from the 1987 meeting. This paper was submitted in advance and underwent the usual anonymous peer review. The other contributions have been accepted directly by editorial fiat, and in several cases, (*Pardonnez moi, mes amis!*) do not have abstracts or lack French versions. I felt that all of these pieces fit more under the heading of "Short

Papers" or "Brief Reports". We include for the first time a paper from Australia, and one (vouched for by Gary Heathcote) from the Peoples Republic of China. I hope that you find all of the pieces worth reading.

As I mentioned, things have been very exciting in the Anthropology Department at Calgary in the past year. We experienced the retirement of 6 of our 12 faculty members, a phenomenon which many Universities are now coming face to face with, and were eventually allowed to hire 4 replacements. The process of trying to interview, rank, and eventually make offers to a select subset of the 60 applicants was a strain for all. We now have a strong Social Anthropology department, but must in the next year embark upon that most difficult of crusades - the finding of a primatologist for the fifth position. Anyone who has been involved in the recruiting process recently will realize what I mean by that. Take note, budding primatologists, it is currently a seller's market!

I was also involved in operation of a primatology field school for senior undergraduates at the Arashiyama West Institute (Dilley, Texas) which was a great success. Not only did students from Saskatchewan, Alberta, and British Columbia take part, but we were able to make a substantial contribution to the operation of the monkey colony. We were, naturally, a source of great amusement among the local populace, they tend to think of us as "frostbacks". For those who are not aware of it, the Arashiyama West Institute operates a colony of Japanese macaques, *Macaca fuscata fuscata*, now numbering over 400 individuals, on a ranch near Dilley, in south Texas. The colony has always operated on a shoestring, but the situation is nearing a crisis this year. The monkeys require a substantial monetary input, and Lou Griffin-O'Neill, the director had to sell her personal vehicle last year in order to pay for the monkey's food. Any contributions that you or your students can make to help support this colony would be extremely welcome. It should be noted that Canadians more than US citizens have been the major researchers at Dilley over the past few years.

Donations may be sent to:

Lou Griffin-O'Neill, director
South Texas Primate Observatory,
Arashiyama West Institute
P.O.Box 702
Dilley, Texas, U.S.A.

By the time you receive this issue, I will be basking in the sun, on the beach at Fiji, enroute to my sabbatical leave locale of Australian National University in Canberra, Australia. So, I leave you with a combined salutation:

"G'day Mate, Eh?"

Jim Paterson, Editor.

President's Message

The publication of this final issue of the Canadian Review of Physical Anthropology/Revue Canadienne d'Anthropologie Physique is a milestone upon which we may reflect with both pride and regret. Because of the wide scope and consistently high quality of its articles, the Review is cited frequently, and is recognized internationally as a valuable contribution to the field. This is an achievement of which CAPA / AAPC can be proud.

Thanks are due to the authors, whose articles made this venture a success, and to the several institutions whose subscriptions helped support it. On behalf of the members, I especially want to thank the Editors past and present: Ross McPhee and William Wade (1974-1979 and 1979-1983 respectively, both terms held at the University of Manitoba), and James Paterson, University of Calgary, 1983 to the present. The position of Editor has required resourcefulness, dedication, and hard work - at no time in greater measure than during the present Editor's term when the problems of sustaining the Review with too few funds and too few manuscript submissions finally became insurmountable.

At the recent meetings or the Association (November 1987), members suggested that our needs in terms of communicating with each other and with colleagues internationally can now best be served through our Newsletter, and the publication of symposia proceedings. Physical Anthropology has matured in this country to the stage where local expertise could provide the focus for international symposia hosted at Canadian centres on topics such as osteology, primatology, and biomedical/population studies. The *Homo erectus* symposium hosted by the Association, the proceedings of which were published in 1981 by the University of Toronto Press, is a good example of what can be achieved with this format.

We are sad to see the demise of the Canadian Review of Physical Anthropology. However, to end on a positive note, I propose that we view this milestone as signifying the possibility of new initiatives.

Nancy Ossenberg, President,
Canadian Association for Physical Anthropology / L'Association pour L'Anthropologie Physique au Canada.

The Psychological Well-being of Captive Primates.

Sponsors: University of Massachusetts/Amherst
Harvard Medical School
New England Regional Primate Research Center
Department of Continuing Education
Tufts University School of Veterinary Medicine

Organisers: Melinda A. Novak, Psychology, UMass
Andrew J. Petto, Primatology, HMS-NERPRC
Klaus Miczek, Psychology, Tufts

Location: Boston, Massachusetts, U.S.A.

Dates: 16-18 September, 1988

Registration:
Regular, US$50
Student, US$30
(some scholarship aid for registration is anticipated)

Activities: Poster sessions especially for graduate students, informal round-table discussions, panel discussions

Panel Topics: Defining and Identifying Psychological Well-being in Captive Primates
Measuring and Promoting Psychological Well-being in Captive Primates
Impact of Well-being Regulations on Biomedical and Behavioural Research
How Regulators and Implementors Intrepret New Regulations
Communicating Research Needs and Results to the Public

Additional Sponsorship by American Psychological Association Applied For.

Contact: Andrew J. Petto, PhD
Harvard Medical School
New England Regional Primate Research Center
1 Pine Hill Drive
Southborough, MA 01772 USA
617-481-0400, X295
Bitnet: PETTO@HUSC3

**Editorial Note: This strange message appeared in my in-basket one day last year, purporting to be an obit for one of our more noteworthy members, however, upon checking the validity of this message, I came accross some very abstruse data pertaining to the said 17 wives, not to mention the 89.5 illegitimates (?) and "other riff-raff". You will all be pleased to know that the ghost of that famous member is still holding court in Armidale, and requests that his colleagues contact him.*

Dr. C.E.Eyman

Died recently in his elegant hovel near Bergen Op Zoom Creek, N.S.W., Australia. As can be seen, the festivities were attended by numbers of his devoted followers, admirers, and relatives. He is survived by 17 wives, 128 grandchildren, 89.5 illegitimates, 35 kids, plus colleagues and other riff-raff.

Donations to his combination mausoleum and lounge should be sent to C."Ernie" Eyman, 200 Galloway Street, Armidale 2350, N.S.W., Australia. These gifts are not necessarily tax deductible nor do they carry a happy hours discount.

THE ANCIENT MAYA FROM LAMANAI, BELIZE: DIET AND HEALTH OVER 2,000 YEARS

Christine D. White
Department of Anthropology
Trent University,
Peterborough, Ontario

Abstract: This research is designed to reconstruct diet and nutrition of the ancient Maya at Lamanai over its 2,000 yr. sequence. The design not only tests proposed Lowland dietary models, but also indirectly tests ecological and nutritional hypotheses for Maya collapse. Both organic (carbon and nitrogen stable isotopes) and inorganic (Sr, Zn, Mg) measurements are used to determine diet and sort out confounding variables. The correlation between the two chemical methods is statistically significant. Maize was found to be the major component of the diet in all time periods, but a dramatic decline in consumption occurred during the Terminal Classic - a period equated with cultural decline at many sites. At Lamanai, however, archaeological evidence indicates the Terminal Classic is a time of florescence. Caries analysis provides statistically significant pathological confirmation of diet trends. The later phases (Postclassic and Historic) are characterized by a maize consumption rate of 65-75%, which is identical to that of modern Maya populations. Analysis of porotic hyperostosis indicates that this level of dependency creates a threshold for iron sufficiency. The frequency of porotic hyperostosis reaches 32-43% respectively for these periods. Although porotic hyperostosis is often associated with high levels of phytate, zinc and magnesium data do not support phytate as the cause. It is hypothesized that alkali processing, in combination with parasitic infection, may be creating the poor health status of the later inhabitants of Lamanai.

Resumé: Le but de ce recherche est de reconstruire le régime et la nutrition des Mayas anciennes à Lamanai pendant les 2,000 ans par ordre historique. Le dessin éprouve les modèles d'alimentation proposés pour les Bas-terres aussi bien que, indirectement, les hypothèses écologiques et nutritifs pour l'effondrement des Mayas. Les mesures organiques (isotopes stable de carbon et nitrogen) et inorganiques (Sr, Zn, Mg) étaient employées ensemble pour éliminer les variables confondants d'environs hétérogène. La corrélation entre les deux méthodes chimiques pour la consommation de maïs est significatif statistiquement. Maïs était le composant principal du régime pendant toutes les periodes de temps, mais la consommation déclina dramatiquement pendant la période Terminal Classique - une période associée avec un déclin generai cultural à beaucoup des sites. Cependant, à Lamanai, évidence d'archaeologie montre floraison pour la période Terminal Classique. Analyse de carie provient évidence que confirme statistiquement les changements du régime. Les phases plus tardes, Postclassique et Historique, sont caractérises par un taux de consommation de mais de 65 - 75%, lequel est identique à ça du populace des Mayas modernes. Analyse de "porotic hyperostosis" indique que ce niveau de la dépendance crée un seuil pour la sufficance du fer. La fréquence de "porotic hyperostosis" atteint réspectifement 32 -43% pour ces périodes. Bien que "porotic hyperostosis" est souvent associé avec les niveaux éléves de phytate, les données pour Zn et Mg ne soutient pas l'interprétation que phytate est la cause. L'hypothèse presenté ici c'est que la traitement alcali, combinée avec l'infection parasitique, sont les causes possibles pour l'état de pauvre sante parmi les habitants postérieures de Lamanai.

Key Words: **Maya, carbon and nitrogen stable isotopes, trace elements, caries, iron deficiency.**

* ***Editorial Note:*** *Ms Christine White was co-winner of the Oshinsky-McKern student prize for the best paper presented at the 1987 meeings of the Canadian Association for Physical Anthropology / L'Association pour L'Anthropologie Physique au Canada. Ms White's paper had been submitted to the Review in advance of the meeting and went through the regular peer review process, and had been accepted prior to winning the prize. Ms White is currently a doctoral student at the University of Toronto. The paper by the co-winner was not submitted to the journal.*

INTRODUCTION

As biocultural correlates, subsistence and diet are recognized as important factors in the physical and cultural evolution of humans. Data on food procurement and consumption are imbedded in both archaeological and osteological remains. The availability of food resources is environmentally determined, whereas the dietary regime depends upon cultural factors such as procurement technology, preparation techniques, ideology, and taste preference. The biological response to nutritional, ecological and cultural factors can be measured in skeletal populations by physiological changes which induce pathology. This research attempts to reconstruct a profile of diet and health for the ancient Maya population from the Lowland site of Lamanai, Belize. Factors of nutrition and ecology are combined with archaeological evidence to create a picture of biocultural dynamics over the 2,000 yr. time span of the site.

In the Maya Lowlands, much recent archaeological research has been directed toward understanding subsistence (Harrison and Turner, 1978; Flannery, 1982; Turner and Harrison, 1983; Lambert, 1985; Pohl, 1985). This focus developed from a recognition of the prosperity of high population densities in ecosystems which had previously been considered too fragile to sustain many people over long term. Two issues associated with maize agriculture and dependency have been used to explain the enigmatic collapse of ancient Maya culture These are ecological deterioration and nutritional disease (Willey and Shimkin, 1973).. It is now known that intensive agricultural techniques were practised. Their development appears to be related to population density and is, therefore, understood by most Maya researchers in Boserupian terms (Turner et al., 1977, Harrison and Turner, 1978; Lambert, 1985). The question still remains, however, as to how much maize was consumed relative to other resources.

Compared with the gains made by archaeologists in subsistence knowledge, osteologists have contributed little due to extremely poor preservation, lack of temporal continuity in excavated samples, and limited techniques available to directly assess paleodiet and nutrition. Evidence for diet is neither specific, nor direct, but restricted to studies of stature differentials (Haviland, 1967; Nickens, 1967; Bennett and Bancroft, 1983), nutritional and dental pathology (Saul, 1972; Danforth, 1985,1986).

Heavy maize consumption has not only been implicated by most of these studies, but has also been assumed from ethnohistoric documentation and modern ethnographic studies (Landa, 1566; Benedict and Steggerda, 1936). Nevertheless, given the ecological diversity of the Maya Lowlands, several optional dietary models would have been feasible (Sanders, 1972), each with better nutritional value than maize. Other suggested staples include root crops (Bronson, 1966) and the ramon nut (Puleston, 1968). Root crops would not be preserved in the archaeological record, but are highly productive, more storable, disease resistant, well adapted to tropical ecosystems, and could have provided a greater surplus than maize. Although root crops have a greater caloric value than maize, the protein content is lower (Benedict and Steggerda, 1936). Therefore, an abundant and renewable protein supplement, such as that obtainable from aquatic and marine resources would have been essential. Heavy reliance on fish and seafood has been suggested by Lange (1971) who, along with others has postulated a root and aquatic resource complex (Netting, 1977; Rice, 1978).

Ramon nut arboriculture is the other proposed single staple model (Puleston 1968). Orchards of ramon trees found around most ceremonial centres, could have provided better nutrition than either the root crop/fish complex or maize with less labour investment and minimal soil destruction. Furthermore, ramon is also more productive and more storable. In contrast with the above staple models, mixed diet models have been offered (Wilken, 1971; Harris, 1978; Marcus, 1982), such as the back-door or kitchen garden and the "artificial rain forest" (Wiseman, 1973).

Differences in the timing, sequence, and intensity of the above subsistence models are still controversial (Puleston, 1977; Siemens, 1977; Hammond, 1980) and provide varied interpretations for the course of Maya culture. Temporal shifts in both subsistence technology and diet could be consequences of both social and environmental factors, e.g. population pressure, ecological deterioration, technological innovation, market and trade development.

The goals of this research are; 1) to test the subsistence models of ancient Lowland Maya using chemical techniques to reconstruct the diet of the skeletal population from Lamanai, Belize, 2) to reconstruct the same diet using caries and assess the validity of the results in light of the chemical data, 3) to determine the nutritional value of the diet by measuring a physiological response, porotic hyperostosis, 4) to combine biological and archaeological data to shed light on some biocultural dynamics of the Maya.

SITE DESCRIPTION

Lamanai is a large ceremonial centre located on the New River Lagoon in northern Belize, about 70 km from the Caribbean coast (see Fig.1). Excavated from 1974 to 1985 by David Pendergast of the Royal Ontario Museum, it boasts the longest continuous occupation of any Lowland site and has yielded skeletal material from most time periods over the 2,000 years spanning the Preclassic (1250 B.C. - 250 A.D.) to the Historic (1520-1670 A.D.). After 900 A.D., when most "heartland" sites had been depopulated, Lamanai was still a strong and active centre with affinities to the culturally vibrant Postclassic populations of the Yucatan (Pendergast, 1985, 1986). Archaeological evidence suggests that the site may have survived this long because it had abundant natural resources and was in a strategic location for the flow of commercial goods and information. The cultural continuity of Lamanai allows one to determine the relationship of diet and health to factors of social and environmental change.

The surrounding area contains several distinct vegetational zones, including swamp (bajo), cohune pine ridge, savanna grasses, jungle (including ramon species), and an alluvial shoreline. The ecological diversity of the site and its proximity to inland and coastal water resources make it an environmental microcosm for the entire Maya Lowlands. Thus, the site is ideal for testing hypotheses of dietary choice. Although its inhabitants could potentially draw from any of the proposed dietary models, resource availa-

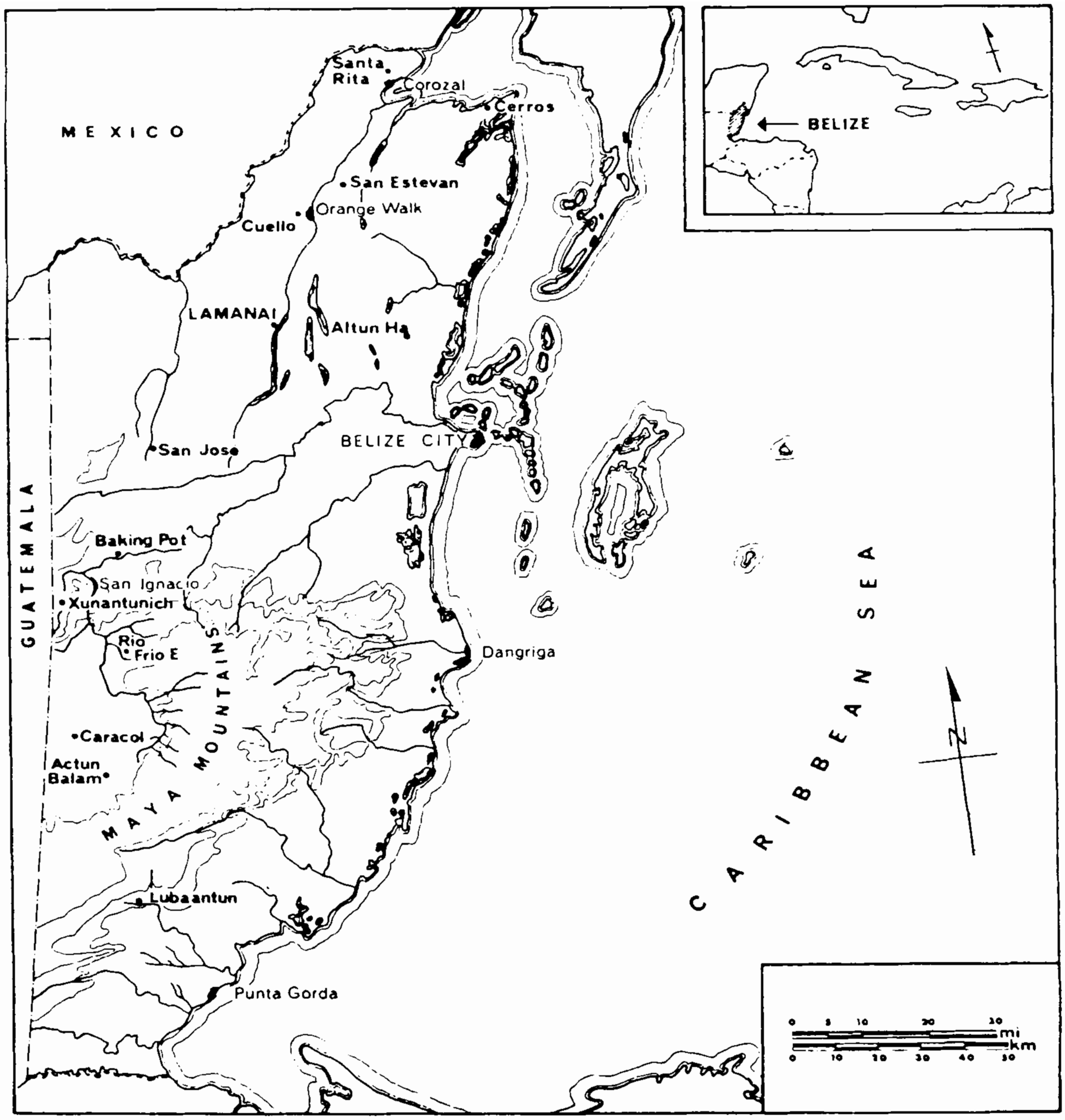


Figure 1: Map of Belize, showing location of Lamanai (after Pendergast, 1981:30).

