The Ivory Palm *Phytelephas aequatorialis* in Western Ecuador

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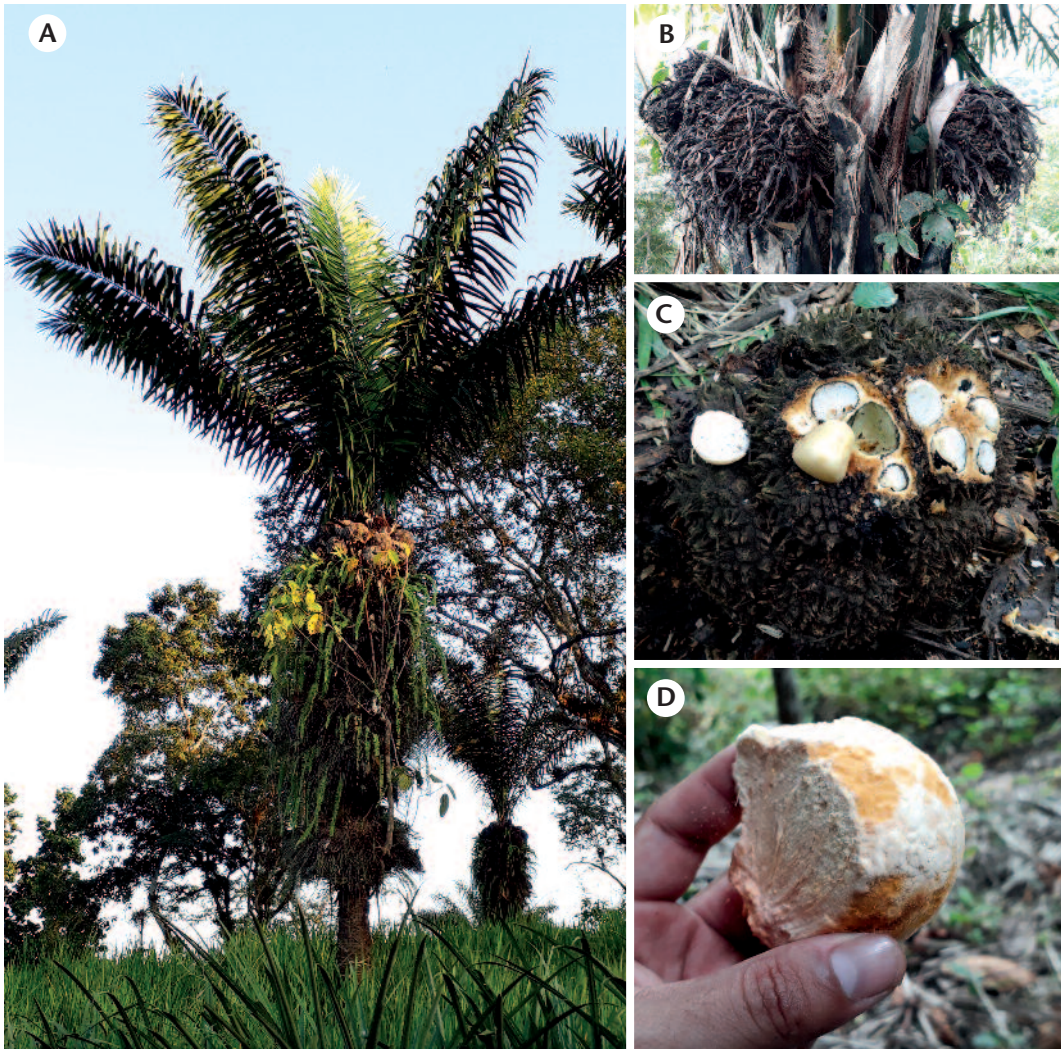
Phytelephas aequatorialis **is the commercially exploited ivory palm in western Ecuador, where less than 25% of the natural forest remains. To determine the conservation status of this palm, we visited 15 populations, growing under different degrees of human disturbance in both the lowlands and the lower Andean slopes. We collected leaf material for genetic analyses, which we hope will provide valuable information that can help the conservation and management of this important species. For a first view, populations growing outside forests in pastures appeared to be threatened because they did not reproduce naturally. The species *per se*, however, is not threatened because of its wide distribution and large populations. Conserving its populations could secure the species' genetic and phenotypic diversity, which, in turn, is the raw material for its domestication.**

