Health and diet of ancient Easter Islanders: contribution of paleopathology, dental microwear and stable isotopes*

by

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KEYWORDS. — Easter island; Skeletons; Health; Diet

SUMMARY. — This paper relates to the study of the health and diet of ancient Easter Islanders. It is based on human skeletons discovered between 1934 and 2009. We studied skeletal markers that revealed poor living conditions during growth (stress indicators) and recorded the presence of infectious diseases. The dietary reconstitution is based on dental microwear and the analysis of carbon and nitrogen stable isotopes. Our study indicates relatively good health and food conditions during childhood. However, we found cases of infectious diseases that probably followed contact with Europeans or Americans. The dental microwear pattern is due to the dominant part of the tubers. The stable isotopes show that, on average, a little more than one third of their dietary proteins came from the sea.

MOTS-CLES. — Île de Pâques; Squelettes; Etat santeaire; Régime alimentaire


TREFWOORDEN. — Paaseiland; Skeletten; Gezondheid; Dieet

SAMENVATTING. — Dit werk handelt over de studie van de gezondheidstoestand en het dieet van de oude bewoners van Paaseiland. Ons materiaal bestaat uit menselijke skeletten ontdekt tussen 1934 en 2009. We hebben pathologische skeletachtige kenmerken bestudeerd die de slechte levensomstandigheden aantoonden gedurende de groei (stressindicatoren) en hebben de aanwezigheid van infectieziekten vastgesteld. De wedersamenstelling van de voedingsgewoonten zijn gebaseerd op de studie van microslijtage van de tanden en de analyse van stabiele koolstof- en stikstofisotopen. Onze studie onthult een relatief bevredigende gezondheid- en voedingstoestand tijdens de kindertijd. We hebben evenwel de aandacht gevestigd op gevallen van infectieziekten die waarschijnlijk het gevolg zijn van contact met de Europeanen of de Amerikanen. Het patroon van de microslijtage is het gevolg van het overwegend gebruik van wortelknollen in de voeding. Stabiele isotopen tonen aan dat gemiddeld iets meer dan een derde van hun eiwitbehoeften van mariene oorsprong was.

1. Introduction

Easter Island (or Rapa Nui) is the most isolated inhabited island of the Pacific (fig. 1). It is located at 27°09’30” S and 109°26’14” W - 3,600 km from the Chilean coasts and 4,200 km of Tahiti. Its closest populated neighbour is Pitcairn Island, 2,075

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km to the west. Easter Island has a volcanic origin and a land area of 160.5 km² (FISHER & LOVE 1993).

According to some authors, the initial human settlement of Easter Island would have taken place between the 8th and the 10th century A.D. (BAHN 1993). For others, it would have occurred more recently and would date back to the 12th century (HUNT & LIPO 2006). Anthropological (TURNER & SCOTT 1977, GILL & OWSLEY 1993), palaeogenetic (HAGELBERG 1994), ethnohistorical (METRAUX 1971) and linguistic (DU FEU & FISCHER 1993) research showed that Easter Islanders would have had a Polynesian origin.

The population of the island started to grow until reaching, according to KIRCH (1984), 9,000 islanders in 1550. A demographic decline began in about 1650 and was accompanied by great upheavals in the social organisation, as well as in the religious and funerary practices. This may have been related to the disappearance of available resources. The palynologic (FLENLEY & KING 1984) and anthropologic (ORLIAC & ORLIAC 1998) analyses show that the island definitely had, until the beginning of the 17th century, a forest cover where palm trees dominated. When the European navigators visited the island in the 18th century (the Dutch explorer Jacob Roggeveen was the first European to discover the island in 1722 on Easter Day, hence its name), Easter islanders were estimated to be no more than 1,000 or 2,000 individuals and the forests had completely disappeared. According to some authors (e.g. KIRCH 1984, DIAMOND 2005) and mainly based on oral tradition (narratives collected in the 20th C.) and on the emaciated wooden anthropomorphic statues (moai kava kava), this deforestation would then have been followed by inter-tribal wars, famines and even cannibalism.