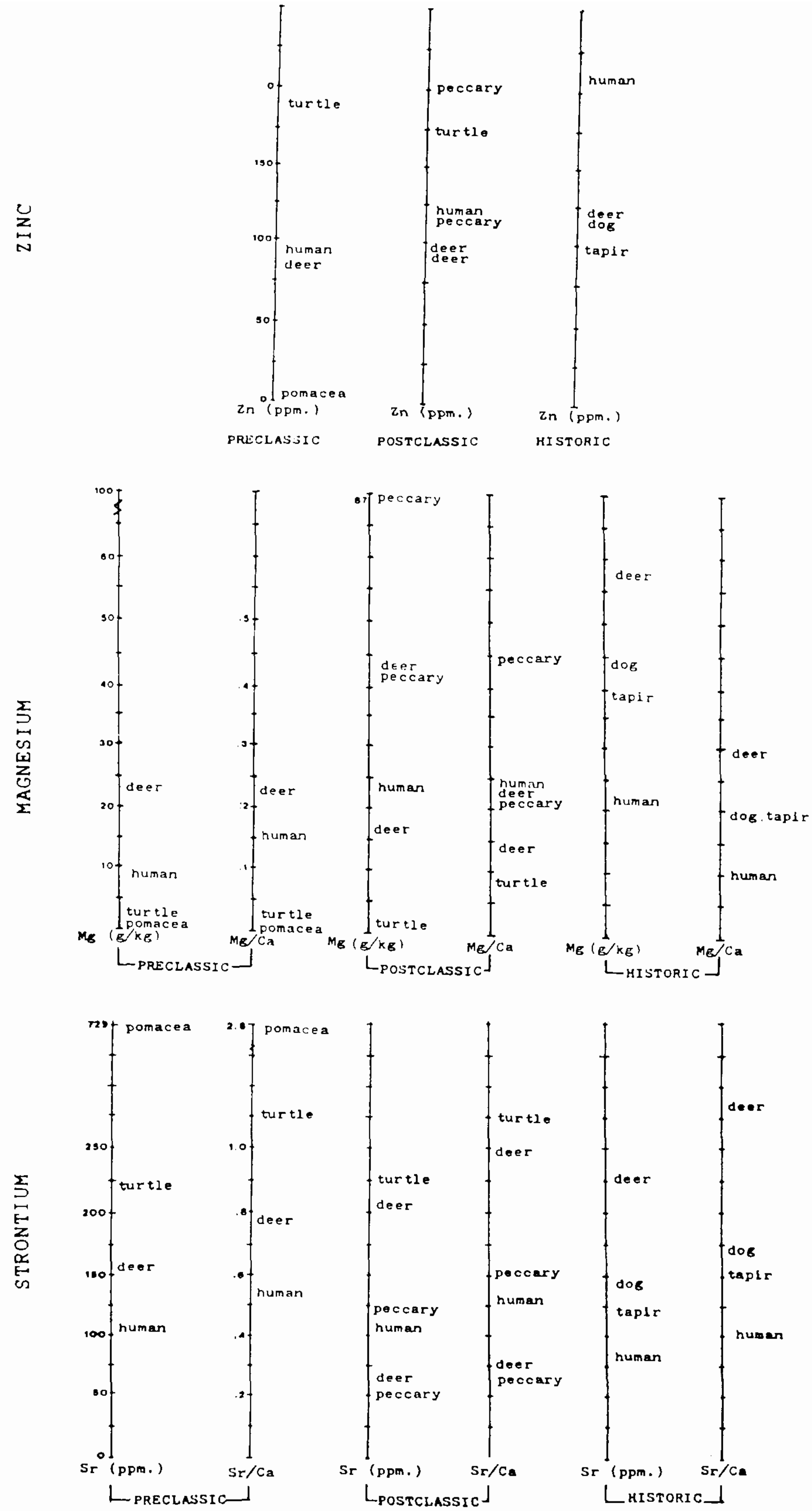
bility does not automatically denote exploitation. It should also be made clear that the generalization of these findings to other Maya Lowland populations is not yet warranted. Lamanai appears to have a long history of maize agriculture. Lagoon pollen cores provide evidence that maize was grown on the site as early as 1500 B.C. (Pendergast, personal communication). According to agronomists, the production potential of the area for maize far exceeded even the highest population estimates (Lambert and Arnason, 1979). There is also evidence of intensive agriculture in the form of raised fields, although the dating of these features is still in question (Lambert et al., 1984).

METHODS

Four distinct sets of data were generated from the total skeletal sample of approximately 300 individuals: 1) stable isotopes of carbon and nitrogen; 2) elements strontium, zinc, and magnesium; 3) dental caries; 4) porotic hyperostosis. While both chemical data sets provide very direct information on diet, organic data (isotopes) may be considered absolute, whereas inorganic data (elements) are relative measures, affected by element levels in soil and water nutrients, as well as food preparation techniques. Both chemical sets were needed to sort out potentially confounding variables arising from the ecological diversity of the site. Although high C4 plant consumption is suspected, the overall $\delta^{13}C$ value could include both marine animals from the coast and maize-eating terrestrial animals. The question of animal consumption was approached through the use of three subsets of data used to determine; 1) if any animals were actually consuming maize; 2) if people were eating animals; 3) which animals, if any, were people consuming. Two sets of archaeological fauna from Lamanai were tested for their isotopic values (i.e. C3 or C4 eating) and element values. These included deer, tapir, peccary, dog, turtle, and pomacea snails, all of which figure prominently either at Lamanai and other sites, or in ethnohistoric sources (Hellmuth, 1977; Wing and Steadman, 1980; Pohl and Feldman, 1982). Specific nitrogen values determine the contribution of marine and terrestrial animals to the diet. Strontium and zinc indicated the relative use of meat, molluscs and other aquatic animals. For example, low strontium and high zinc values indicate consumption of meat, whereas high strontium and high zinc indicate seafood or molluscs.

Differentiation of plant resources was also made with a combination of organic and inorganic data. A thorough review of ethnohistoric and paleobotanical remains of edible field, root, and tree crops grown in the Lowlands supports the contention that maize was the most significant, if not the only C4 cultigen in the Lowland PreColumbian diet (White, 1986). C3 plants include the two proposed alternate staples - root crops and ramon nuts. Isotopically, it is impossible to distinguish their relative contributions, so elements were used for this purpose. For example, nuts are extremely high in strontium (Rosenthal, 1981) and magnesium (Schroeder et al., 1969), but low in zinc (Szpunar, 1977). It is assumed, therefore, that a diet isotopically predominant in C3 plants combined with very high strontium and magnesium levels, and low zinc levels would indicate significant ramon consumption. Because most other vegetable plants are midrange in both magnesium and strontium scales (Schroeder et al., 1969; Rosenthal, 1981), it is assumed that root crop or mixed plant dependence would be similarly represented.

Maize is extremely low in strontium (Rosenthal, 1981), but fairly high in both magnesium (Schroeder et



al., 1969) and zinc (Stewart, 1975). The absorption of these latter two elements is prevented, however, by the chelating action of phytate (Mertz, 1972; Stewart, 1975), an organic phosphate found in the pericarp of maize (Nations, 1979). Therefore, human levels of magnesium and zinc would be expectedly low for a maize diet unless phytate is removed by processing.

Carbon and Nitrogen Isotopes The difference between the isotopic composition of the diet and that of collagen for both carbon and nitrogen isotopes can be expressed as;

Figure 2: Strontium, magnesium, and zinc faunal scales for available time periods.

$\Delta_{dc} = \delta$ diet - δ collagen (Schwarcz et al., 1985) where Δ_{dc} for carbon = -5‰ (van der Merwe and Vogel, 1978) and dc for nitrogen = +3‰ (DeNiro and Epstein, 1981) (possible revision of the nitrogen figure may be necessary in future studies - Schwarcz - personal communication). Although a weighted composition of nitrogen resources is not definable, the proportion of C4 plants in the diet can be estimated according to the following equation;

$$\%C4 = \frac{(\delta_c - \delta_3 + \Delta_{dc})}{\delta_4 - \delta_3} * 100$$

Values are assigned to this equation based on average values for C3 plants and specific values for maize. Vogel (1981, cited in Schwarcz, et al.1985) has determined the average value for C3 plants to be -26.5‰. The control sample of beans grown near Lamanai is in agreement with this figure with a value of -26.4‰. In consideration of inability to assess the weighted isotopic composition of the potential diversity of C3 foods in the diet, the value assigned to δ_3 is -26‰.

Average values for C4 plants have been estimated at both - 12.5‰ (van der Merwe and Vogel, 1978) and - 14‰ (Smith and Epstein, 1971). Maize values, however, are higher than this, ranging from -8.8‰ (DeNiro and Epstein, 1982) to -11.3‰ (Bender et al., 1981). The value for modern dried corn grown at Lamanai was -10.7‰. Because maize is distinctively higher than other C4 plants and because there is no evidence to support consumption of additional C4 plants in the Maya Lowlands in ancient times, the value assigned to δ_4 is specific to maize and is conservatively estimated at -9‰ (after Schwarcz et al., 1985). A more realistic representation of consumption can thus be derived. No correction for the "canopy effect", (i.e. altered carbon levels in the atmosphere below the forest canopy Lerman and Troughton, 1975), was felt necessary because maize was grown in the open atmosphere of either milpas or raised fields. This decision also produces more conservative results.

Although it is assumed that metabolic differences do not affect isotopic values, any potential problems of this sort are precluded by the consistent use of ribs in analysis. Samples were chosen from individuals of known age and sex (n=51). Because $\delta^{13}C$ and $\delta^{15}N$ values are unaffected by age (Lovell et al., 1986), a subset (N=6) of juveniles was randomly selected to determine whether children were eating the same foods as adults. The sex ratio for this and all other studied samples is equal (1:1.2) for the combined Postclassic and Historic periods only. It is important to note that all burials come from the ceremonial core of the site and are, therefore, likely to be relatively high status. An exception are the two notably high status tomb burials from the Early Classic.

Bone collagen was extracted after a variation of the method by Longin (1970), using the method suggested by Chisholm et al. (1983) after Sofer (1980). Samples were burned at 550 °C and isotopic measurement was carried out with the assistance of Henry Schwarcz on the McMaster-owned VG 602D mass spectrometer, which has a precision of analysis of ±0.1‰

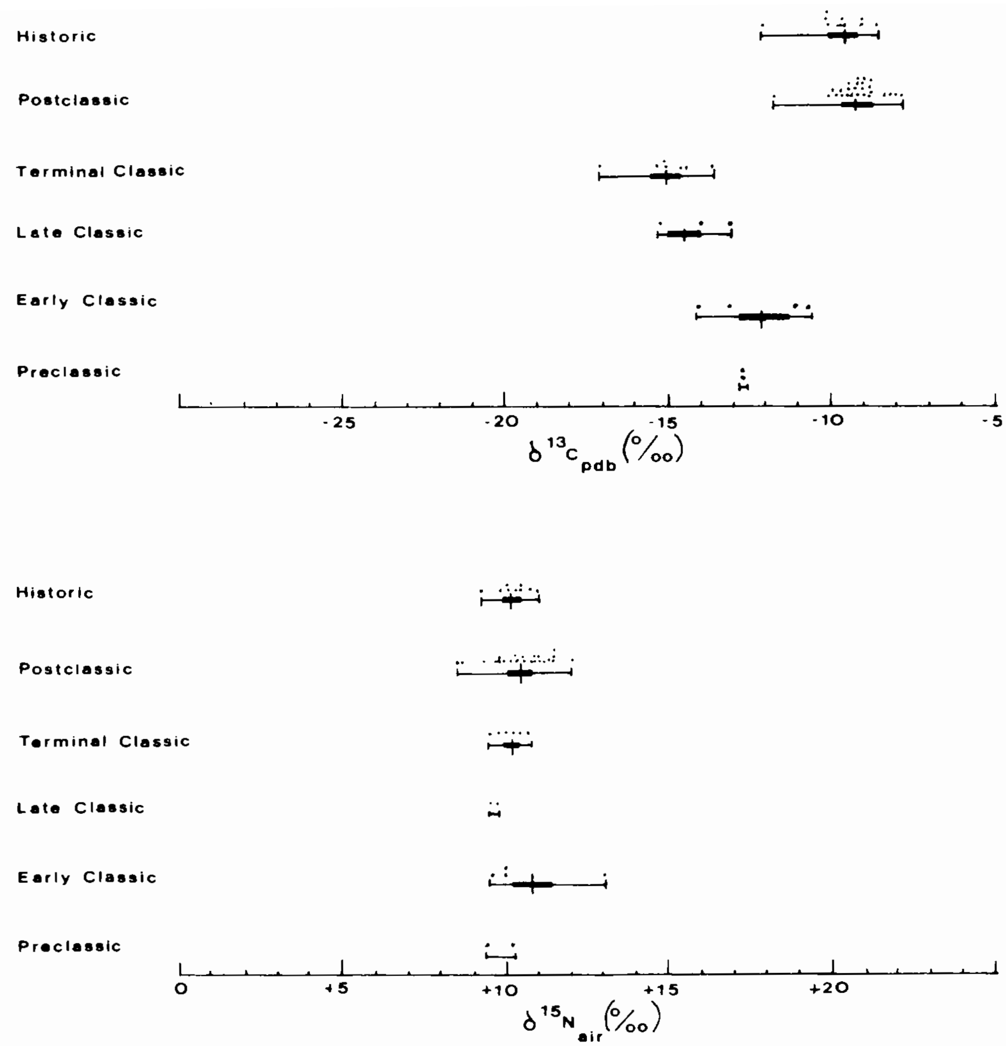


Figure 3: Mean, standard deviation, and range for $\delta^{15}N$ *and* $\delta^{13}C$ *values of bone collagen over time.*

for ^{13}C when tested against the NBS 21 calcite standard and ±0.2‰ for ^{15}N when tested against the inter-laboratory glycine standard.

Strontium, Zinc, and Magnesium

All paleodietary element analyses are predicated on the assumption that the chemical composition of bone is not significantly affected post-mortem by chemical alteration or diagenesis. Although diagenesis needs to be assessed for every sample (Nelson et al.,1986), composite results of diagenetic studies (Lambert et al., 1979, 1982, 1985a, 1985b) indicate that strontium, zinc, and magnesium are the most stable. Diagensis was controlled through the use of Ca/P bone ratios, soil and associated bone values, and faunal herbivores and omnivores. Faunal sets were available for Preclassic, Postclassic and Historic periods only.

Unlike isotopic values, element concentrations are subject to metabolic differences within and between bone elements, as well as to age. Although ribs are metabolically more active than cortical bone and therefore, not the optimal element to use, they were selected for controlling bone metabolism because they were the most commonly preserved and identifiable element, and least diagnostically useful for other studies (exceptions consist of cortical fragments used for three Preclassic individuals, one Early Classic, and one Terminal Classic for whom ribs were not available). To avoid confounding the data with metabolic age differences, only adults were chosen (N=42) (with the possible exception of two badly preserved Postclassic individuals, who could be below age 20). For further control, the adult inorganic and organic samples have 75% of individuals in common.

To prevent contamination, samples were cleaned ultrasonically in deionized water and ground with an agate mortar and pestle. Ashing was carried out after the method used by Katzenberg (1984). The dispersive x-ray fluorescence spectroscopy (XRF) measurement technique was chosen for its sensitivity, precision, multi-element run capability, non- destructiveness, and its ability to overcome the effect that calcium and phosphorus have in occluding the spectral line for strontium. All bone samples were measured against the IAEA animal bone sample on the McMaster-owned Phillips PW 1450, which has a precision of ±1 ppm. for strontium and ±2 ppm. for zinc (magnesium is a bulk element for which this kind of precision is not required).

Caries

All preserved adult teeth (No. of individuals=103) were included in analysis, with the exception of those from one Historic structure (YDL). Because this material had only just been excavated and reconstruction was incomplete at the time of this analysis, only a small random sample (N=14) of determinable age and sex was used from this structure.

Carious lesions are considered to be the most reliable dental indicator of diet because they are highly sensitive to dietary stress, easily recorded, and observable in poorly preserved samples such as this one.