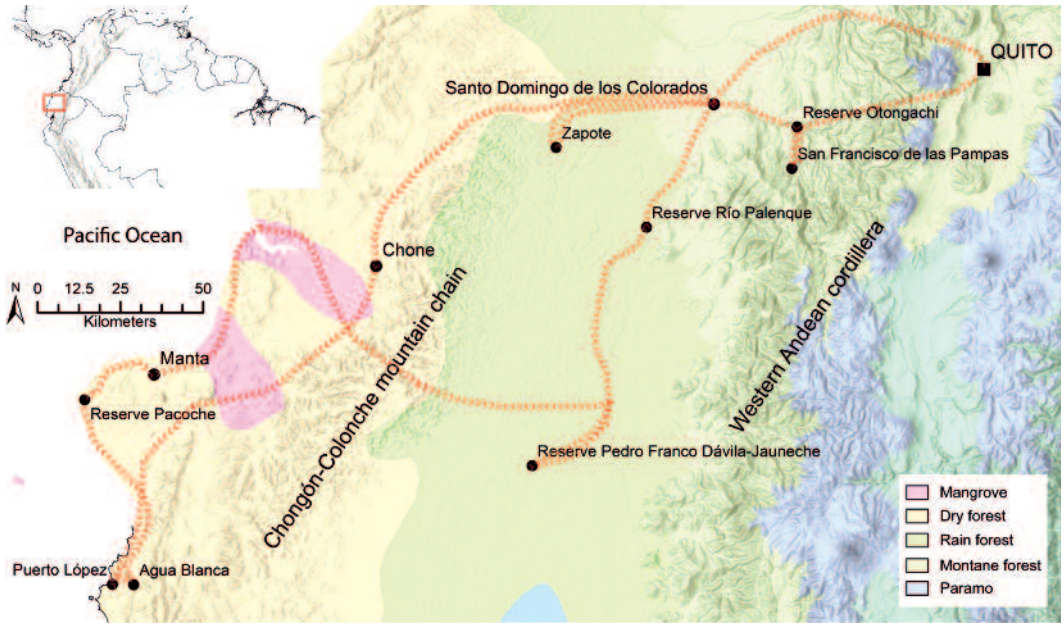
The palm *Phytelephas aequatorialis* (Fig. 1), also known as *tagua* or ivory palm, is endemic to western Ecuador, which is a region highly affected by deforestation. *Tagua* grows from sea level up to 1500 m above sea level, in lowland rain forests and semi-deciduous forests along the Pacific coast, and it extends up the slopes in pre-montane and montane forests on the western Andean foothills (Borchsenius et al. 1998).

Its populations are fragmented because 77% of the coastal region of western Ecuador has been deforested (Sierra 2013), and forests in the highlands are also rapidly disappearing. *Tagua* grows well in agroforestry systems or pastures where it has been left standing (Borgtoft Pedersen & Skov 2001). Nevertheless, populations in pastures lack natural regeneration, which can be seen by the absence of sub-adult individuals (Velásquez-Runk 1998, Brokamp et al. 2014) and which endangers the populations future (Montúfar et al. 2013). The loss of populations due to deforestation may reduce the species' resilience capacity and economic potential.

Tagua is an important Non-Timber Forest Product (NTFP) commercialized in rural and urban areas of western Ecuador. Natural populations of this palm are mainly exploited for harvesting the hard, white endosperm of its seeds, also known as *tagua* or vegetable ivory. *Tagua* (the seed) is used as raw material in button and handicraft manufacturing, and its commerce has been a profitable industry in

1. *Phytelephas aequatorialis* near the town of Chone. A. Adult female individual growing in a pasture. B. Rounded infructescenses of *tagua*. C. Obconical fruits showing the hard endosperm of the seeds. D. Detail of an individual seed covered in fleshy mesocarp. Photos by S. Escobar.





2. Route followed during the field trip in western Ecuador.

western Ecuador since the 19th century until today (Barfod et al. 1990, Montúfar et al. 2013, Brokamp et al. 2014). The leaves of *tagua* palms, locally known as *cade*, are in turn harvested for thatching (Borchsenius & Moraes 2006). Despite the economic importance of *tagua*, there is no available information about its intraspecific diversity at the genetic level. This information is essential for improved conservation and management of this palm. With this in mind, we undertook a study in western Ecuador (Fig. 2) where we sampled populations of *tagua* as part of the more wide-ranging PhD research on *P. aequatorialis* by the first author.

Our field trip started on Tuesday July 10, 2018, early in the morning and lasted for eight days of hard work in the field. We left Quito, Ecuador's capital located in the middle of the Andes at 2800 m above sea level and descended the spectacular western flanks of the Andes towards the Pacific Ocean. We made a quick stop close to the town of Santo Domingo de los Colorados where we saw the first *tagua* individuals growing in pastures. These adult individuals were fairly old and tall, since farmers had left them standing for their fruits. In these pastures, we noted the absence of seedlings and juvenile individuals around the adult palms. We observed similar alterations in the population structure in other pastures visited during the trip. We continued driving all day arriving at dusk at the small touristic village of Puerto López, famous for its good whale sightseeing. After checking into our hotel, we noticed that the key-holders were made of, guess what? Yep, *tagua*.

This region of the lowlands towards the Pacific Ocean in Ecuador is spectacular. First, we are at the limit of the influence of the cold Humboldt Current, which creates dry conditions to the adjacent land. Second, there is a small mountain chain called Chongón-Colonche, which creates a smooth relief. This leads to an intricate mix of dry forests dominated by the kapok *Ceiba pentandra* (Malvaceae), with humid forests in which *tagua* palms are abundant. In these forests, populations of *tagua* are naturally fragmented which is one of the reasons for our visit.