Thereafter, two tragic episodes continued to decimate the population (LAVACHERY 1935, FISCHER 2005). Between December 1862 and March 1863, Peruvian slave traders captured approximately 1,400 natives (men, women and children) to work in farms and to harvest the guano primarily on Chincha Islands, Peru (MAUDE 1981). More than 90% of them perished following the bad working conditions, maltreatment and diseases. In August 1863, international protests put an end to the slave trade and the survivors, carrying smallpox and tuberculosis, were repatriated on the island. An epidemic of smallpox then decimated over a thousand islanders. Then, in 1868, Dutrou-Bornier, a French adventurer, established himself on the island and created a reign of terror. In 1873, missionaries invited all the inhabitants to leave the island to live in the Gambier Islands and Tahiti. Only 111 Natives requisitioned as labour by the tyrant remained on the island (METRAUX 1941). Dutrou-Bornier was assassinated in 1876. In 1888, the island was annexed by Chile and was then exploited from 1897 by a Chilean businessman. In 1903, the lands were rented to a Scottish sheep breeder company. Until 1954, the small Polynesian island was no more than a large farm managed by this company and the Rapanui were gathered in a single village: Hanga Roa (FISCHER 2005).

The absence of written archives and the disappearance of the majority of the ancestral culture holders during the slave raids and the epidemics, unfortunately led to the loss of most of the information relating to the history of the island and its traditions. The teeth and human bones consequently constitute the main source of direct information on the lifestyle of ancient Easter Islanders.

Until now, anthropological studies have mainly attempted to define the ethnic origin of the settlement (see higher), to determine the degree of endogamy and/or exogamy between the different "tribes" of the island (STEPHAN 1999) and to evaluate the impact of European contact (interbreeding, infectious and traumatic pathology).
(OWSLEY et al. 1994). Paradoxically, the diet and general health status of the ancient population were barely studied by anthropobiologists. In fact, only two papers relate to these topics through the study of dental caries (OWSLEY et al. 1983, 1985).

This paper aims to document both themes by the study of the palaeopathology, dental microwear and stable isotopes.

2. Material

The archaeological surveys undertaken as from the end of the 19th century on Easter Island allowed the discovery of the remains of several hundreds of individuals where often, unfortunately, only the skulls were taken. The majority were buried in monuments (ahu). In the ancient period (13-15th centuries), the dead were generally incinerated and their ashes gathered in stone-lined cists located at the rear of the ahu (AYRES & SALEEBY 2000, HUYGE et al. 2002, POLET 2003). After the deforestation, the progressive abandonment of the giant statues (moai) cult and their overthrow, Easter Islanders continued to bury their dead in the ahu but, this time, mostly in niches dug in the platform or under lying moai (SEELENFREUND 2000). In addition, there are also burials in caves that seem to have taken place after the discovery of the island by the Europeans (SHAW 2000). Some of them contained individuals who died during the great epidemics of the 19th century.

The chronological attribution of the skeletons, however, is problematic as most of the monuments were used over long periods. Moreover, dating was mainly carried out on obsidian artefacts (SEELENFREUND 2000, SHAW 2000) but rarely directly on human remains. Diachronic studies cannot thus currently be considered.

The samples studied come from 18 sites mainly dated between the 17th and the 19th century (fig. 1 and table 1). They are composed of:

— skulls and long bones brought back to Europe in 1935 by A. Métraux and H. Lavachery (LAVACHERY 1935). They come from the north of the island and belong to the collections of the Royal Belgian Institute of the Natural sciences (RBINS);
— skeletons exhumed at the end of the 1970th by G. Gill (GILL & OWSLEY 1993). They belong to the collections of the Father Sebastián Englert Anthropological Museum of Easter Island which holds the majority of the anthropological material recently excavated;
— fragmentary human remains collected in 1996 by C.M. Stevenson and S. Haoa from cult and settlement sites at La Pérouse Bay (STEVENSON & HAOA 1998). They are housed at the Museum Sebastián Englert;
— skeletons discovered lately by N. Cauwe and D. Huyge of the Royal Museums of Art and History (RMAH) (HUYGE & CAUWE, 2002, CAUWE et al. 2006, CAUWE 2011). They are housed at the Sebastián Englert Museum (except for the individual from Ahu Motu Toremo Hiva, which was reburied according to the will of the local authorities).