Although most dental pathology is age-dependent, the use of age cohorts was not feasible in this case. Age determination was impossible for 38% of the sample. This problem is not particular to Lamanai. No other published dental studies for ancient Mayans have been divisible by adult age group. A carious lesion was defined here as any macroscopically observable lytic defect into which the tip of a dental explorer can be inserted. Using SPSSX, the total number of lesions on all tooth surfaces was calculated per individual as a percent of the observable number of teeth. These data were then collapsed to a mean percent for each time period.

Porotic Hyperostosis

Although iron deficiency anemia has been found clinically to produce cranial changes similar to the genetic anemias (Eng, 1958), acquired blood disorders appear to be more important than inherited ones in most New World studies (El-Najjar, 1976). Frequencies of porotic hyperostosis found in the Maya area are very high (Ricketson, 1931; Hooton, 1940; Saul, 1972), "much higher than the gene frequencies of thalassemia and abnor-

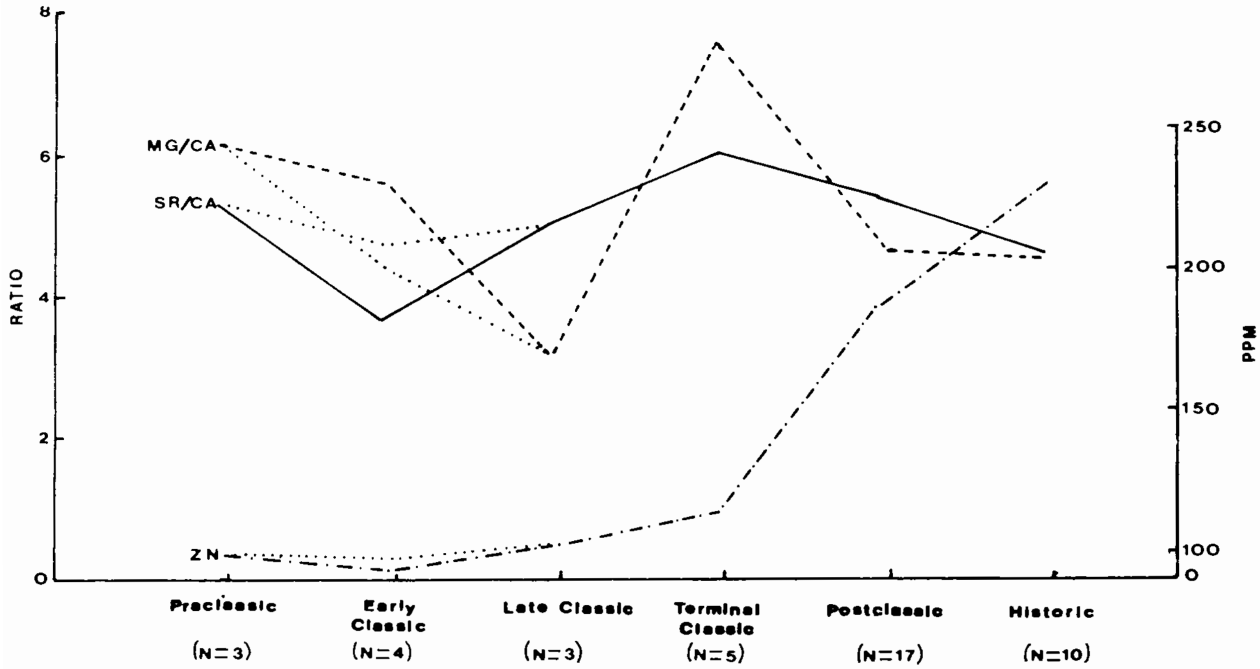


Figure 4: Ratio values of Sr/Ca and Mg/Ca, and absolute values for zinc platted over time. The dotted lines

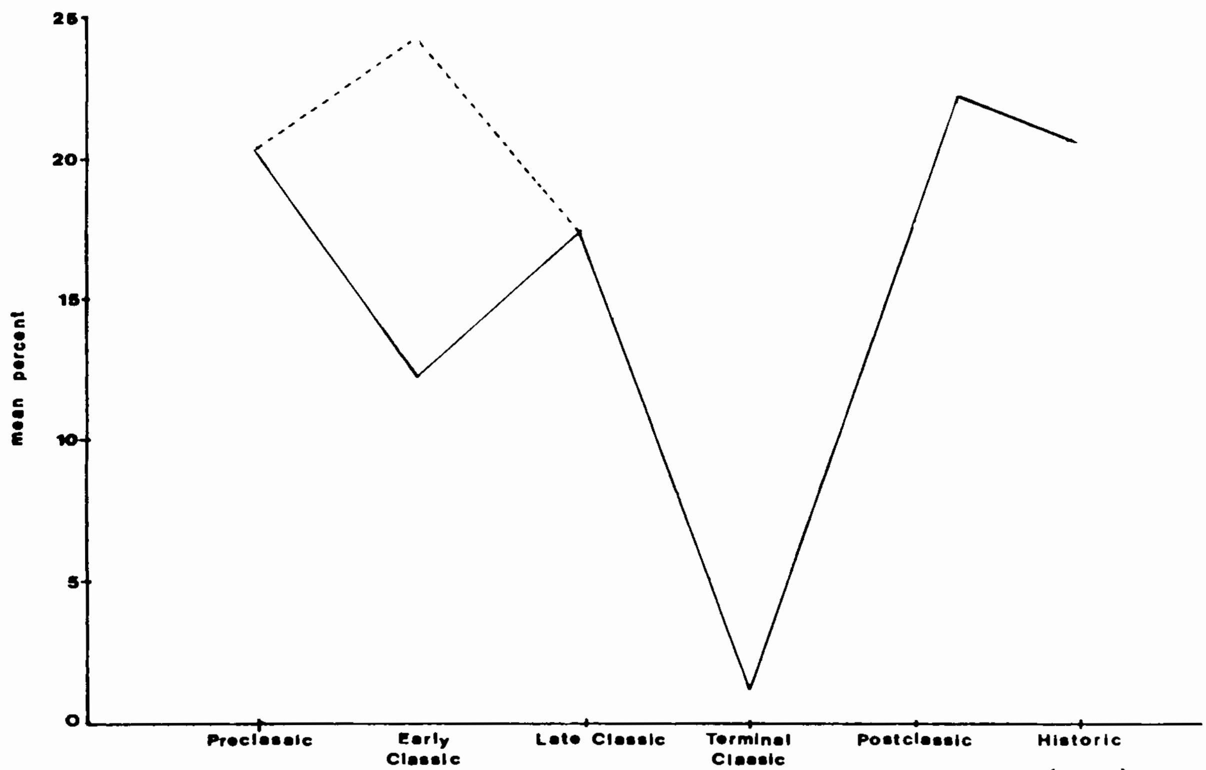


Figure 5: Mean percent of caries plotted over time. The dotted lines represent status adjusted values.

mal hemoglobins in modern populations" (Steinbock, 1967:237). In fact, the high frequency observed by Hooton (1940) at Chichen Itza prompted the explanation of nutritional deficiency for cultural collapse. Iron deficiency is the most important cause of anemia everywhere in the world today (Davidson et al., 1969). Resultant bone pathology is, however, uncommon (Steinbock, 1976; Ortner and Putschar, 1981), and seldom indicates the severity of anemia (Steinbock, 1976). Consequently, the frequency of individuals manifesting skeletal evidence of anemia underrepresents the real incidence.

Differential diagnosis was based on the criteria outlined by Aksoy et al. (1966) and Steinbock (1967). The entire population was examined for cranial vault lesions, porous degeneration and trabecular striation of the elbow joint, and cribra orbitalia. An obscure area of diagnosis is the "healed lesion" used for Maya material (Saul, 1972). It is described by Hooton (1930) as "a transformation of the outer portion of the spongy bone into a very thick layer of compact tissue, or by a proliferation of the tabula externa over the diseased portion" (pg. 316). Many of the Lamanai skulls also display cranial thickening which, in cross- section, resemble Hooton's criteria for healed lesions. Because the crania are very fragmented, radiographs which would provide evidence of internal pathological change are difficult to take. Nevertheless, one complete skull with a thick vault but no porotic lesions was x-rayed. The parietals in the radiograph illustrate the mild presence of the "hair-on-end" appearance characteristic of hematological disorder. Therefore, both active lesions and those assumed to be healed are included in the data. The frequency of porotic hyperostosis is expressed as a percentage of the observable sample.

RESULTS AND DISCUSSION

Control Results

All herbivorous animals used for isotopic control (deer, turtle, and tapir) were found to be C3 plant consumers with values ranging from –21.4 ‰ to -23.3‰. The only omnivore (dog) sampled either scavenged or was fed large quantities of maize ($\delta^{13}C$ = -10.6‰ or 62%).

Differences in the element values of fauna by dietary type are also evident. Although deer in the isotopic faunal set were evidently browsers, the larger faunal set for elements revealed the presence of grazing deer and peccary. These species are known to invade cornfields and may have even been semi-domesticated. Using the interpretation that maize consumption reverses the "normal" trophic order (Katzenberg, 1984), the omnivore (dog, N=1) value can be placed intermediate to wild or browsing herbivores (deer, peccary, tapir, N=6) and semi-domesticated or maize-grazing herbivores (deer, peccary, N=3) (see Table I). This interpretation is also supported by faunal data for the site of Tipu, Belize where Bennett (1986) found the carnivores to have the highest strontium levels and deer and tapir the lowest. Using all species, faunal variation over time appears to have been independent of human variation with the possible exception of zinc (see Fig. 3).

Although calcium carbonate deposition from the limestone bedrock at Lamanai could have been problematic, Ca/P ratios (X = 1.86) do not reflect enrichment after the criteria of

White and Hannus (1983). The absence of diagenetic change due to carbonate deposition was demonstrated using a one-way ANOVA ($p<0.25$, F (5,36)). Ca/P ratios of fauna also demonstrated stability using a one-way ANOVA over Preclassic, Postclassic, and Historic periods ($p<0.25$, $F(2,10)$).

Soil values did not reveal any statistically significant correlation with associated bone values for any element or time period studied using Spearman's Rank Correlation ($p<0.05$) (r_s Sr =.18, Zn = .39, Mg =-.39).

The high ash content of 94.4% (SD = +1.4) suggests considerable organic loss but is similar to the 92.2% (SD = +2) value found by Schoeninger (1979) at Chalkatzingo, Mexico. Organic loss is substantiated by the low percent yield of collagen (2.57 + 1.9). Nevertheless, C/N ratios of a random sample (N=18) range from 2.7 to 3.7 and are within or close to the acceptable range (2.9 - 3.7) defined by DeNiro et al. (1985).

Sex and age differences were tested for Postclassic and Historic samples only. This limitation is created by the inadequate sample size and sex representation in other periods. Using the Student's t-Test ($p>.05$) no statistically significant differences were found for either of these variables in chemical and caries data sets (see Table 2).

Chemical Data

These data reveal temporal differences which provide an interesting comparison with what is known archaeologically and ethnohistorically of Maya diet (see Table 3). In general, the organic and inorganic measures of maize consumption are complementary. The estimation of 50% maize consumption in the Preclassic is consistent with data for other populations in early stages of transition to maize dependence (Lynott et al., 1986; Schwarcz et al., 1985). Status differentiation is evident in the Early Classic tomb vs. non-tomb burials. Here, the high status male in tomb N9-56/1 is consuming less maize than any of his contemporaries. The C4 component of the diet begins to drop during the Late Classic, reaching a dramatic low of 37% in the Terminal Classic. It should be noted here that if the artificial rain forest model applied, $\delta^{13}C$ values would be affected and the amount of maize consumed would be even lower. Strontium values also peak during this time period. Palynological data from other sites suggest that the decline in maize production during the Classic to Postclassic transition was not unique (Vaughan et al., 1985; Wiseman, 1985). Unlike many other sites where the Terminal Classic reflects cultural decay, intensive building activity at Lamanai suggests a period of cultural florescence. The dramatic decline in maize consumption at this time could be a result of political re- allocation of the agricultural labour force to building structures that would improve the status of the site. Although the possibility of imported food cannot be ignored, any imported supplies could not have included large quantities of maize. Soil exhaustion is highly unlikely, given the many options the Lamanai Maya had for growing maize (Lambert, 1985). Other plant food substitutes include a wide variety of C3 plants. Ramon can probably be excluded from these because, although strontium values peak, they are not high enough to include nuts. Root crops are unlikely substitutes based on caries data. Caries incidence is almost negligible during the Terminal Classic compared with other periods. This finding implies that maize was not substituted by another carbohydrate staple such as manioc. Given the convergence of the three data sets, the mixed species model is probably the most appropriate for the Terminal Classic.

Another shift in resource exploitation occurs during the following Postclassic and Historic periods, when maize consumption doubles from the previous period. According to Katz et al. (1974), maize-dependent populations adapt to high levels of consumption by using alkali processing to improve the balance of amino acids and the yield of nutrients. Lime-lined colander ceramics from the Postclassic provide good material evidence for alkali processing of maize. The effects of lime processing on the isotopic composition of maize are yet unknown. Although lime could reduce the lipid content and produce more positive $\delta^{13}C$ values, the data in this study are quite credible in light of modern ethnographic data which estimate maize consumption to be almost identical at 65-70% (Benedict and Steggerda, 1936). Strontium levels drop expectedly. The behaviour of magnesium and zinc, however, must be interpreted in light of the chelating action of phytate. Magnesium behaves inversely to strontium after the Late Classic and zinc does the same after the Postclassic (see Figure 4). If phytate is being consumed, the pattern for these two elements should be reversed. This finding is inconsistent with the isotopic data, unless a processing technique developed at the end of the Classic period effectively removed the chelating agent. Two kinds of evidence refute phytate consumption, the presence of lime-lined colander ceramics at Lamanai (Pendergast, personal communication) and a 16th century ethnohistoric account of the removal of the maize pericarp during alkali treatment (Landa, 1566, in Gann, 1918).

As an organic phosphate, phytate is also a caries preventer (McClure, 1963). Yet caries incidence in skeletal populations rises concomitant with maize dependency (Cassidy, 1980) and is highest during the later time periods at Lamanai. The effect of phytate vs. carbohydrates on caries incidence warrants study, particularly with regard to the level of phytate needed for cariostatic effect. If, however, the majority of phytate is processed out of the diet, susceptibility to caries should still be quite high. The comparability of the data sets used to measure maize consumption was tested using Spearman's Rank Correlation Coefficient. Statistically significant correlations exist between $\delta^{13}C$ and strontium values (rs = -.342, p>.05), between $\delta^{13}C$ values and caries incidence, (r_s =.82, p>.05) but not between strontium values and caries (r_s= -.77).

Nitrogen isotope analysis has the potential for indicating what kinds of dietary substitutions in protein might have been made during the shifts in plant consumption described above. The nitrogen data do not demonstrate any significant changes throughout time (see Table 3, Figure 2). $\delta^{15}N$ values are within the range given by Schoeninger et al., (1983) for Mesoamerican agriculturalists. In humans, higher values indicate consumption of terrestrial herbivores ($\delta^{15}N$ = +12‰), marine mammals (+19‰ -

Schoeninger et al., 1983), and freshwater fish (+16%o - Schwarcz et al., 1985), whereas lower values indicate legumes (+4%o - Price et al., 1985). The protein component derived from beans, marine foods, and terrestrial animals appears to have been constant and mixed in quantity (see Fig. 2). A special note must be made, however, regarding the high status male tomb burial (N9- 56/1). Not only was he was eating less maize than his Early Classic counterparts, but his nitrogen value (+13.2%o) is also anomalous, within the range of Bahamian reef fisher- agriculturalists defined by Schoeninger et al., 1983). This finding supports a heretofore untested theory regarding the importation of coastal resources (Lange, 1971) and illustrates their restricted use by very high status individuals. Limited access to marine resources is not surprising, given the extra effort required by inland inhabitants to exploit them. Terrestrial animals could have been similarly valued because of their scarcity around densely populated areas (Janzen, 1970). It is surprising, however, that lagoon resources were not consumed more by everyone. Fish bones are not well preserved, but large quantities of turtle are found in middens throughout the Lamanai sequence, predominantly in the Postclassic. Also, freshwater *Pomacea* snails are notably present in Preclassic middens. Nevertheless, $\delta^{15}N$ values do not support a high consumption of either of these resources.

Porotic Hyperostosis

The physiological effects of the maize-dependent diet were tested using porotic hyperostosis. The frequency of this condition appears to rise in relation to the amount of maize in the diet. The high incidence in the Postclassic suggests the threshold for iron sufficiency can be set at 65-75% maize dependency.

In spite of the very strong association found between diet and disease here, the assumption that high maize consumption is the direct cause for anemia must be questioned in light of the data suggesting phytate exclusion. Because phytate also chelates iron, it has been strongly implicated as a direct cause of porotic hyperostosis (El-Najjar, 1976). It is important to note, however, that ecological and synergistic physiological factors have also been cited as major causes (Lallo et al., 1977, Walker, 1986). At Lamanai, it is possible that ecological factors combined with the alkali processing technique are of major importance if not more directly causal than the phytate, low iron content of maize. Large amounts of lime in the diet would reduce the amount of acid in the gut and improve the survival rate of intestinal parasites (Katz, personal communication). Not only are parasites known to be a major contributing factor in the etiology of porotic hyperostosis (Carlson et al., 1974; Walker, 1986), but the modern parasitic infection rate in many rural Guatemalan villages today is often as high as 100% (Scrimshaw and Tejeda, 1970). The tropical lagoon environment of Lamanai provides a potential for both helminthic and insect-borne parasites. Furthermore, there is a rise in the incidence of porotic hyperostosis from the Postclassic to Historic periods which is cannot be explained by maize consumption alone (see Table 4). This phenomenon raises the possibility that parasitic infection increased with lifestyle changes introduced by the Spanish. Furthermore, a small subset of individuals (N=9) exhibiting active and healed lesions did not demonstrate any statistically significant difference in $\delta^{13}C$ values or element levels from "normal" individuals. The combination of ecology, high maize consumption, and alkali processing are factors which produce a synergistic model. Unfortunately, it is not possible to weigh these factors with the data at hand.

The subset of juveniles was similarly tested for dietary difference against the adult sample. This discovery that children were consuming the same quantity of maize as adults (see Table 2) has strong nutritional implications for the young, whose amino acid requirements are higher than those of adults. Because it is a physical impossibility for children to consume sufficient maize to meet protein demands (Béhar, 1968) and because children are rarely weaned onto a diet that includes meat protein, Lamanai children were not only at risk for protein-calorie malnutrition, but also iron deficiency anemia. Weaning onto low-iron maize gruel, the complications of weaning diarrhea, parasitic and infectious disease, and the synergistic relationship between protein deficiency and iron deficiency would have made weaning age a critical time. Because the true incidence of anemia is underrepresented by skeletal pathology, it is safe to assume that well over one-third of the population was anemic at some point in life from Postclassic times on. Although a high frequency of anemia in children would be implicated by their isotopic data, poor preservation of children's crania precluded a useful study. Only 3 cases of cribra orbitalia were found throughout the sequence. Furthermore, it was expected that females would exhibit more lesions than males because of greater physiological demand for iron. No such difference was found. The prevalence of iron deficiency anemia in the Lamanai population would mean that working capacity and productivity must have been adversely affected during the later phases of civilization.

CONCLUSION

These isotopic and element data have provided the first direct and diachronic evidence for Maya diet. The chemical and dental data sets used in this study are not only significantly correlated with one another, but also enhance reconstruction so that finer distinctions can be made in dietary interpretation. Conjointly, they allowed all major dietary models to be tested. Although maize dependency is the predominant regime, the degree of dependency fluctuates markedly in relation to cultural change. The lowest consumption of maize occurs in the Terminal Classic and the highest during the Postclassic and Historic. Protein consumption remains stable throughout time, but it appears that precious reef resources were reserved for only those of highest status. The caries data suggest that a carbohydrate substitute for maize in the Terminal Classic does not seem feasible. Rather, a shift to a mixed plant species model is implicated. Ironically, the relaxation of an obvious taste preference for maize created a diversity in the diet which probably provided the most sound nutrition in the entire sequence. Ecological theories fot the collapse of the Maya clearly do not apply at Lamanai, as maize consumption was lowest during a period of florescence. This has led the author to speculate that human energy resources were being redirected from agricul-

Table 1.

Differences in Element Values in Fauna by Dietary Type

Element		Wild Herbivores (N = 6)	Omnivore (N = 1)	Semi-domesticated Herbivore (N = 3)
Sr/Ca:	X	.88	.69	.29
	SD	.25	-	.03
Zn:	X	118.5	115.7	105.3
	SD	43.8	-	32.8
Mg/Ca:	X	.23	.21	.24
	SD	.04	-	.18

N.B. Wild herbivores include deer, tapir, and peccary. Semi-domesticated herbivores include deer and peccary. Omnivore is a dog. An unusually high Mg value for the semi-domesticated peccary has caused the Mg/Ca ratio to be high.

Table 2.

Student's t-test values for comparing differences between means by age and sex

	AGE			SEX		
	t value	df	α level	t value	df	α level
$\delta^{13}C$	.92	33	0.4	1.64	27	0.2
$\delta^{15}N$	.87	32	0.4	1.19	25	0.4
Sr/Ca	-	-	-	1.14	25	0.4
Zn	-	-	-	2.50	25	0.02*
Mg/Ca	-	-	-	1.85	25	0.1

* significant at p>0.05

Table 4.

Frequency of Porotic Hyperostosis Over Time at Lamanai

	Late Classic	Terminal Classic	Post-Classic	Historic
Total N	11	27	108	150
Observable N	6	5	53	100
% Observable	54	18	49	67
With/Without Lesions	1/5	1/4	17/53	43/100
% With/Without Lesions	16*	20*	32	43
Total Healed Lesions	1	-	12	26
% Healed Lesions	16	-	29	26
Total Active Lesions	-	1	5	17
% Active Lesions	-	20	9	17

* Percentages are inflated by observable sample size.

Table 3.
Temporal Means for isotopic, element and dental analysis

	$\delta^{13}C$	%C	$\delta^{15}N$	Sr/Ca	Zn	Mg/Ca	Caries
Preclassic							
X	-12.4	50	+10.2	.53	87.6	.07	20.0
SD	.3	.0	.6	.12	11.5	.01	19.9
Early Classic							
X	-11.8	56	+10.1	.36	85.4	.08	24.5
SD	1.3	7.4	.2	.04	16.3	.03	24.2
tomb male							
	-14.11	42	+13.2	.60	544.8	.14	0
Late Classic							
X	-14.2	42	+10.3	.49	89	.16	17.1
SD	1.1	6.5	.1	.03	24.2	.08	21.0
Terminal Classic							
X	-15.0	37	+9.9	.59	102.8	.10	1.8
SD	1.2	6.8	.4	.07	6.3	.06	3.2
Postclassic							
X	-9.3	70	+9.5	.54	145.8	.14	22.8
SD	.8	4.3	.9	.09	50.5	10	40.4
Historic							
X	-9.9	67	+9.7	.43	213.5	.10	20.1
SD	.91	5.3	.6	.07	87.5	.04	25.7

Spearman's Rank Correlation Coefficient (r_s)

$\delta^{13}C$/Sr	-.34 *
$\delta^{13}C$/Caries	.82 *
Sr/Caries	.77

* significant at $p>0.05$

ture to building activity during the enigmatic Terminal Classic. There is little doubt, however, that further archaeological research at Lamanai will shed more light on the kind of cultural activity which has biological consequences.

This study also provides a direct estimation of the threshold for iron sufficiency for a maize-based diet in an archaeological population. The data are in agreement with observations made on alkali processing by Katz et al. (1974). When data on porotic hyperostosis are incorporated with chemical data, however, the role of phytate as the direct cause for iron deficiency is questioned. Magnesium and zinc data do not support the presence of significant levels of phytate in the diet. An increase in the incidence of porotic hyperostosis from the Postclassic to Historic periods cannot be explained by diet and therefore, also cannot be attributed to phytate. The possibility that alkali processing deletes most phytate from the diet and synergistically predisposes to parasitic infection is an hypothesis to be tested. Regardless of etiology, the later inhabitants of Lamanai manifest very high frequencies of porotic hyperostosis. The nutritional theory for the decline of Maya culture is neither supported by the timing of the appearance of this pathology, nor by the tenacity of the Lamanai inhabitants. Nevertheless, their general health status must have been very poor at the time of Conquest.

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Cancer Mortality of Chinese Canadians in Ontario 1964-77: A Study in Descriptive Epidemiology

Joseph K. So
Anthropology Department
Trent University

Introduction

The area of biocultural factors in health and disease has been of increasing concern in anthropology in recent years. The anthropological approach to the study of disease, being integrative anc cross-cultural in nature, focuses on the interactions of sociocultural as well as biological variables in the etiology of disease. The epidemiology of malignant neoplasms is particularly suited to this approach. It has been said that 80% of all cancers are environmentally related, and the study of migrant populations have been proposed as a useful model to uncover the gene-environment interplay of some forms of this disease (Fraumeni 1975; Lilienfeld 1980). Migrant populations presumably have a greater degree of heterogeneity; some adhering to a traditional way of life while others may adopt the dietary patterns and overall lifestyle of the host country. Any changes in the disease profile of the migrants may be attributed to environmental factors while a lack of change reflects the underlying strength of genetic factors. The province of Ontario, with its multicultural makeup, is an ideal place to conduct such a study. Cook and Hewitt (1972) studies the differences in cancer incidence of Ontario residents of various ethnicity based on hospital records while Newman and Spengler (1984) looked at cancer mortality statistics of British, Italian, German, Dutch, Polish and Russian immigrants. All observed a cancer mortality profile significantly different from the Ontario general population.

Subjects and Methods

The present study is a descriptive epidemiological survey using mortality data from the Ontario Cancer Treatment and Research Foundation cancer registry. Mortality statistics was collected on residents of Ontario of Chinese ethnic-origin from 1968 to 1977. Because ethnicity information was not available from the data base, a nominal roll of approximately two hundred Chinese surnames was compiled in order to access the data from the Registry. This was followed by a manual search of the death certificates of the subjects housed at the Registrar General of Ontario in order to validate their Chinese origin. The shortcomings of this method concern 1) the completeness of the nominal roll; and 2) Chinese women who have married non-Chinese will not be included in the sample, though it was most likely a very small number of individuals. Cook and Hewitt (1972) have also used the surname method with satisfactory results.

Through the CANSIM project of Statistics Canada, a data bank of mortality including place of birth for the years 1964-1973 became available after the original data was collected. The original sample consisted of 326 males and 136 females for a total of 462 individuals. The addition of the years 1964-68 yielded an additional 170 cases, giving a total of 632 (Table 1). Population (denominator) data fro Ontario was obtained from Statistics Canada. Mortality data consisted of year of death, age at death, country of birth and cancer site (ICDA, or International Classification of Diseases, 8th revision). Standardized mortality ration (SMR) was possible only for the years of 1969-1973 when both place of birth for the deceased and for the Ontario general population were available, using the 1971 census as midpoint. Analysis for 1964-1068 and 1974-1977 data was through Proportionate Mortality Ratio (PMR) only.

As sites were included for the original analysis (Table 1). Due to the small number of cases in some sites, SMRs were calculated for those where the number of cases were sufficiently large for statistical analysis (Table 2). Five-year age-specific mortality rates were calculated for colon, rectum, liver, and lung for males and colon, liver, and lung for males and colon, liver, lung, and breast for females (Tables 3 & 4). Due to the small numbers involved, the age groups were expressed in 10-year intervals: 50-59, 60-69, 70-79, and 80 years and over in the calculations of age-specific mortality rates. All age groups were included in the calculations of SMRs.

In an attempt to show possible temporal changes, PMRs of selected sites were calculated for the years 1964-68, 1969-73, and 1974-77 (Table 5). Unlike cancer mortality rates, PMRs do not provide any information on the absolute frequency of cancer deaths in any given population. It only provided information on the relative frequency of deaths due to a particular cancer site among the total number of cancer deaths. The PMRs of Ontario Chinese were compared to those from British Columbia (1964-73), Hong Kong (1978) as well as the general Ontario population (1970-74) (Table 6).

Results

The SMRs of Chinese-born residents of Ontario, standardized to Canadian-born rates, for the years 1969-1973, are presented in Table 2. A SMR grater than unity is considered in excess to that of the reference population, while one less than unity is considered a deficit. Significance levels based on Poisson distribution are provided. For males, sites that show statistically significant excesses include nasopharynx, stomach, colon, liver, lung, while prostate shows a significant deficit. For females, nasopharynx and liver show significant excesses while gallbladder and breast show significant deficits. In general, these findings agree with that of King and Locke (1980) who reported elevated risks of nasopharynx and liver for males and nasopharynx, stomach, liver, and gallbladder for females. Sites of low risks include urinary organs and skin for both sexes, prostate for males and breast for females.

Five-year age-specific rates for Chinese males and females are given in Tables 3 and 4 respectively. The relative risk figures represent the Ontario Chinese values relative to the Ontario general population. A relative risk value greater than one is considered in excess while less than one is considered to be in deficit. For Chinese males, colon, rectum, liver and lung are all in excess while for females, elevated risks are found for liver and lung while colon and breast show a significant deficit. The results are in general agreement with that of the British Columbia Chinese as reported by Gallagher and Elwood (1979). They reported elevated risks for nasopharyngeal carcinoma for both sexes, and of the liver and esophagus in males and lung in females. Deficits were observed for stomach and prostate for males and colon, breast, and ovary for females.

King and Locke (1980) reported a temporal increase of cancers of the lung and colon in males but no increase for cancer of the breast and uterus for females, contrary to the results of the Japanese in Hawaii. Due to the unavailability of denominator data other than for years 1969-73, no comparisons of mortality rates were possible. Proportionate mortality ratio comparisons for the years 1964-68, 1969-73 and 1974-77 are to be used with caution due to small sample sizes and the inherent limitations of this type of analysis. These were likely the reasons for some of the inconsistencies observed, with two major exceptions. Female lung cancer and breast cancer PMRs show a substantial increase from 1964-68 to 1974-77. This is consistent with the general Ontario experience of high and/or rising lung and breast cancer rates.

Comparisons of the PMRs of Chinese from Ontario, British Columbia, Hong Kong as well as the Ontario general population are presented in Table 6. Some comparisons are not possible due to missing or incompatible data. Compared to the Ontario general population, greater Chinese PMRs are found for the following sites: nasopharynx, esophagus, and, except the Hong Kong Chinese, colon. Sites with lower PMRs are lung, malignant melanoma, prostate, and leukemia. Chinese female PMRs that show higher values are nasopharynx, stomach (except Ontario Chinese), and lung. Lower PMRs are found in colon, breast, uterus, and ovary. Among the three Chinese groups, generally Hong Kong PMRs deviate the most from the Ontario general population values, especially for nasopharynx, esophagus, lung(female), and the female reproductive cancers. The results are in keeping with those of King & Locke (1980); King & Haenszel (1973); MacLennan et. al. (1977).

Discussion

While migrant study is a useful model to look at the relative effects of culture and biology on disease profile, this approach has a number of inherent limitations. Compared to people in the country of origin, migrants are often, though not always, better educated, economically better-off, more highly skilled, healthier, and in general not representative of the original population. The age at immigration is important because most diseases are age-dependent. Moreover, if the premigration environment is etiologically important for a particular disease, the migrant will likely have the same disease rate from the people in the country of adoption. This could be erroneously interpreted as genetic factors being primary.

The use of birthplace data to determine ethnic origin will not work in a multiethnic society, and even in an essentially racially homogeneous society such as China and Hong Kong, it has to be used with caution. The alternate method of using surnames have simi-

Table 1
Ontario Chinese Cancer Deaths, 1964-77

ICDA #	SITE	Male	Female	Total	ICDA#	SITE	Male	Female	Total
141	tongue	2	-	2	173	other skin	2	1	3
142	saliv gland	1	-	1	174	breast	-	24	24
143	gum	1	-	1	180	cervix	-	9	9
144	fl. of mouth	1	-	1	182	uterus	-	2	2
145	mouth unsp.	1	-	1	183	ovary	-	5	5
147	nasopharynx	18	6	24	185	prostate	16	-	16
149	pharynx	-	1	1	188	bladder	10	1	11
150	esophagus	9	2	11	189	urin. unsp.	5	-	5
151	stomach	48	5	53	191	brain	1	1	2
153	colon	58	18	76	193	thyroid	-	1	1
154	rectum	29	8	37	196	lumph sec	1	-	1
155	liver	50	12	62	197	resp. dig. sec	6	-	6
156	gallbladder	-	-	-	198	other second.	-	1	1
157	pancreas	17	9	26	199	unsp. sites	12	7	19
158	peritoneum	1	1	2	200	lumphosarc	9	1	10
159	digest.unsp.	3	-	3	201	Hodgkins'	1	-	1
160	nasal, sinus	-	1	1	202	other lumph.	4	-	4
161	larynx	2	1	3	203	mult. myel	2	9	11
162	trachea, lung	120	26	146	204	lymph. leuke	7	1	8
163	resp. unsp.	2	-	2	205	myel. leuke	4	3	7
170	bone	-	2	2	207	unsp. leuke	2	1	3
172	melanoma	3	-	3	208	n polycy. vera	2	-	2
					(unsp. 1964-68)		22	9	31
					Total =		632		

Table 2.
Standardized mortality ratios of Chinese-born residents of Ontario, Standardized to Canadian-born rates 1969-73, selected sites.

ICDA #	Site	Male Obsv	Cases Expl.	SMR	Sig.*	Female Obsv.	Cases Expl.	SMR	Sig.*
141	tongue	2	.713	2.80	n.s.				
147	nasopharynx	3	.197	15.18	.02	3	.053	56.07	.002
150	esophagus	1	2.762	.36	n.s.				
151	stomach	14	8.453	1.65	.10	5	2.59	1.92	n.s.
153	colon	22	13.12	1.68	.05	7	9.57	.73	n.s.
154	rectum	11	6.336	1.73	n.s.				
155	liver	5	1.19	4.20	.02	6	.39	15.38	.002
156	gallbladd.	3	1.091	2.74	n.s.	1	1.31	.76	.10
162	lung	55	28.351	1.94	.002	7	4.32	1.62	n,s.
174	breast					4	14.93	.27	.002
180	cervix					5	3.38	1.48	n.s.
183	ovary					1	4.70	21	n.s.
185	prostate	2	17.50	.11	.002				
188	bladder	3	5.68	.53	n.s.				
200.	lymphosar.	2	2.23	.90	n.s.				
203	mult. myel.					1	.87	1.15	n.s.
204-7	leukem.	6	4.81	1.25	n.s	3	1.65	1.82	n.s.

* Significance level based on Poisson distribution

Table 3.
Five-year age-specific rates of male Ontario Chinese and Ontario general population, per 100,000 population, 1969-73, selected sites.