3. Methods

Health was studied through the recording of infectious diseases and stress indicators. Diet was reconstructed using dental microwear and stable isotope analyses.
3.1. Skeletal pathology

The majority of infectious diseases do not leave traces on the skeletons and, when they do, it is frequently in a generalized and non-specific way. Moreover, often only severe or advanced stages will leave sequels. Some diseases however can cause specific modifications of the skeleton and can thus be identified in the archaeological record. The most studied are tuberculosis, leprosy and syphilis (ORTNER 2008, POLET 2011). Tuberculosis leaves characteristic traces on vertebrae. Leprosy is characterized by damage to the bones of the face, fingers, and toes. Syphilis tends to destroy the skull vault and the tibiae.

Easter Island skeletal samples were examined macroscopically and pathological changes were recorded.

To get a glimpse of the general health status of ancient Easter Islanders, we have studied two skeletal markers revealing bad living conditions during growth (stress indicators): dental enamel hypoplasia and cribra orbitalia.

Dental enamel hypoplasia consists of localised defects (fig. 2) generally in the form of horizontal depressions due to a temporary disturbance in amelogenesis (GOODMAN & ROSE 1990). In most cases, hypoplasias originate from a problem of malnutrition and/or of health (high fever or infection). The formation of a defect requires at least several weeks of stress. As enamel does not remodel once it is formed, hypoplasias are permanent markers left on the tooth crown. We recorded the presence of hypoplasia on the deciduous and permanent incisors and canines (POLET 2006a).

Cribra orbitalia is a porotic lesion in the bony orbital roof (fig. 3). It has long been strictly associated with iron-deficiency anemia (STUART-MACADAM 1992) but recent work shows that it can also be related to a vitamin-B12-deficient diet [1]*, scurvy or chronic infections (WALKER et al. 2009, OXENHAM & CAVILL 2010). We recorded the presence of cribra orbitalia on individuals presenting at least one complete orbital roof (POLET 2006a).

3.2. Dental microwear

Since the end of the 1970’s, dental microwear is a field of research that has been integrated in the dietary reconstitutions of ancient populations (TEAFORD 1994). The density, dimensions, as well as the orientation of these microstructures are a function of the type of food as well as its preparation (MOLLESON et al. 1993, LALUEZA et al. 1996). On the vestibular surface of the teeth, the vertical and long striations would be caused by meat chewed quickly while the short horizontal and oblique striations would result from crushing harder (more abrasive) vegetal food. Vegetarians also show more striations than carnivores.

We examined the vestibular surface of the first and second permanent molars with scanning electron microscopy at 178 X magnification (Philips SEM 515 of the RBINS) (POLET et al. 2008). The number of striations, their length and their orientation were recorded in a circular area of 300µm diameter (fig. 4) using the software Microware 4.02 of UNGAR (1995) [2].

* Numbers in brackets [] refer to the notes, p. XXX
3.3. CARBON AND NITROGEN STABLE ISOTOPE ANALYSES

Carbon and nitrogen stable isotopes analyses have proved to be efficient methods for reconstructing palaeodiet (TYKOT 2004, BOCHERENS & DRUCKER 2005). They are based on the fact that the differences in chemical composition between different categories of food are reflected in the bones or teeth of the consumer (in other words: “you are what you eat”). They give a direct measure of long term diets on the individual level and consequently enable associations to be highlighted between diet and certain attributes such as social status, age or sex (POLET 2008).