ICDA#.	Site	Age Interval	Chinese	Ontario	Relative Risk
153	colon	50-59	33.06	26.20	1.26
		60-69	236.68	73.24	3.24
		70-79	217.69	141.39	1.54
		80+	137.93	227.42	0.61
Total			625.06	468.25	1.33
154	rectum	50-59		13.98	
		60-69	47.34	34.54	1.37
		70-79	163.26	69.86	2.34
		80+	206.89	101.31	2.04
Total			414.49	219.69	1.88
155	liver	50-59	33.06	2.84	11.64
		60-69	23.67	7.52	3.15
		70-79	54.42	12.15	4.48
		80+		14.88	
Total			111.15	37.39	2.97
162	lung	50-59	132.23	94.13	1.40
		60-69	331.36	220.66	1.50
		70-79	489.80	294.10	1.66
		80+	1241.38	213.95	5.80
Total			2194.77	822.84	2.66

Table 4.
Five-year age-specific rates of female Ontario Chinese and Ontario general population, per 100,000 population, 1969-73, selected sites.

ICDA#.	Site	Age Interval	Chinese	Ontario	Relative Risk
153	colon	50-59	19.90	30.55	0.65
		60-69		69.13	
		70-79	197.53	134.46	1.47
		80+		227.36	
Total			217.43	461.40	0.47
155	liver	50-59	19.90	1.16	17.15
		60-69	39.41	2.62	15.04
		70-79	49.38	5.43	9.09
		80+	210.52	3.50	60.14
Total			319.21	12.71	25.11
162	lung	50-59		22.24	
		60-69	98.52	31.41	3.14
		70-79	49.38	37.03	1.33
		80+	210.52	34.98	6.02
Total			358.42	125.66	2.85
174	breast	50-59	19.90	72.55	0.27
		60-69	39.41	96.38	0.41
		70-79		115.94	
		80+		158.18	
Total			59.31	443.05	0.13

Table 5
Comparison of Proportionate Mortality Ratio (PMR) of Chinese cancer deaths in Ontario over time, selected sites, (1964-68, 1969-73, 1974-77)

		Males			Females		
ICDA#.	Site	64-68	69-73	74-77	64-68	69-73	74-77
141	tongue		1.3				
147	nasopharynx	4.1	1.9	4.1	9.1	5.1	
150	esophagus	1.4	0.6	3.5	3.0		1.4
151	stomach	13.8	9.0	8.2	6.0	8.4	1.4
153	colon	13.8	14.2	10.0	12.1	11.8	5.7
154	rectum	6.9	7.1	7.6			10.0
155-6	liver & gallbladder	7.6	5.1	15.3	3.0	11.8	8.5
157	pancreas	3.4	1.9	2.2	3.0	11.8	2.8
162	lung	22.0	35.5	21.8	9.1	11.8	20.0
172	melanoma	0.6		0.5	3.0		
174	breast				9.1	6.8	17.1
180	cervix				3.0	8.4	5.7
182	uterus						2.8
183	ovary				3.0	1.7	2.8
185	prostate	4.1	1.3	4.7			
188	bladder	2.7	1.9	2.2			1.4
200	lymphosarc.	0.6	1.9	2.9		1.7	
203	mult. myelom			1.1	6.1		7.1
204-7	leukemia	3.4	3.8	1.7	3.0	5.1	1.4

Table 6.
Proportionate Mortality Ratio (in %) of Selected Sites.

		British Columbia Chinese (1964-73)		Ontario Chinese (1968-77)		Hong Kong Chinese (1978)		Ontario General (1970-74)	
ICDA#	Site	M	F	M	F	M	F	M	F
142	salivary.			0.30		.NA	.NA	.NA	.NA
147	nasopharyn.	3.79	3.82	3.68	2.20	8.39	5.04	1.20	0.51
150	esophag.	3.79		2.76	0.73	6.31	2.68	2.40	1.23
151	stomach	7.36	7.64	7.97	2.20	7.61	7.43	7.70	5.66
153	colon	12.72	5.09	11.65	10.29	4.28	6.09	9.87	14.53
154	rectum.	7.81	2.55	5.83	5.88	3.44	3.40	4.51	3.90
155	liver	7.81	1.91	9.81	3.67	18.07	8.19	.NA	.NA
156	gall.	2.23	1.91	2.14	4.41	.NA	.NA	.NA	.NA
157	pancreas.	3.57	0.63	3.68	5.88	.NA	.NA	.NA	.NA
160	nasal sinus	0.45			0.733	.NA	.NA	0.26	0.13
162	lung	24.33	17.83	26.99	16.91	27.77	23.60	28.36	6.96
172	melanoma.	0.67		0.61		0.28	0.37	0.84	0.87
185	prostate.	6.25		3.06		1.11		8.98	
188	bladder.	1.56	1.27	1.84	0.73	.NA	.NA	3.70	1.84
191	brain	0.45		0.30	0.73	.NA	.NA	.NA	.NA
193	thyroid	0.67	1.27		0.73	.NA	.NA	0.24	0.46
200-2	lymphomas	2.90	3.82	3.98		.NA	.NA	3.63	3.62
203	mult. myel	1.56	1.27	0.61	5.15	.NA	.NA	.NA	.NA
204-7	leukemias	2.45	1.91	2.45	2.94	2.61	3.69	4.30	4.03
174	breast		7.64		15.44		8.82		21.07
180	cervix		8.28		5.88		5.20		4.21
182	uterus		1.91		1.47		0.80		2.86
183	ovary		1.27		2.94		.NA		6.80

lar drawbacks previously mentioned..

SMR Analysis

Among the standardized mortality ratios of Ontario Chinese (1969-73) that show substantial differences from the Ontario general population, the following seem to stand out: nasopharynx, colon, liver, lung, prostrate among males, and nasopharynx, liver, and breast among females. Nasopharyngeal carcinoma is extremely high among Chinese in southern China (Liang 1964); Hong Kong (Ho 1967); Singapore (Shanmugaratnam & Tye 1970); and California (Buell 1965). The Chinese population in Ontario, until very recently, was composed of people from areas where nasopharyngeal carcinoma was endemic. Thus the high rates are in keeping with previous findings.

Belamaric (1973) reported a high rate of intrahepatic bile duct cancer among Hong Kong Chinese. Etiologically very different from hepatocellular cancer which is the common form here in Canada, it is related to the consumption of improperly cooked fish in which the parasite *Clonorchis sinensis* is found. Although no distinction of cell type is made in the Ontario data, it is likely that the extremely high rate of Ontario Chinese females (Relative risk of 25.11 in Table 4) may be due to intrahepatic bile duct type of liver cancer.

The higher lung cancer rate among the Ontario Chinese males is in keeping with findings from previous studies (Kong & Haenszel 1973; MacLennan et. al. 1977). The failure of Ontario Chinese female rates to show statistical significance may be due to the small sample size of 7 versus 55 in the males. However, in the age-specific rate analysis (Table 4), the relative risk of Chinese to Ontario rates is a substantial 2.85. The higher lung cancer rates have been attributed to a variety of causes, from smoking to the use of cooking fuels or incense in a confined environment. More research is needed before this question can be satisfactorily answered.

The extremely low Ontario Chinese breast cancer rate is expected. Similarly low rates have been observed among Japanese women in British Columbia (Gallagher & Elwood 1979). Low rates of prostatic cancer among Chinese males, observed in the Ontario data, is also reported elsewhere (King & Haenszel 1973). It has been suggested that cancers of the reproductive organs are etiologically related to animal fat and dairy product consumption (Fraumeni 1975). The Chinese have traditionally consumed less fat and dairy product and more poultry, fish and leafy vegetables which may account for the lower rates.

PMR Analysis

The use of PMRs to detect time trends (Table 5) proved somewhat less than satisfactory. Due to the lack of cases or very small number of cases, not all sites can be compared. A few sites show a tentative trend toward an increase of cases, such as breast and lung in females while a decrease is noted in stomach and colon among males. The sharp increase in breast PMR of Ontario females in 1974-77 is unexplained. It is tempting to suggest that a time trend towards an increase in breast cancer exists in Ontario, as reported among Japanese women in the U.S., but further research is needed before this conclusion can be drawn.

Comparisons of Ontario PMRs with those from British Columbia and

Hong Kong show substantial differences. Again the most noticeable sites are nasopharynx, esophagus, colon, liver, lung, prostate, and the female reproductive cancers. These findings are in general agreement with other studies.

Conclusion

Descriptive epidemiological studies using cancer mortality statistics is designed to provide an overview of the mortality profile of a population. Its strength lies in its ability to detect peculiarities in the cancer patterns. By the same token, its descriptive nature does not allow inferences about etiology to be made. The present study serves to (1) confirm the findings of other studies that Chinese immigrants have a distinctly different overall cancer mortality profile from that of the countries of adoption; (2) show that traditionally high rates of cancers of the nasopharynx, liver, lung and low rates of reproductive cancers, with the exception of cervix, observed in other Chinese migrant populations, are also true for Ontario Chinese; (3) pinpoint the need for retrospective case-control studies involving detailed analysis of biocultural indices such as dietary, occupational, socio-economic, and behavioural aspects of the Chinese immigrants in Ontario. This has yet to be done and represents a potential area of fruitful research in the future.

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"Fall Fever" in *Lemur catta*: Near death from agonistic encounters between adult males.

Andrew J. Petto
Harvard Medical School
New England Regional Primate Research Center
Southborough, Massachusetts

Abstract: In a study of the reproductive span of ring-tailed lemurs, *Lemur catta*, intragroup agonistic encounters among adult males resulting in life-threatening injuries occurred in two successive years. These injuries followed a general increase in agonistic behaviours associated with the fall breeding season.

Resumé: Une étude de la durée de la capacité réproductrice des makis, *Lemur catta*, nous a montré que les interactions agonistiques intragroupes parmi les mâles ont produit des meurtrissures fatales. Ces meurtrissures suivent d'une hausse générale des comportements agonistiques associée avec la saison réproductrice automnale.

Key Words: **Intermale aggression, Reproductive behaviour, Reproductive span, *Lemur catta*.**

Introduction:

Intragroup agonistic encounters among male lemurs are known to increase dramatically during the fall breeding season (Colquhoun, 1987; Sussman, 1977; Sussman and Richard, 1974; Budnitz and Dainis, 1975). In his study of *Lemur fulvus* behaviour during the breeding season, Colquhoun (1987) termed these behavioural changes "fall fever". Sussman (1977; Taylor and Sussman, 1985, Sussman and Richard, 1974) and Budnitz and Dainis (1975) have noticed similar seasonal changes in the frequency of intermale agonistic behaviour in the ring-tailed lemur, *Lemur catta*.

During a 1985 study at the New England Regional Primate Research Center (NERPRC), we uncovered two cases in which a single male *Lemur catta* sustained severe injuries as a result of agonistic interactions during the fall breeding season. One incident was observed directly as a part of a study of reproductive behaviour in aged, female lemurs. An earlier incident was discovered in a retrospective review of the records of the injured animal. Both incidents suffered by this adult male were life-threatening.

The NERPRC *Lemur catta* Group:

The original group of ring-tailed lemurs consisted of six animals introduced from the Oregon Regional Primate Research Center (ORPRC) in November, 1982. One female (38782) (NERPRC animal identification numbers consist of a three digit acquisition number follow by a two-digit year number. For example, 38782 means the 387th animal born or introduced into the Center in 1982.) was the mother of three of the others.

She was wild-caught as an adult in 1963, and so was at least 23 years old at the time of the study in 1985. She was one of a few animals in the ORPRC colony that regularly gave birth to twins (Pasztor and Van Horn, 1976), and one set of her twins (38582 and 38682, born in 1966) arrived with her. Another of her daughters that arrived with her (38882, born April, 1967) gave birth to twins in our colony in 1984 and to single infants in 1985 and 1986.

The group included two other adult animals. The male (38982) was born at ORPRC in 1966, and the female (39082) was wild-caught as an adult also in 1966. At the time of our study the youngest animal was 18 years old. The main goal of this study was to observe which animals exhibited the behavioural changes normally expected in reproductively active animals and to try to estimate the age at which the absence of these seasonal behavioural changes might indicate the end of the reproductive span.

The NERPRC Environment:

All six lemurs (and later, their offspring) were housed in a single indoor/outdoor enclosure. Their enclosure was one of eight similar pens on the east side of an 18 x 13.5 m building.

The adjacent pens housed spider monkeys (*Ateles geoffroyii*) and crab-eating macaques (*Macaca fascicularis*). The building also housed some *Macaca mulatta* groups.

The outdoor enclosure measured 13.1 m^2, and was separated from the adjacent pens by hardware cloth stretched over 2.5 cm weave, 8 gauge wire. The ceiling and end walls were also constructed of wire. There were a pipe swing suspended from the ceiling on a chain and a 24 cm wide, wooden plank along the south wall for a perch.

The heated, indoor pen was 6.9 $m^2$and separated from the outdoor by insulated, corrugated steel panels, and from adjacent pens by painted composition board. The interior wall was made of wire. Access to indoors was via a 38 x 60 cm swinging plastic door. Both indoor and outdoor pens were 2.4 m high.

The animals were fed twice daily with commercial, Old World monkey chow supplemented in the afternoons by fresh vegetables and fruit. Water was available ad libitum from two automatic sippers mounted indoors.

This group was observed from directly in front of the end walls while in full sight of the animals. On two or three days each week, one minute scan samples were made in two sessions of twenty minutes each. Observations were made at both the indoor and outdoor parts of the enclosure on the same day. These sessions were scheduled between feedings and took place at various times between 1000 and 1500h.

Observations ran from 28 August through 12 December, 1985. NERPRC is located at 42° 16' north latitude, about 35 km from Massachusetts Bay. During the study period, mean temperature minima ranged from 15.4° to -6.3°, and mean maxima from 27.9° to 3.9°. The relative humidity ranges from 70 to 73%.

Results:

In our group only one adult female ever reproduced. At eighteen, Di

(38882) was the youngest of the offspring of the matriarch (38782). Her last birth before the colony was disbanded was in 1986 at age nineteen. Although she enjoyed a high rank in this group, her twin brother (38682) suffered severe injuries during the breeding seasons in 1984 and 1985. Neither injury was observed directly, but the behaviours of group members were recorded before and after the incident in 1985.

The earliest sign that 38682 was being excluded from the group showed up in mid-September. He often sat alone when others were grooming or huddling, and his attempts to groom or huddle were invariably broken up by the juvenile member of the group (20485), his sister's son. By early October, the pattern of solitude has solidified, and soon after 38682 enters an area of the pen, the others leave; and he is consistently displaced by all other members of the group. By 3 October, 38682 is involved in fewer than 6.25% of social interactions occurring in the group. Although he was consistently seen huddling and grooming with a single female (Queenie), these interactions were always disrupted by one of the other animals within a few minutes. After these disruptions, 38682 would leave the area without attempting to reestablish contact.

During the next weeks, his participation increased to between 25 and 33% of all interactions, but most of these are agonistic encounters. By the 17th, the dominant male 38982 (Scar) has established a pattern of vocalizing, scent- marking, and chasing away 38682. By 24 October, 38682 is always found on the opposite side of the exterior wall from Scar.

On the morning of 12 November, 1985, 38682 was found moribund in the outside enclosure. He had apparently been forced by the other animals to remain outside for the night in near-freezing temperatures. After a successful resuscitation and rewarming in our clinic, he remained out of the group until the group was sold the following year.

After his departure, Scar increased his affiliative behaviours with two adult females. He was engaged in mutual grooming and huddling especially with an adult female known as Di. Even though these bouts were frequently interrupted by the two immature animals, Scar resumed the activity immediately after the disruption ended. The infant born to Di and Scar in May, 1986 was most certainly conceived after the expulsion.

A review of the records of male 38682 showed that he had also sustained a serious injury in the previous breeding season that had caused him to be absent during the time that the infant 21085 was likely conceived. These records show that 38682 was hospitalized on 30 November, 1984 for excision of necrotic tissue associated with a severe bite wound. The excised tissue includes the right testis. The necrosis indicates that the wound had occurred considerably earlier.

Conclusions:

Competition between male ring-tailed lemurs during the breeding season can result in life-threatening injuries. A subordinate male was seriously injured in two successive breeding seasons, and the infants born the following seasons were both conceived after the expulsion of this male was complete. The expelled male was the son of the matriarch of the group and the brother of the fertile female. His expulsion and harassment by other group members is consistent with Taylor and Sussman's (1985) report of attacks on related males by breeding females.

Whereas the agonistic encounters of male ring-tailed lemurs were thought to be chiefly limited to various displays and minor injuries (Sussman and Richard, 1974), these incidents illustrate that such encounters can escalate into life-threatening situations. Like Colquhoun's (1987) findings that normally "docile" male brown lemurs (*Lemur fulvus*) experience a behavioural transformation during the breeding season, the breeding season behaviours of these ring-tailed lemurs at NERPRC have earned them the title "Baboons of the Strepsirhini".

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The Inferior Petrosal Sinus, a non-metric trait restricted to Oceania

Colin Pardoe

The Australian Institute of Aboriginal Studies
The Australian National University
Canberra Australia

Abstract: An alternative exit of the *inferior petrosal* sinus is described. This cranial non-metric trait occurs as a small (<7mm) foramen found 5 - 15mm anterior to the jugular foramen. The distribution of the trait appears to be restricted to Australia and the Pacific, and is found in proportions between 4 and 21% regionally. The author would like to know if skeletal biologists have observed the trait in North America or elsewhere.

Key words: **non-metric trait, cranial venous drainage, osteology, Australia, Melanesia, Polynesia**

Distribution of the Inferior Petrosal Sinus in Oceania

Introduction:

Very few morphological features of the skeleton are population specific. In this paper I will describe a non-metric trait that, to my knowledge, is unknown outside Oceania (Australia + Pacific). My purpose in writing is to inquire whether this trait exists in other parts of the world. I will present a description of the trait and data on its occurrence in Oceania along with some negative evidence for its presence elsewhere in the world.

Description:

The *inferior petrosal* sinus normally courses posteriorly and laterally to join the *signoid* sinus at, or below the jugular bulb. These two sinuses then become the internal jugular vein. The *inferior petrosal* sinus creates a groove of varying depth on the internal surface of the basicranium. The sinus follows the joint edge of the basi-occipital and the petrous portion of the tympanic for most of its length.

The variant on this normal course is found where the inferior petrosal sinus exits the cranium through a separate foramen up to 7mm in diameter formed by two semilunar notches in the basi-occipital and temporal bones (fig. 1). The notch is usually larger and deeper in the former bone, and occasionally the foramen may be totally captured by the basi-occipital. The edges of this foramen, both internal and external are smooth and rounded.

The foramen is approximately 5-15mm antero-medial to the jugular foramen. In some individuals, the internal groove stops at this foramen and the remaining length, where the normal course lies, is not grooved.

Alternative diagnosis:

Two skeletal variants might be

Figure 1: A basal, external view of the cranium (left side, posterior to top) showing variation in structure of the separate exit of the *inferior petrosal* sinus (large arrow). The foramen may be variably placed in the petrous - occipital fissure between 5 and 15mm anterior to the jugular foramen. It varies in size and shape as illustrated. The foramen is usually formed by both bony elements (i, ii), although the occipital contributes more in many cases (i). More rarely the foramen will be found completely in the occipital bone (iii). **a**, foramen magnum; **b**, left occipital condyle; **c**, occipito - mastoid suture; **d**, jugular foramen; **e**, petrous - occipital fissure. The diagrams are based on a single drawing, with the relevant details drawn from actual examples. The drawings were done by Betsy-Jane Osborne (illustrator, Prehistory Department, Research School of Pacific Studies, The Australian National University).

confused with *inferior petrosal* sinus variation. These are transverse fissure of the basi-occiput and bridging of the jugular foramen.

Ossenberg (1969) described transverse fissure of the basi-occiput, as a hypostotic trait that is presumably a remnant failure of complete ossification between two centres of the basi-occiput. In Australia these show up as 'pinprick' foramina, often symmetrical. However, Ossenberg (1969:160) notes that:

"in most cases of traverse fissure of the basi-occiput the bone is pierced by a narrow oval canal, approximately 2-5 millimetres in its traverse diameter and 1 millimetre in its antero-posterior diameter. This feature extends neither to the lateral margin nor to the midline."

It may occur on both sides, or on one only. These foramina occur within the body of the basi-occiput, usually as much as 10mm medial to the lateral border and 10-20mm posterior to the *foramen magnum*. The foramina of the transverse fissure of the basi-occipital open interiorly to the basi-occipital, never into the petro-occipital fissure. This trait and the alternative exit of the *inferior petrosal* sinus differ in size, position, direction and frequency. I had recorded the transverse fissure in Australia initially and the proportions here are similar to those found by Ossenberg, that is, less than 2%.

Bridging of the jugular foramen is described by Dodo (1986) who characterises much of the complex hyperostotic variation of this area. For these bridges the main feature is that they grow across an existing foramen. The *inferior petrosal* sinus still joins with the *sigmoid* sinus at the jugular bulb to produce the internal jugular vein. Bridges of three kinds have been described and studied: medial external, middle internal and lateral (Pardoe 1984). Dodo has given a detailed description of the latter two, which he calls types I and II respectively. He notes a third type (1986:16, fig. 11) which he suggests might be related to the inferior petrosal sinus. This is the type I called 'medial external' and which I suggested separated the *glossopharyngeal* nerve from the rest of the nerves and vessels which pass through the jugular foramen.

In fact, both *inferior petrosal* sinus and medial external bridging can occur together, negating the possibility of the latter being a channel for the *inferior petrosal* sinus, as Dodo suggested. Furthermore, the *interior petrosal* sinus always is to be found at least 5mm anterior to the jugular foramen.

Distribution:

This new trait is found throughout Australia, and for the limited number of samples I have been able to investigate. Melanesia and Polynesia too. Summary data are presented in table one. It is by no means a rare trait, reaching a proportion of 36% in a more local sample from southern Victoria. At the mouth of the River Murray, a group of six burials was found in which four of the individuals had the trait; two bilaterally.

The earliest occurrence of this variant of the *inferior petrosal* sinus is at circa 12,500 years ago in the Coobool Creek sample from the upper River Murray (Brown 1982, n.d.). It is also found in Tasmania. Since Tasmania was separated from the mainland at about 12,000 years ago by sea level rise, the origins of this feature must be considerably earlier. The trait is not found in the Mungo I cranium from southeastern Australia, dated to 26,000 years ago. Nor is it found in the Solo crania from Java.

I have not seen this feature in my own studies in North America. Other negative evidence includes an appeal to anatomy texts: a review of the literature has revealed no hint of this particular anatomical detail. Again, something not mentioned by many authors is suggestive rather than conclusive.

Relevance to Canadian Physical Anthropology:

Does this feature occur in North America? There are very few features of skeletal morphology that are unique to small groups. Our level of analysis is with variability of common traits, rather than with variability expressed as 'private polymorphisms'.

Skeletal studies form a large portion of the material evidence in Australian prehistory and an even larger portion of relevant direction and theoretical perspective of the discipline. A consistent theme of Australian prehistory is colonisation: who, when, how. The 40,000 year time depth to occupation does however, allow for considerable study of regional variation as well as more long term evolutionary trends.

One of the results of the focus on colonisation is that our view of interaction on the continent is very much a receptive one: what has Australia received from the outside world in prehistory? All the arrows on maps go from north to south. These arrows may represent populations, individual people, genes or material culture. Speculation on in-migration is rife (Bowdler 1977, Thorne 1980, Horton 1981) but the possibility of out-migration or gene flow is rarely considered.

Some archaeological evidence (that is, goods and/or ideas rather than genes) is also derived from outside of Australia, to the north. The later pre-

Table 1
Presence of the Inferior Petrosal Sinus by region.
(Proportions calculated by individual.)

Sample	frequency/n	%
Australia		
Torres Strait	1/24	4.2
North Central Australia	35/272	12.9
Western Australia	12/68	17.7
East Coastal Australia	29/267	10.9
Upper River Murray	59/334	17.7
Central River Murray	21/179	11.7
Lower River Murray	53/375	14.1
Southeastern Australia below River Murray	38/179	21.2
Tasmania	13/96	13.5
Melanesia		
New Guinea	19/220	8.6
Bismarck Archipelago	14/94	14.9
Solomon Islands	5/60	8.3
Vanuatu	9/92	9.8
New Caledonia	1/16	6.3
Fiji	2/13	15.4
Polynesia	8/60	13.3

historic period at about 4-3,500 years ago sees the arrival of dingo (*Canis familiaris dingo*) and according to some prehistorians, material culture in the form of a microlith technology.

Some people have pointed to connections with the 'outer world' in reference to blood genetics (Kirk 1972, 1976), material and ideological culture (Moore 1979), and skeletal biology (Larnach and Macintosh 1970. Macintosh and Larnach 1973). This is mainly to New Guinea; and it must be remembered that up until about 8,000 years ago. New Guinea was part of Sahul, or greater Australia.

There is no doubt that this north-south orientation exists. Latitudinal clines are found in morphology and are structured primarily because of 1) a historical structure of north to south migration; 2) environmental variables such as temperature; and 3) a wide, well-watered strip of land to the east of the arid zone that reaches from Cape York to Tasmania. That is, there exists a north-south orientation to the landmass. Any morphological trait might be expected to have a strong relationship with latitude because of these factors.

This has certainly proven the case with non-metric traits along the eastern seaboard (Larnach and Macintosh 1966, Larnach 1978, Pardoe 1984) and continentally (Pardoe 1984). However, metric variation seems at this point somewhat problematic. The methodological faults in Brace's work (1980) undermine his assessment and other studies (van Holst-Pellekaan 1982, Donlon 1986) have not found the same structure.

In a preliminary discussion (Pardoe 1986), I suggested that this non-metric trait, the *inferior petrosal* sinus, which apparently exists nowhere else outside Oceania, was most common in the extreme southeast of Australia and decreased from south to north. I suggested that the trait had evolved locally and had spread, through gene flow and with some selective value perhaps, not only through Australia, but out into the Pacific. In effect this is gene flow out of Australia.

A definitive refutation of this hypothesis would be to find the trait regularly in other populations throughout the world. If the hypothesis is proven wrong, at worst we gain a non-metric trait that is easily scored and systematic in its variation. If the *inferior petrosal* sinus is specific to Australia and the Pacific, then not only do we have a better grasp of the biological prehistory of Australia, but also of Australia's role in shaping the history of Melanesia and Polynesia.

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REGRESSION ANALYSIS OF FOUR PHYSICAL CHARACTERISTICS -- STATURE, LENGTH OF UPPER ARM, LENGTH OF FOREARM AND LENGTH OF HAND OF MALE POPULATION IN SICHUAN PROVINCE

Chen Dezhen
Institute of Vertebrate Paleontology and Paleoanthropology
Academia Sinica
Beijing, Peoples Republic of China

Abstract:
This article deals with four physical characteristics - stature, length of upper arm, length of forearm and length of hand of 394 male adult individuals in Sichuan Province. Using regression method twelve linear regression equations and three ternary regression equations have been established. Also the stepwise regression method was used in order to select the most important independent variables entering into the equation, three stepwise regression equations including a quarternary regression equation are established. These equations possess a certain applied value in the individual identification aspects of forensic medicine. This article provides some statistical data for explaining the relationship among four physical characteristics of Sichuan population.

Key Words: **regression, stepwise regression, stature, length of upper arm, length of forearm, length of hand**

Materials and Methods:

This study deals with 394 male individuals from the Sichuan population covering four physical characteristics - stature, length of upper arm, length of forearm and length of hand. The measuring method is based on Martin's somatometry. Stature (Martin No. 1) is the vertical distance from the summit of head (v) to the ground. Length of upper arm (Martin No. 47) is the difference between Acromion height and Radiale height. Length of forearm (Martin No. 48) is the difference between Radiale height and Stylion radiale height. Length of hand (Martin No. 49) is the distance from the middle point of a line between Stylion radiale point (sty.r) and stylion ulnare point (sty.u) on the metacarpal surface to the third dactylion point (da III). For the first three measurement items, the instrument used was an anthropometer and for the last item a sliding caliper was employed. The statistical method used is linear regression, ternary regression and stepwise regression.

Results and Analyses:

Table 1 shows sample number (N), range, mean (X), standard error of mean (SEx), standard deviation (SD) and coefficient of variation (CV) of four variables.

Linear Regression:

Firstly, the linear regression, which is the case with one dependent variable for one independent variable is conducted. As for these four physical characteristics - stature, length of upper arm, length of forearm and length of hand, there are twelve linear regression equations, including six with their own inverse linear regression equations. Table 2 indicates the linear regression equations, the standard deviation from the residual variance and the 95% confidence limit for the sampled means of the dependent variable.

Table 3 demonstrates the correlation coefficient (all values are positive), the regression coefficient and their significance tests. With 392 degrees of freedom, the critical values are nearly 1.980 at the 5% level of significance and nearly 2.617 at the 1% level of significance. The result is that all of twelve observed values of t in correlation coefficient and regression coefficient are larger than the 1% critical value, so we can reject the null hypothesis. It is clear that all of the regression coefficients and the correlation coefficients between every two variables from four variables are highly significant at $P< 0.01$. Among the correlation coefficients related to stature, the correlation coefficient between stature and length of hand is the biggest one with the value 0.650521; next is the correlation coefficient between stature and length of upper arm with the value of 0.613127; followed is that between stature and length of forearm with the value 0.608833.

Ternary Regression:

Secondly, the ternary regression equation, which is the case of one dependent variable for two independent variables, is established. There are three ternary regression equations with stature as dependent variable and with every other pair of the three variables as independent variables. Besides the ternary regression equations, shown in Table 4 are the residual standard deviation, the 95% confidence limit for the sampled mean μr according to means of two independent variables, and the coefficient of multiple correlation (R) and the variance ratio (F) as well. Testing the significance of observed values of R and F (with df 391 for R test and with df $n1 = 2$, $n2 = 391$ for F test) proves that the three ternary regression equations all are highly significant at $P<0.01$, because all of the observed values of R and F are larger than their 1% critical values.

In Table 5 are shown the partial regression coefficient and the partial correlation coefficient (all of their values are positive) and their significance tests. The result illustrates that all of their t values are larger than their 1% critical values (for df 391 the critical values are nearly 2.627 at the 1% level of significance and nearly 1.980 at the 5% level of significance). It means that all of them possess highly significant at $P<0.01$.

Stepwise Regression:

Thirdly, in order to select the important variables from the set of independent variables, the stepwise regression equation of four physical characteristics was setup with stature as dependent variable and the other three variables as independent . To begin with, some independent variables are added to the set of predictors according to the magnitude of contribution of every variable, step by step. In the process some unimportant variables in the set of predictors will be removed from equation also step by step, because these variables gradually loss their original importance as subsequent other variables are added to. Thus, the final equation only keeps the most important and relevant variables in it, employing an F value of 7.0 as the inclusion criterion. The first variable selected is the length of hand (X_3) with its magnitude of contribution 0.423178, therefore, a linear equation is established. The second variable selected is the length of upper arm (X_1) with its magnitude of contribution 0.111768, thus , a ternary regression equation is established, with length of hand and length of upper arm as independent variables. The third step is to remove above-selected variable - the length of upper arm and F test proves that the length of upper arm could not be removed. Then adding a new variable, length of forearm (X_2) to the set of predictors with its magnitude of contribution 0.055092, therefore a quarternary regression equation is established. Again through the use of the F test, no independent variables could be removed from the equation. Table 6 lists the stepwise regression equation, the residual standard deviation, the 95% confidence limit for the sampled mean μr of the dependent variable according to means of their own independent variables, the coefficient of multiple correlation (R) and the variance ratio (F). The significance test of the observed R and F proves that all of them are significant at $P<0.01$. Two of the stepwise equations are separately the same as one of the linear equations and one of the ternary equations previously obtained.

Comparison:

Table 7 shows the change of standard deviation of stature from the linear regression equation, ternary regression equation to quarternary regression equation, that is there is a tendency towards reduction without exception, as added variables gradually increase. In order to further determine whether the ternary equation and quarternary equation are much better than the linear equation in prediction, Table 8 illustrates the test of increment in determination due to two independent variables over determination by one independent variable and due to three independent variables over determination by two independent variables separately. The result proves that the increments in the coefficient of determination all are significant at $F. > F_{0.01}$, that is the ternary regression equation is better than its corresponding linear equation and the quarternary equation also better than any ternary equation in this study.

Conclusion:

The conclusions are as follows:

1. Based on four physical characteristics - stature, length of upper arm, length of forearm and length of hand, six linear regression equations and their inverse equations are established. The significance test of regression coefficient and correlation coefficient illustrates that all of these equations are significant and that high correlation exists among four characteristics. The biggest correlation coefficient is the one between stature and length of hand, with the value 0.650521; following is the one between stature and length of upper arm with the value 0.613127; next is the one between stature and length of forearm with the value 0.608833.

Table 1.

Sample number, range, mean, standard error of mean, standard deviation and coefficient of variation fo four variables.

Variable	N	Range	$\chi \pm SE_{\chi}$	SD	CV
Stature (y)	394	144.4-185.4	164.3868 ± 0.2910	5.7758	3.5135
Length of Upper arm (x_1)	394	26.0-36.8	31.5655 ± 0.0864	1.7158	5.4356
Length of forearm (x_2)	394	18.3-26.8	23.0800 ±0.0662	1.3150	5.6975
Length of hand (x_3)	394	16.0-21.5	18.0365 ± 0.0376	0.7459	4.1353

Table 2.

Linear regression equation of four physical characteristics.

	Linear Regression Equation	Sy.x	95% Confidence Limit
Predicting y on x_1	$Y = 99.237427 + 2.063944\ x_1$	4.568576	0.455720
Predicting x_1 on y	$X_1 = 1.624274 + 0.182139\ y$	1.357166	0.135379
Predicting y on x_2	$Y = 102.667569 + 2.674149x_2$	4.587739	0.457631
Predicting x_2 on y	$X_2 = 0.293454 + 0.138615y$	1.044507	0.104191
Predicting y on x_3	$Y = 73.529115 + 5.037421x_3$	4.392209	0.438127
Predicting x_3 on y	$X_3 =4.226920 + 0.084007y$	0.567200	0.056579
Predicting x_1 on x_2	$X_1 = 16.593546 + 0.648699x_2$	1.490600	0.148689
Predicting x_2 on x_1	$X_2 = 11.052434 + 0.381034x_1$	1.142408	0.113956
Predicting x_1 on x_3	$X_1 = 10.970432 + 1.141851x_3$	1.491379	0.148766
Predicting x_3 on x_1	$X_3 = 11.225341 + 0.215780x_1$	0.648320	0.064671
Predicting x_2 on x_3	$X_2 = 7.538512 + 0.861664x_3$	1.148695	0.114583
Predicting x_3 on x_2	$X_3 = 11.638397 + 0.277217x_2$	0.651547	0.064992

Table 3

Correlation coefficient, regression coefficient, and their significance.