C and N isotopes are chiefly measured in bone (and dentine) collagen, the main component of their organic fraction. Results are expressed as isotopic ratios (= ratio of abundance of the heavy to light isotope) relative to an international standard. They are reported as delta (δ) notation in units per mil (‰). δ is calculated in the following way for carbon and nitrogen stable isotopes:

\[ \delta^{13}C (‰) = \left[ \frac{(^{13}C/^{12}C) \text{ sample}}{(^{13}C/^{12}C) \text{ standard}} - 1 \right] \times 1000 \]

\[ \delta^{15}N (‰) = \left[ \frac{(^{15}N/^{14}N) \text{ sample}}{(^{15}N/^{14}N) \text{ standard}} - 1 \right] \times 1000 \]

δ is positive if the sample is enriched in heavy isotopes compared to the standard, a negative δ indicates the opposite.

For carbon isotopes, the internationally defined standard is V-PDB (for Vienna Pee Dee Belemnite). The nitrogen isotopes are reported relative to AIR (for atmospheric air).

We sampled 200-300mg of compact bone with a drill. Collagen was extracted by acidic demineralization followed by a step of contaminants removal (BOCHERENS et al. 1991). The carbon and nitrogen isotopic compositions were measured with the Finnigan MAT 252 mass spectrometer of the University of Tübingen, Germany.

4. Results and discussion

4.1. SKELETAL PATHOLOGY

There is presently no study giving the prevalence of infectious diseases in ancient Easter Islanders. This is probably due to the lack of a large-scale study and to the fact that pathological diagnoses are uncertain as most individuals are incomplete (many are only represented by one skull) and fragmented.

We present here two pathological examples that we have studied: an individual that might have suffered from leprosy and another from syphilis.

The probable case of leprosy comes from Ahu Motu Toremo Hiva, a site excavated by the RMAH in 2004 (CAUWE et al. 2006). The skeleton was buried in a peculiar position: in ventral decubitus, face against the ground. The individual would be a Polynesian male who probably reached forty years (POLET 2006b). Radiocarbon dating shows that he died at the end of the 19th century or at the beginning of the 20th. Several osseous pathologies can be observed (fig. 5):
1) a resorption of the anterior nasal spine and of the maxillary alveolar process with the loss of the left upper central incisor,
2) an osteolytic remodelling of the proximal foot phalanges,
3) a proximal extension of the distal articulation of the middle phalanx of the left little finger that could result from a chronic hyperflexion of the concerned finger,
4) an enlargement of the nutrient foramen of hands and feet bones.

These symptoms indicate that the individual could have suffered from an early stage from the lepromatous form of leprosy. The extraction and amplification of *Mycobacterium leprae* DNA from the bones of this individual should make it possible to confirm this hypothesis. According to historical sources, the first proven case of leprosy on Easter Island dates back to 1888. The disease seems to have been brought from French Polynesia (FISCHER 2005, p. 151). It quickly became endemic in the indigenous population, affecting approximately 7% of the inhabitants. Leprosy was finally eradicated in the years 1980. The individual from Ahu Motu Toremo Hiva could be one of the first lepers of Easter Island. It is also the first probable case of leprosy diagnosed on a Rapanui skeleton.

The supposed case of syphilis comes from Ahu Te Niu, a site excavated by the RMAH in 2008 and 2009 (CAUWE 2011). The pathological bones consist of 19 fragments of a skull vault (fig. 6). Stratigraphically, they should be later to the 17th century although no direct dating has yet been done. The outer table of the skull presents a sclerotic remodelling with circumvallate cavitations and radial scars very similar to the evolutionary stages published by HACKETT (1976). The inner table is not involved. These observations suggest tertiary syphilis. Complementary analyses are necessary in order to confirm this diagnosis. Symptoms of syphilis have been briefly described by OWSLEY et al. (1994) on 3 adults and 2 children from Easter Island (congenital syphilis). For one of the adults, the diagnosis was confirmed by the extraction of *Treponema pallidum* DNA (KOLMAN et al. 1999).

No enamel hypoplasia was observed in the 7 deciduous dentitions of Easter Island but this pathology concerns 18.0% of the permanent teeth of Rapanui (table 2). On the island of Guam however, 12.7% (17/134) of the individuals display this stress indicator in their primary teeth (STODDER 1997). *Cribra orbitalia* concerns 12.7% of our sample (table 2).