Variable	r	b	S_b	tr=tb	P
Predicting y on x_1	0.613127	2.063944	0.134315	15.366481	<0.01
Predicting x_1 on y	0.613127	0.182139	0.011853	15.366481	<0.51
Predicting y on x_2	0.608833	2.674149	0.175987	15.195134	<0.01
Predicting x_2 on y	0.608833	0.138615	0.009122	15.195134	<0.01
Predicting y on x_3	0.650521	5.037421	0.297046	16.958360	<0.01
Predicting x_3 on y	0.650521	0.084007	0.004954	16.958360	<0.01
Predicting x_1 on x_2	0.497168	0.648699	0.057180	11.344873	<0.01
Predicting x_2 on x_1	0.497168	0.381034	0.033586	11.344873	<0.01
Predicting x_1 on x_3	0.496376	1.141851	0.100862	11.320873	<0.01
Predicting x_3 on x_1	0.496376	0.215780	0.019060	11.320873	<0.01
Predicting x_2 on x_3	0.488741	0.861664	0.077687	11.091535	<0.01
Predicting x_3 on x_2	0.488741	0.277217	0.024994	11.091535	<0.01

Table 4

Ternary regression equation with stature as dependent variable.

Ternary Equation	$S_{y.xx}$	95%	R	F	P
Predicting y on x_1, x_2 $Y = 79.633901 + 1.388110x_1 + 1.773684x_2$	4.099877	0.408967	0.706178	194.476744	<0.01
Predicting y on x_1 $Y = 59.307247 + 1.296382x_1 + 3.557146x_3$	3.948829	0.393900	0.731400	224.881515	<0.01
Predicting y on x_2, x_3 $Y = 60.874426 + 1.678672x_2 + 3.590971x_3$	3.951336	0.394150	0.730996	224.348329	<0.01

Table 5.

Partial correlation coefficient, partial regression coefficient and significance.

	Predicting y on x_1 , x_2		Predicting y on x_1, x_3		Predicting y on x_2, x_3	
r	$r_{yx1.x2}$ 0.451010	$r_{yx2.x1}$ 0.443524	$r_{yx1.x3}$ 0.440188	$r_{yx3.x1}$ 0.504789	$r_{yx2.x3}$ 0.439023	$r_{yx3.x2}$ 0.509987
b	$b_{yx1.x2}$ 1.388110	$b_{yx2.x1}$ 1.773684	$b_{y1.x3}$ 1.296382	$b_{yx3.x1}$ 3.557146	$b_{yx2.x3}$ 1.678672	$b_{yx3.x2}$ 3.590971
tr=tb	9.992110	9.785201	9.693835	11.562868	9.662056	11.723480
P	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table 6

Stepwise regression equation of four physical characteristics.

Stepwise Regression	$S_{y.x}$	95% Confid.	R	F	P
Predicting y on x_3 $Y = 73.529115 + 5.037421x_3$	4.392209	0.438127	0.650521	287.585976	<0.01
Predicting y on x_3, x_1 $Y = 59.37247 + 1.296382x_1 + 3.557146x_3$	3.948829	0.393900	0.731400	224.881515	<0.01
Predicting y on x_3, x_1, x_2 $Y = 53.41228 + 0.971554x_1 + 1.254685x_2 + 2.846935x_3$	3.712313	0.370307	0.768139	187.102686	<0.01

Table 7

Change of standard deviation from unexplained variance of stature.

		Stature	
SD		5.775757	
$S_{y.x}$	$S_{y.x1}$ 4.568576	$S_{y.x2}$ 4.587739	$S_{y.x3}$ 4.392209
$S_{y.xx}$	$S_{y.x1x2}$ 4.099877	$S_{y.x1x3}$ 3.948829	$S_{y.x2x3}$ 3.951336
$S_{y.xxx}$		3.712313	

Table 8

Comparisons among the linear regression, the ternary regression, and the quarternary regression.

F	Quarternary Equation	Ternary Equation	Linear Equation	F
86.902091		$R_{y.x1x2}$ 0.706178	r_{yx1} 0.613127	95.750157
			r_{yx2} 0.608833	99.842263
52.409379	$R_{y.x1x2x3}$ 0.768139	$R_{y.x1x3}$ 0.731400	r_{yx1} 0.613127	133.699925
			r_{yx3} 0.650521	93.970437
52.971215		$R_{y.x2x3}$ 0.730996	r_{yx2} 0.608833	137.439983
			r_{yx3} 0.650521	93.355331

2. Three ternary regression equations with stature as dependent variable are established and the result of significance test proves all of established equations are significant at $P<0.01$.
3. Using stepwise regression according to the magnitude of contribution of variable to choose the most important variables entering into equation and to eliminate some unimportant variables as predictors, step by step, three equations are obtained: one is a linear equation with length of hand as independent variable;other is a ternary equation with length of upper arm and length of hand as independent variables; another is a quarternary equation with length of upper arm, length of forearm and length of hand as independent variables. In the process of calculation, none of above-mentioned variables are removed as predictors, so these three variables are important in the respect of explaining the variation of dependent variable and the length of hand is a variable of all others most related to stature.
4. Comparisons among the established quarternary equation, ternary

equation and corresponding linear equation based on F test (all of the observed F values are more than the 1% critical value) means that in this study the established ternary equation is better than the corresponding linear equation and the quarternary equation is better than the ternary equation, so under the condition of having multiple variables, the quarternary or ternary regression equations should be used as much as possible so as to improve the predicting effect in the individual identification of forensic practice.

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LIFE TABLE PROGRAM: IN MS-DOS BASIC LANGUAGE

D. Spano and L.A. Sawchuk
Department of Anthropology
University of Toronto,
Scarborough Campus

Introduction:

As numerous studies have shown the life table can provide the investigator with an elegant means of obtaining comparative information on the mortality experience of a community at the inter- and intra-populational level (see e.g.., Ascadi and Nemeskeri, 1970; Moore, Swedlund, and Armelagos 1975; Weiss,1975; Howell, 1982; Friedlander, Schellenkens, Ben-Moshe and Keysar 1985). To assess the quality of the reconstructed mortality profile, Howell (1986) suggests that the investigator compare the mortality experience of the target population with that of one of a series of the model life table (Coale and Demeny, 1966; Weiss, 1973). Given the unrealistic assumptions underlying the life table (no immigration, no emigration, the birth each year of a new cohort of 10,000, and no change in the age-specific death rates), deviations from the idealized conditions can and do arise from violations of stable model theory of small sample size. Given the fact that most populations examined by anthropologist are numerically small, it is critical that estimates of mortality functions are shown with their corresponding standard error. As Benjamin and Pollard (1980) have shown the standard error provides an indication of the range of confidence that can be placed in the value of a given life table function. The life table program presented here not only generates reliable estimates of the life table functions but also provides much needed information about the standard errors of the probability of dying and the life expectancy at age x. The system requirements are modest requiring only a system running MS-DOS. Since it is written in the language BASIC, it can be made to run on IBM clones or indeed, can be modified to run under Lotus 1-2-3.

The Life Table Program:

The methodology for the life table is that presented by Barclay (1966). The formulae for the standard error of qu and ex are based on those presented by Chiang (1984).

For skeletal data, however,a the probability of dying in the ith age-group [i.e. q(i)] is obtained via

$$nqx = \frac{1 - 1(x+n)}{1(x)}$$

Where 1(x) refers to the number of people who had survived to age x (see Weiss 1973). In arriving at an estimate of the person years for the terminal age group, it assumes that everyone interred in the cemetery had died within five years of the age suggested by the terminal age-category. Other potential problems in computing life table functions for skeletal collections have been discussed by Weiss (1973, 1975), Peterson (1975), Howell (1979), Van Gerven and Armelagos (1983).

Appendix 1 and 2 provide a hardcopy of program 1 and program 2. A working copy can be obtained from the authors by simply providing a disk and self-addressed envelope.

Using the Life Table Programs: Two versions of the life table are presented here: program 1 - where both the number of individuals dying and at risk2 are known for a set of given age intervals, and program 2, where only the number of deaths at given age intervals are known. Unless otherwise indicated, the procedures given below refer to both programs.

From the MS-DOS diskette, load the language BASIC into memory by simply typing BASIC. Then, with the data diskette in the appropriate drive, load the program to be edited by pressing the F3-key and then typing the name of the program (say program 1), followed by depressing the ENTER-key. Once the program is in memory, you may generate the life table results by depressing the run F2-key.

Five columns of information will be shown: age, a(x), standard error of q (x), d(x), and 1(x). At this point you can obtain a hardcopy of the output by depressing the SHIFT-key and the PrtSc-key. To obtain the remaining output, depress the continue key - F5. On the screen, you will see the values of L(x), T(x) and e(x) and its respective standard error.

To input your own data, you must first edit the existing data resident in the program. Use the F1-key or the list command. To input data where vital statistics and census data is available for the seventeen age-intervals (program 1) list line number 190, position the cursor to the first value and simply overtype the existing values with your own data in the specified ascending order. Depress the Enter-key and now modify the number of individuals at risk by listing line 200 and entering the appropriate number. At this point you can save the program before running the modified program 1.

For a skeletal sample, use program 2. The age-intervals in program 2 are restricted to seven groups: under 5, 5-14, 15-24, 25-34, 35-44, 45-54, and 55 and older. List line 250 to alter the data.

Once you are finished with the program, you can return to MS-DOS by typing SYSTEM.

Notes:

1. For example, the life tables put out by Statistics Canada indicate that, in 1981, the life expectancy at birth was 71.88 years for Canadian males and 78.98 years for Canadian females. Using the methodology suggested here, the results are 72.14 and 80.46 respectively.
2. A very crude estimate of the number of person years can be obtained by multiplying the mid-period population size by the number of years in the base period.

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Appendix Program 1

```
10 CLS
20 DIM D(19) : REM D(I) represents the deaths in age group I
30 DIM P(19) : REM P(I) represents the person years in age group I
40 DIM Q(19) : REM Q(I) represents qi
50 DIM SEQ(20), SEE(20), B(20), L(20), H(20), W(20), A(20), F(20)
60 DIM X(20), T(20), Y(20), E(20), Z(20)
70 FOR I=1 TO 17
80 READ D(I)
90 NEXT I
100 FOR I=1 TO 17
110 READ P(I)
120 NEXT I
130 LET Q(1)=(D(1)/P(1))/(1+(.5*D(1)/P(1)))
140 LET Q(2)=(8*D(2)/P(2))/(2+(4*D(2)/P(2)))
150 FOR 1-3 TO 16
160 LET Q(I)=(10*D(I)/P(I))/(2+(5*D(I)/P(I)))
170 NEXT I
180 Q(17)=1
190 FOR I=1 TO 17
200 SEQ(I)=(((Q(I)^2)*(1-Q(I)))/D(I))^(1/2)
210 NEXT I
220 REM the first two lines of data refer to the deaths
230 DATA 2016, 331, 205, 198, 535, 713, 690, 721, 1161
240 DATA 1745, 2640, 3876, 5611, 7600, 9960, 12234, 49664
250 REM the next two lines of data refer to the person years
260 DATA 98189, 391144, 487712, 486793, 485022, 481825, 478310, 464602, 469745
270 DATA 462599, 451806, 435607, 412091, 379204, 335334, 279788, 475701
280 REM
290 REM
300 REM
310 REM L(I) represents 1i and B(I) represents di (i.e. the deaths in the life table population
in the age interval i)
320 L(1)=100000!
```

```
330 FOR I=1  TO  16
340 B(I)=Q(I)*L(I)
350 L(I+1)+L(I)-B(I)
360 NEXT  I
370 B(17)=L(17)
380  X(I)=(.3*L(1))+(.7*L(2))
390 X(2)=(2*L(2))+(2*L(3))
400 FOR I=3  TO  16
410  X(I)=(2.5*L(I))+(2.5*L(I+1)
420 NEXT I
430 M=D(17):REM  age-specific death rate for final age interval
440 X(17)=L(17)/M
450 T(17)=X(17)
460 FOR  I=16  TO  1 STEP  -1
470 T(I)=X(I)+T(I+1)
480 NEXT  I
490 H(1)=1
500 H(2)=4
510 FOR I=3  TO  16
520 H(I)=5
530 NEXT  I
540  A(1)=.12
550  A(2)=.46
560 FOR I=3  TO  17
570  A(I)=.5
580 NEXT  I
590 FOR I=1  TO  17
600 E(I)=T(1)/L(I)
610 NEXT  I
620 FOR I=I  TO  16
630  SS=((L(I)/L(I))^2)*((E(I+1)+((1-A(I))*H(I)))^2)*((SEQ(I))^2)
640 FOR J=I+1  TO  16
650  SS=SS+((L(J)/L(I))^2)*((E(J+1)+((1-A(J))*H(J)))^2)*((SEQ(J))^2)
660 NEXT  J
670  F(I)=SS
680 NEXT I
690 FOR I=1  TO  17
700 SEE(I)=(F(I))^(1/2)
710 NEXT  I
720 REM to change the title, simply edit line 720 i.e. type the new title
730 PRINT "
740 PRINT "    age              q(x)              S.E.q(x)              d(x)              1
(x)":PRINT
750 N1$="  0 - 1":REM to define first age interval
760 N2$="  1 - 4":REM to define second age interval
770 PRINT  N1$, Using "#.#######      ";Q(1);SEQ(1),
780 PRINT  USING  "######.##        ";B(1);L(1)
790 PRINT  N2$,USING  "#.#######           ";Q(2);SEQ(2),
800 PRINT  USING  "######.##          ";B(2);L(2)
810 S=2:REM loop to define remaining age intervals
820 FOR I=5  TO  70  STEP  5
830  S=S+1
840 PRINT  I"-"I+4,  USING  "#.#######                 ":Q(S); SEQ(S),
850 PRINT USING  "######.##              ";B(S);L(S)
860 NEXT  I
870 PRINT  "  75+", USING  "#.#######             ";Q(17);SEQ(17),
880 PRINT  USING "######.##              ";B(17);L(17)
890 STOP:PRINT:PRINT:PRINT
900 PRINT  "    age              L(x)              T(x)              e(x)              S.E.e(x)"
```

```
910 PRINT
920 N1$=" 0 - 1"
930 N2$=" 1 - 4"
940 PRINT N1$, USING "#######          ";X(1);T(1);
950 PRINT USING "##.##          ";E(1);
960 PRINT USING "#.#######";SEE(1)
970 PRINT N2$,USING "#######          ";X(2);T(2);
980 PRINT USING "##.##          ";E(2);
990 PRINT USING "#.#######";SEE(2)
1000 S=2
1010 FOR I=5 TO STEP 5
1020 S=S+1
1030 PRINT I" - "I+4, USING "#######          ";X(S);T(S);
1040 PRINT USING "##.##   ";E(S);
1050 PRINT USING "#.#######";SEE(S)
1060 NEXT I
1070 PRINT " 75+", USING "#######          ";X(17);T(17);
1080 PRINT USING "##.##          ";E(17);
1090 PRINT USING "#.#######";SEE(17)
1100 STOP:END
```

Appendix Program 2

```
10 CLS
20 DIM D(19):REM D(I) represents the deaths in age group I
30 DIM P(19):REM P(I) represents the person years in age group I
40 DIM Q(19):REM Q(I) represents qi
50 DIM SEQ(20), SEE(20), B(20), L(20), H(20), W(20), A(20), F(20)
60 DIM X(20), T(20), Y(20), E(20), Z(20)
70 FOR I=1 TO 7
80 READ D(I)
90 NEXT I
100 LET S=D(1)
110 FOR I=2 TO 7
120 LET S=S+D(I)
130 NEXT I
140 REM P(I) is the number of survivors to age I
150 LET P(1)=S
160 FOR I=2 TO 7
170 LET P(I)=P(I-1)-D(I-1)
180 NEXT I
190 FOR I=1 TO 6
200 LET Q(I)=1-(P(I+1)/P(I))
210 NEXT I
220 LET Q(7)=1
230 FOR I=1 TO 7
240 SEQ(I)=(((Q(I)^2)*(1-Q(I)))/D(I))^(1/2)
250 NEXT I
260 REM the next line of data refers to the deaths
270 DATA 7, 4, 8, 12, 4, 1, 4
280 REM
290 REM
300 REM
310 REM
320 REM L(I) represents 1i and B(I) represents di (i.e. the deaths in the life table population
in the age interval i)
330 L(1)=100000!
340 FOR I=1 TO 6
```

```
350 B(I)=Q(I)*L(I)
360 L(I+1)=L(I)-B(I)
370 NEXT I
380 B(7)=L(7)
400 X(1)=(2.5*L(1))+(2.5*L(2))
410 FOR I=2 TO 6
420 X(I)=(5*L(I))+(5*L(I+1))
430 NEXT I
450 X(7)=L(7)*5
460 T(7)=X(7)
470 FOR I=6 TO 1 STEP -1
480 T(I)=X(I)+T(I+1)
490 NEXT I
500 H(1)=5
520 FOR I=2 TO 6
530 H(I)=10
540 NEXT I
560 A(1)=.46
570 FOR I=2 TO 7
580 A(I)=.5
590 NEXT I
600 FOR I=1 TO 7
610 E(I)=T(I)/L(I)
620 NEXT I
630 FOR I=1 TO 6
640 SS=((L(I)/L(I))^2)*((E(I+1)+((1-A(I))*H(I)))^2)*((SEQ(I))^2)
650 FOR J=I+1 TO 6
660 SS=SS+((L(J)/L(I))^2)*((E(J+1)+((1-A(J))*H(J)))^2)*((SEQ(J))^2)
670 NEXT J
680 F(I)=SS
690 NEXT I
700 FOR I=1 TO 7
710 SEE(I)=(F(I))^(1/2)
720 NEXT I
725 PRINT "Life Table for Skeletal Populations Using 7 Age groups"
730 REM to change the title, simply edit line 725 i.e. type the new title
740 PRINT:PRINT
750 PRINT "     age          q(x)          S.E.q(x)          d(x)          l(x)"
:PRINT
760 N1$=" 0 - 4":REM to define first age interval
780 PRINT N1$,USING "#.#######          ";Q(1);SEQ(1),
790 PRINT USING "######.##          ";B(1);L(1)
820 S=1:REM loop to define remaining age intervals
830 FOR I=5 TO 45 STEP 10
840 S=S+1
850 PRINT I"-"I+9,USING "#.#######          ";Q(S);SEQ(S),
860 PRINT USING "######.##          ";B(S);L(S)
870 NEXT I
880 PRINT " 55+",USING "#.#######          ";Q(7);SEQ(7),
890 PRINT USING "######.##          ";B(7);L(7)
900 STOP:PRINT:PRINT:PRINT
910 PRINT "     age          L(x)          T(x)          e(x)          S.E.e(x)"
920 PRINT
930 N1$=" 0 - 4"
950 PRINT N1$,USING "#######          ";X(1);T(1);
960 PRINT USING "##.##          ";E(1);
970 PRINT USING "#.#######";SEE(1)
1010 S=1
1020 FOR I=5 TO 45 STEP 10
```

```
1030 S=S+1
1040 PRINT I"-"1+9, USING "#######                    ";X(S);T(S);
1050 PRINT USING "##.##            ";E(S);
1060 PRINT  USING "#.#######";SEE(S)
1070 NEXT I
1080 PRINT " 55+",  USING "#######                    ";X(7);T(7);
1090 PRINT USING '##.##            ";E(7);
1100 PRINT USING "#.######";SEE(7)
1110 STOP:END
```

Computer Based Data Collection

James D. Paterson
Department of Anthropology
University of Calgary

Why use a computer?

Imagine for a moment, this scenario. An observer standing on a trail in a tropical rain forest, head tilted back as she strains to keep track of the activities of a monkey 35 metres above her in the canopy of a strangler fig tree. She notes that the monkey selects a patch of fruits after inspecting two others, and begins to feed. These activities are noted with half dozen keystrokes on the keypad built into the top of the binoculars, the data is visually checked as it is projected in the field of one eyepiece. A moment later her subject is involved in a high speed agressive interaction, and with the push of a button she shifts to voice recognition and dictates, in a few code phrases, an account of it. Later that day, she settles down in her camp, and connects a single cable from her conventional portable computer to the binoculars. An intelligent program in the former queries the binoculars' processor, and data is transfered into the portable, and thence to the main computer at her home university via a satellite uplink. At the university computing centre the data is received, checked and verified, out of range values checked against a repeat from the binoculars, the validated data is then subjected to analysis in a set of programs previously specified by the researcher, and a tabulated set of results with graphics is returned to the tent in the forest for inspection.

This is for the moment a fantasy, but it may become a real possibility within the next decade, although probably not in this exact fashion. It does however present one of the implied advantages of the use of a computer based data collection system, the capacity to encode data directly, only once, and immediately proceed to analysis.

But what is wrong with pencil and paper?

Initially, one is inclined to say either not very much, or everything, depending on one's perspective. Paper and pencil do have some limitations, the paper must be appropriate to the environment, it is often necessary to use waterproof paper in tropical rain forests, and that in turn requires special pencils or pens. Then again the problem that some people have, and I must confess to displaying it in large measure, is the inability to write legibly in straight lines while looking at something else. This naturally entails a great deal of attention shifting between subject and writing pad. Afterwards, comes the process of transcribing rough notes into good copy, or at least legible copy, coding the information for analysis, and then entering it into a computer. A more controlled approach makes use of check sheets for the data record, but this is also subject to transcription and coding delays. At each stage of these procedures, a substantial amount of time is involved and a potential for error creeps into the process.

Then what is wrong with a tape recorder?

The tape recorder is one of the most obvious and natural subsitutes for the pencil and paper procedure, but is potentially a disaster for the observer. The most frequent concern can be termed the "motor-mouth phenomenon", a tendency to run on verbally to great lengths in inexhaustable detail. The result is obvious, a large amount of tape, and progressively lengthy transcriptions, with increasing difficulty in extracting useful data from the material. Again the problems of transcription and coding loom large in the workload of the researcher, exacerbated by the shift to an apparently "easier to use" technology, but one which puts the observer at one step further removed from the final analytical process.

So what's wrong with a computerized data collector?

A computer based data collecting mechanism then seems to beckon to the observer with its promises of avoiding the transcription and coding labour. And, due to its input mechanism and program limitations, it promises to avoid the motor-mouth phenomenon. But there are still drawbacks. If one starts from scratch, and embarks upon the development of such a machine, one must expect to have a very great deal of patience and a large amount of funding. Very rarely does the technological world have ready and waiting the exact materials needed to fulfill an embryonic idea. It is inevitable that the development of a field data collector will be confounded with problems of weight, power consumption, circuit complexity, and above all, high development costs. No matter how well planned and organized the project, the resultant product will inevitably be overweight, overly demanding of power, too complex for local technicians to understand, and always over budget.

Commercially available machines?

The obvious way to circumvent the development cycle is to see what is available in the commercial field. It is possible to find equipment which is suitable to use under some circumstances, and there are some special purpose devices whose sole reason for existance is to collect observational data. Among the latter are the products of the Electro-General Corporation, who product the Datamyte series of data loggers. One difficulty with these is that they are very much special purpose machines, and have limitations on their operating environmental conditions, they cannot generally be used in rain, nor in high temperature, humid conditions. They are all of substantial size and weight, a problem for some workers which would not be recognized by others. These devices are special purpose, programable machines which, with many research designs and observing circumstances, are appropriate, but expensive solutions. A more general type of computer is the Husky Hunter, an MS-DOS compatible available through Forestry Suppliers Inc. This unit looks much like a Radio Shack Model 100, uses a similar screen, but is waterproof and environmentally hardened for use in the forestry industry. It is also rather expensive at $2,700 U.S. With one of these devices, working on arboreal species in a hot,humid rain forest would require an arm to hold the device, one to type/

enter data with, and one or two more to manipulate the binoculars.

In less stressful observing conditions, the common microcomputer has come into its own, and captive studies done in fixed locations have made use of Apples, Commodores, Radio Shack TRS-80's, and Heath Z-100's among others. Of the lot, the most practical, useful, and inexpensive of such computers have been the Radio Shack Model 100, and Model 102, although for many situations they should be supplied with a "Safe-Skin" cover to improve their environmental hardening.

Evaluating the commercially available products for field use can be a complicated process, but the following guidelines may be of some benefit.

1) Is the unit able to do the job - does it have sufficient memory to hold the expected amount of data which will be collected - does it have a reasonable programming language available, and are there programs available which will be suited for the collection routine, and will perform the required analyses?

2) Is the unit appropriately portable? Will the process of data entry interfere with the maintenance of observation? Will the weight of the unit cause excessive fatigue in the observer?

3) Is the unit sufficiently hardened against environmental damages? It should be waterproof, and able to operate beyond the temperature extremes of the study location. It should also be resistant to physical damage.

4) What do you do for repairs? Is it a fix it yourself operation, return to manufacturer (with a concomitant 3 month wait), or is it servicable worldwide?

5) What do you do while your machine is down, have you provided yourself with a backup research design and data collecting procedure?

All of these guidelines can only provide advice, for in the end, the selection and implementation of a computerized data gathering system is very much a product of personal evaluation and preference.

Personal Experiences with the development of data collectors:

As a cautionary model for other researchers, I offer my own experiences in the quest for a computer system to control, enrich, and speed up the data acquisition process. A quest which has spanned more than a decade, but has yet to produce a fully functional machine.

Introduction to microprocessors - 1977-78:

In 1977, I encountered the article by Stevenson et al (1975) which presented an interaction recorder constructed and used at the Wisconsin Regional Primate Reseach Centre, and in the interests of getting out of the write, rewrite, code, compute loop, I obtained a copy of the schematic, and was dismayed to learn that it would cost almost $2,000 dollars to build. An acquaintance introduced me to a technician in the education faculty who was working with one of the first KIM-1 computers, a machine which promised to do a lot for a mere $350, and I immediately embarked upon a foray into the world of bits, bytes, and baud. A linkage was forged with Dr Fred Trofimenkoff of the Electrical Engineering department, and together we started on the development of Datac-1. Datac-1, for DATa ACquisitor first model, was build upon an RCA S020 single board computer using the RCA 1802 microprocessor. These were chosen because of their low power design, and their tolerance of a wide range of environmental conditions, since they were originally orientated towards industrial process control. The major problem in Datac-1 was a display, but we eventually found one in a new technology, that of Liquid Crystal Displays, but at a very high price. It was intended that the machine should be functional for my sabbatical year in Mexico, 1978/79, but programming problems made it impossible to achieve this goal. As a consequence Datac-1 never left the confines of the laboratory.

Datac II - RCA microboards and Pocket Computers 1980-82:

The second model Datac II was the result of a great deal of cogitation about the problems of fieldwork, and a slight change of research orientation. I now wanted to collect data about environmental variables as well as the observed behavioural details. This led to the development of a sensor pole with the climatological instruments built into it, and a connection to what now had to be a larger computer, and with the benefit of hundreds of hours in the forest with my head tilted back to full extension, and the weight of binoculars and tape recorder in hand, the need for a wrist mounted or binocular mounted keyboard-display unit became apparent. The result was a backpack sized device with 4 RCA Microboards (4 by 6 inches in size), with a large battery pack, a cable to a Radio Shack Pocket Computer (Model 1) which was used as the keypad entry subsystem, and another cable to the sensor pole.

The field trial of Datac II:

Datac II went to Arashiyama West at Dilley,Texas, in the summer of 1982 after running flawlessly in the lab and on location in Calgary. However, after the trip to San Antonio, when it was powered up, it was totally nonfunctional, and local technicians were unable to help. Later, it was determined (after 3 days of work in the engineering lab), that a single "gate" chip had died. The failure of twelve cents worth of silicon had killed a $3000 computer system.

Datac III - The software solution for the Pocket Computer 1982:

In order to salvage the field trip, I was forced to fall back on pen and paper for a while, but was also able to restructure the program used on the Pocket Computer for a different purpose. This program had been originally written to accept the behavioural data as numeric codes, and then to transfer them to the backpack device via its tape recorder interface. Restructuring the program around the need to take direct environmental monitored data as well as the behavioural data led to a system which could be used as a substitute for the paper, but it was only later realized that getting the data from the tape to any other computer was a significant problem in itself. This was eventually solved in a roundabout way by constructing a transfer device which would allow the tape recorder audio signal to be encoded as an RS-232C signal and fed into a desktop computer. The signal then had to be converted to ASCII from its original form and formatted for analysis by statistical programs. It should be obvious that by this point it would have been a great deal simpler and less costly to have done the whole study with pen and paper!

Portions of the program constructed there have found their way into similar programs for the Radio Shack PC2, and the PC4. There are very severe restrictions presented to anyone attempting to make use of these "programmable calculators", primarily related to the hardware design. Only the PC2 can hold an array, and hence have the ability to construct a file in the machines own memory, the others have fixed variable registers which are very limited and controlled by a direct naming call in the programming language. This means that the capacity is functionally limited to 26 variables of 6 digits, after which the data must be flushed, or transfered to the tape recorder. This latter process itself takes 50 seconds. Getting the data out requires that one possess one of the printers for the particular model, and be prepared to take the hardcopy of the data and manually reenter it into another computer. The complexities and aggravation associated with this software approach to the problem and the limitations of the hardware mitigate strongly against it.

Kibos - a general purpose observing program with some stats capability:

In 1985 I encountered a brief report of a BASIC program called KIBOS, which appeared in Behavior Research Methods, Instruments, and Computers (Lifshitz et al, 1985) and promised to handle a great many data recording chores, it would even produce summary statistics of each observational set. After consulting with the authors of this program, I made plans to produce a version of this program for use on the Radio Shack Model 100 computers which we had recently acquired for student field use. However, after working on the conversion of KIBOS for some weeks in early 1988, and becoming more cognizant of the maze of "goto" commands within its structure, it was decided to abandon the original code (which had been written for the Zenith Z100 computer), and proceed to development of a modularly structured program of our own design.

Datac IV for the Radio Shack Model 100 1988:

The newly developed program, now labeled as "Datac IV" is intended as a utility for data collection using either continuous or interval recording on either a Model 100 or 102 computer. The program builds project control files, raw data output files, and summary statistical files as part of its operation. Due to the size to which the latter two kinds of files may grow in the course of an observational session, it is not possible to have other files in memory unless some form of expanded or paged memory has been added to the machine. The project file is designed to control the data types, the code forms of data, and the format of the observational routine, and thus maintain equality from one session to another. The project files along with the raw output and summary statistic files can be examined and edited through the Model 100's built in TEXT program, and they can be uploaded to a larger computer using the TELECOM program and a null-modem type cable. With Datac IV, one of the objectives of development has been achieved, that of a moderately simple and relatively inexpensive field data collecting system, which with the addition of a "Safe-Skin" keyboard cover, is useable under a variety of field conditions. However, it is not expandable, nor is it able to handle inputs from independent instrumentation which may be running in parallel with the observational routines. In the case of my own research I require a record of the set of temperatures, and the light level present at the subjects' locations. Other researchers will have different needs, or this particular type of problem may be irrelevant to their project.

Datac V - The Onset Computer Tattletales:

While the Datac IV software approach solves many of my research problems, it does not do the one thing that I require, as mentioned above. In late 1987 I had encountered a small advertisement in Byte magazine by the Onset Computer Corporation, announcing the latest in their line of Tattletale data loggers, devices which appear to be fully functional microcomputers (without any input/output devices) squeezed onto a 5 by 10 centimetre card. The capacities for taking signals from the sensor pole, converting them and storing them in RAM, implied that only an input/output device such as a portable terminal would be all that I needed to have the next generation data logging system, one that would replace the bulk and slow operation of the Datac IV. Unfortunately it did not prove to be so simple. The problem turned out to be, as it always has been, the wrist mounted I/O device. The final solution has turned out to be the setting up of the Tattletale to operate as an independent entity, to record the observational data on either a Model 100 or a Psion II (see below), and latter to merge the two data files in a Macintosh.

The Psion Organizer II - a new development:

In the middle of March 1988 a new possibility for field use came into view in the form of the Psion Organizer II, a computer approximately the same size as an older "pocket calculator". This new device is a descendent of the Psion Organizer of 1981/82 which was categorized as a terminal and data logger, but was half the size of the Model 100 and weighed in at 2.5 Kilograms! The Organizer II is only 250 grams, has 36 keys, a two line liquid crystal display, 32K of RAM, and uses EPROM (Electrically Programable Read Only Memory) packs of up to 128K size as data storage, or alternatively a 32K battery backed up RAMPack. The packs are smaller than the 9 volt battery which provides 3 to 6 months of life to the unit. An accessory RS232 module and cable allows it to communicate with a larger computer for data exchange, and a variety of built in programs, as well as accessory programs are available. It also can be programmed in its own BASIC-like language. The Psion has all of the features which make the Radio Shack Model 100/102 field useable, but does it in a very much smaller and lighter package, and most closely approaches the field device which I had envisioned back in 1977. Conversion of the DATAC IV program to run on the Psion is now in progress.

Is a computer recommended for field use?

This question is very much one that must be answered on a personal basis. For some the use of a computer under field conditions may be seen as a pretentious arrogance, for others it may be considered as an absolute necessity.

With the current expansion of the "laptop" full function computers, virtually any anthropologist of any research inclination can find a use for one in the field. They have recently been advocated by the Dyson-Hudsons (1986) and Wood (1987) for ethnographic field work, and the organizing of research notes in the field. They have been seen in the hands of physical anthropologists and archaeologists at field excavations, and in the tents of linguistic investigators in Tibet. The place of the computer in fieldwork is becoming well established, but its adoption is still a matter of personal choice, there is always a place for the pen and paper, the tape recorder, and the camera in any research design. For the field worker in primatology, the picture is less clear. While the laptop computer is a valuable asset and would be useful for secondary work in the field, the progress in data logging instruments has been less satisfactory, and while I would be prepared to suggest that the Radio Shack Model 100/102 and the Psion II are useful instruments under many situations, nothing is yet available in a suitable form for use under the more extreme conditions of tropical rain forest research.

Under what conditions?

Thus if one elects to consider the use of a data collecting computer system in primatological field research, it is necessary to first of all consider whether or not the device will accomplish the job required of it. Second, it is necessary to consider whether or not the device would be able to function under the environmental conditions of the study area. In this it is wise to examine the operational specifications for the machine. If it says "less than 90% non condensing humidity", then the likelihood of its functioning in a tropical rainforest is virtually zero, although it may be perfectly fine for a dryer environment. Many computers are also restricted to a maximum temperature of 40°C, although I can attest that Radio Shack equipment can operate satisfactorily at up to 47°C. Similarly, anyone using a device with a liquid crystal display should be aware that the display (but not the computer) will slow down at low temperatures, and eventually cease to function at 0°C.

What precautions to take.

As has been mentioned earlier in this document, it is inadvisable to place total reliance upon any machine in the field, irrespective of whether it is mechanical or electronic. Computers are often mechanical as well as electronic, and thus are prone to malfunctions in both areas. If the device is a homebrewed entity, without the schematics and test data in your hands, even the most skilled techician may be unable to help. Indeed, repair may not be possible by anyone except the individual who constructed it. In the realm of commercially manufactured machines, the problems may be slightly less, but still the possibility of finding a Toshiba, NEC, Psion, or Radio Shack repair shop in the backwaters of third world countries is very low.

The only safe procedure would be to have spares of everything, but that is not generally a viable solution. However, one must at least recognize that storage media fail and backing up data on a daily or at least weekly basis is a vital necessity. And where the environment is different from the standard northamerican office, it may be advisable to keep sensitive devices in airtight cases, with recently baked silica gel packets to ensure dryness. Finally, one must always have an available means of salvaging the trip, even if that means retreating to the "primitive technology" of pencil and paper.

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