The percentage of the Rapanui adults and children with enamel hypoplasia and the percentage of *cribra orbitalia* are in the range of variation of other historic and prehistoric [3] Pacific samples (POLET 2006a) (fig. 7). These are however much lower than European medieval populations from the 6th to the 15th century AD (POLET 2006a).

Within the Rapanui sample, women show significantly higher hypoplasia frequencies than men (table 2). This leads to the assumption of a preferential investment in boys (GUATELLI-STEINBERG & LUKACS 1999) as the tooth crown records stress events that occurred during its formation, i. e. childhood.

The percentage of *cribra orbitalia* is higher in the children than in the adults (table 2), as in many other populations (POLET & ORBAN 2001: p. 120, PIETRUSEWSKY et al. 1997). This result could be explained by the healing and disappearance of the lesions with age.

4.2. **DENTAL MICROWEAR**
In the sampled circular area, the total number of microscratches of Easter Islanders varies between 21 and 119 with an average of 53.9 features (or 77 scratches/mm²). Their average length is 50.9 µm and they display a high proportion of horizontal and horizontal-oblique orientations (fig. 8).

If one refers to studies carried out on individuals of known diet (Lalueza et al. 1996), the amount, the length and the orientation of these scratches indicate a low abrasive vegetable food prevalence. This result can be related to the dominance of sweet potato (Ipomoea batatas) in their daily meals as it is stated by historical (Pollock 1993, Flenley 1993), ethnographical (Routledge 1919, Métraux 1971) and archaeobotanical (Flenley 1993, Cummings 1998) data. The high percentages of caries recorded by Owsley et al. (1983, 1985) confirm this hypothesis because sweet potato and other tubers eaten by Rapanui (taro, yam and arrow-root) are rich in starches and highly cariogenic (Lingström et al. 2000).

There is unfortunately no dental microwear study of other Polynesian populations. We thus decided to compare our group with samples studied by García-Martín (2000). These are individuals from Belgium belonging to the collections of the RBINS: Neolithics from the Meuse Basin (end of the 5th Millenium - first half of the 3rd Millenium before our Era), Mediaeval individuals from the Dunes abbey of Coxyde (12th-15th c.) and from Ciply and Torgny (6th-7th c.). Compared to these samples, Easter Islanders display in fact a small total number of striations (fig. 9). Furthermore, multivariate statistical analyses based on the length and the orientation of the scratches reveal that the microwear pattern of Easter Islanders presents the most similarities with that of the Cistercians of Coxyde (Polet et al. 2008) where marine fish consumption is attested. This ichtyophagy is confirmed by the marine faunal remains (Steadman et al. 1994, Ayres et al. 2000) and by the fishing implements (e. g. Lavachery 1935, Ayres 1985) discovered in Easter Island archaeological sites.

Within our adult sample, we did not observe any sex or age-related differences in microwear pattern (Polet et al. 2008). It indicated that these two parameters did not determine a preferential access to the various foodstuffs once adulthood is reached.

4.3. Carbon and Nitrogen Stable Isotope Analyses

We present here preliminary results for 15 Rapanui individuals. Their isotopic ratios are plotted in figure 10 and compared to data of animals with known feeding strategies. The Easter Island humans are located between the values of the terrestrial and the marine reference ecosystems. To estimate the proportion of marine food in their diet, we applied the linear mixing model of Mays (1997) based on the carbon isotopes. In this model, an entirely terrestrial diet leads to a value of -21.5 ‰ and a wholly marine-based one to -12 ‰. Except for one man from Ahu O’Nero who displays a δ13C signature of -20 ‰ and who would have only consumed 15.8 % of marine products, the marine proportion of Easter Islanders varied between 29.5 and 49.5 %, with an average of 35.8 % [4]. It would be nevertheless interesting to analyze animal remains coming from archaeological sites of Easter Island in order to establish a local faunal reference frame.

6. Conclusion
This study provides information on health and dietary habits of ancient Easter islanders.

The stress indicators indicate relatively good health conditions during childhood. Infantile malnutrition was far from being severe as opposed to the catastrophist theories (chaos, wars and famines following the deforestation) popularised by DIAMOND (2005: p. 79-119). The paleopathologic study reveals nevertheless, new cases of infectious diseases probably resulting from contact with Europeans or Americans. Enamel hypoplasia suggests gender disparities in the access to basic resources resulting from a preferential investment in sons.

Dental microwear evidences the dominant part of the tubers, which was their staple food. The preliminary stable isotopes analysis shows that, on average, a little more than one third of their proteins came from the sea.

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NOTES

[1] The primary sources of this vitamin B12 are meat, poultry, (shell)fish, milk and eggs.
[2] This program can be downloaded at the following internet address: http://comp.uark.edu/~pungar/software.htm.
[3] Prehistoric here means anterior to the first contacts with the Europeans.
[4] The actual proportion of marine food in their diet must have been rather lower since collagen is preferentially produced from the dietary proteins (AMBROSE & NORR 1993).

REFERENCES


FIGURES CAPTIONS

Fig. 1. — Location of Easter Island and the different studied sites. RMAH = Royal Museums of Art and History.

Fig. 2. — Enamel hypoplasia in a child of approximately 12 years from Ahu O Nero.
Fig. 3. — *Cribrum orbitalia* in a young woman from Oroi cave.
Fig. 4. — Positive replica of a molar from *ahu O Rongo* seen from its buccal side. The selected zone (rectangle) is located on the mesio-buccal cusp near the occlusal surface. Microwear was recorded in a circular area of 300μm diameter.
Fig. 5. — Individual from Ahu Motu Toremo Hiva probably suffering of leprosy. A. Skeleton in situ (Drawing: N. Cauwe, RMAH). B. Skull with resorption of the anterior nasal spine and of the alveolar process of the maxilla with the loss of the left upper central incisor. C. Proximal extension of the distal articulation of the middle phalanx of the left little finger (→). D. Osteolytic remodelling of the diaphysis of the fifth proximal phalanx of the left foot (→). E. Enlarged nutrient foramen on the left talus (→). F. Enlarged nutrient foramen on the head of the left metacarpal II (→).
Fig. 6. — Fragments of skull vault of an individual buried at Ahu Te Niu and displaying symptoms evocative of syphilis. A. Outer table characterised by a sclerotic remodelling with lesions looking like to the stages 4 and 5 of HACKETT (1976). B. Inner table.

SYphilis Sequence
(Hackett, 1976)

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Clustered Pits</td>
</tr>
<tr>
<td>2</td>
<td>Confluent Clustered Pits</td>
</tr>
<tr>
<td>3</td>
<td>Focal Superficial Cavitiation</td>
</tr>
<tr>
<td>4</td>
<td>Circumvallate Cavitiation</td>
</tr>
<tr>
<td>5</td>
<td>Radial Scar</td>
</tr>
</tbody>
</table>
Fig. 7. — A. Frequencies of enamel hypoplasia on permanent teeth in the Easter Island sample compared to those collected in 7 archaeological and extant Polynesian samples (references are in POLET 2006a). B. Frequencies of *cribra orbitalia* in the Easter Island sample compared to those collected in 5 archaeological Polynesian samples (references are in POLET 2006a).
Fig. 8. — Distribution (pie-chart) of the Easter Islanders micro-striations in 4 orientations classes (horizontal, horizontal / oblique, oblique and vertical / oblique).

Fig. 9. — Distribution of the 71 Easter Islanders and of the individuals of 4 comparative samples from Belgium (Neolithic individuals of the Meuse bassin, Merovingian individuals from Ciply and Torgny, monks from the Dunes Abbey of Coxyde (Low Middle Ages)) for the total number of striations. The individuals are sorted in ascending order by their total number of striations.
Fig. 10. — Bivariate plot of $\delta^{15}$N and $\delta^{13}$C values from animals of known feeding strategies (data from SCHÖNINGER & DE NIRO, 1984) and 14 Easter Islanders.