Our next stop was the Agua Blanca community, famous for its *tagua* crafts and *cade* rooftops, located within a dry forest with shrubby vegetation. Upon arrival, we did not see any *tagua* individuals, which is normal given the climate. We quickly found a local guide who explained to us that the inhabitants in the area fetch *tagua* in the nearby humid Chongón-Colonche mountains. After a 3-hour, mainly uphill hike in the boiling hot sun, we arrived in a more humid area where the xeric vegetation had disappeared and instead, we found a humid rain forest. This forest represented a small rain forest pocket surrounded by drier vegetation, created thousands of years ago. But first things first, we had to take a rest and rehydrate ourselves because this walk had put our physical

3. Sebastián Escobar and Rommel Montúfar improvising a tool in the forest near Agua Blanca community for reaching young leaves of *Phytelephas aequatorialis*. Photo by T.L.P. Couvreur.

4. Production of *animelas*, the precursors of buttons, in the town of Manta. A. Drying of *tagua* seeds under the sun. B. Dried seeds. C. Selection of dried seeds according to their size. D. Slices resulting from the cut using a sawblade. E. Making of a hole in the slices. F. Resulting *animelas* sorted by size. G. Refined *animelas* conserving the pericarp of the *tagua* seeds. Photos by S. Escobar.

condition to the test. Interestingly, *tagua* was the only palm species occurring in this forest. Some individuals were very tall, and we estimated that they were over 100 years old. We then took our time to sample numerous individuals (Fig. 3) since we assumed that this population might harbor interesting genetic diversity, probably different from those located within the many forest fragments created by man's deforestation over the past half century.

After finishing our sampling, we headed north following the highway along the ocean. We arrived at Pacoche, which is a national reserve composed of separate patches of secondary forest and local farms. This reserve is comparable to an oasis since it is a humid ecosystem embedded within a semi-deciduous forest. Besides *tagua*, we saw several other palm species, and in particular the impressive and massive western Ecuador subendemic royal palm *Attalea colenda* (Borchsenius et al. 1998). This species is also threatened by the continuous deforestation in the region. Another common palm here was *Chamaedorea linearis*, which is easily recognized by its regularly ringed vividly green stem.

In Manta, we visited a factory that uses *tagua* seeds to produce *animelas*, the precursors of buttons. Most of the production is exported to Europe, generating around $14 million annual income to Ecuador (Brokamp et al. 2014). To enter the factory, you must walk on a "carpet" of drying *tagua* seeds (Fig. 4). The owner of the factory took us for a tour, explaining along the way how the dried seeds were selected and processed. Selected seeds are first cut into thin slices using a fast-rotating blade that is handled masterfully by the men. The women then

5. Variation in the distribution of leaf segments of *Phytelephas aequatorialis*. A. Leaf of a juvenile individual from the lowland rain forest at the Agua Blanca community, with segments aggregated in different planes. B. Leaf of an adult individual from the montane forest of Otongachi, with segments regularly inserted in one plane. Photos by S. Escobar.

make a hole in the slices of tagua with utmost precision. A last selection process sorts the resulting *animelas* into low- and high-quality products, ready for export.

At this point, we left the coastal Pacific plain and went deeper inland, where the natural forests have been transformed into agricultural land. First, we visited the region between Manta and Chone. Sometimes we drove for kilometers without seeing any *tagua*, or any palms for that matter apart from the coconut palm, *Cocos nucifera*, which is widely cultivated in this region. Nevertheless, we managed to find large populations of *tagua* growing in humid forests on hills. Then we moved eastwards, where the human influence on the forests was even greater. Along our way, we saw people selling small red vividly colored fruits of *Bactris gasipaes* var. *chichagui*, the wild variety of the peach palm, which occurs naturally in this part of South America (Couvreur et al. 2006). *Chontilla*, as it is locally known in Ecuador, is consumed in a thick soup called *borroque*. This region is dominated by monocultures of maize, oil palm, and several types of banana. We drove through tens of kilometers (literally!) of these plantations and could not stop wondering how beautiful the forests that once grew there must have been.

Luckily, we were able to find a couple of remnants of tropical rain forest at the natural reserves Pedro Franco Dávila-Jauneche and Río Palenque. These forests are the last remnants for kilometers around; and they are well worth the visit. There is no transition zone, no buffer, one goes from the fields to the rain forest in a few steps. It triggers an interesting sensation between sadness linked to all the destruction mixed with hope and joy because these patches of forest are still there. These forests are safe-havens for plants, palms in particular, as well as animals. For example, a small population of howler monkeys (*Alouatta palliata*) naturally inhabit Pedro Franco Dávila-Jauneche. Besides *tagua*, other palm species occurring there are *Attalea colenda* and *Astrocaryum standleyanum*. These patches could be likened to a forest museum, harboring the remains of a once incredible natural diversity.

For our next stop we visited a small village called Zapote. Here, we met Anelio Loor, an old friend, known for his everlasting smile and his passion for nature. Anelio is what we could call a real-life conservation hero. He was trained as a technician in biodiversity inventories in the large Forest Dynamics Plot project in Yasuni National Park in the Ecuadorian Amazon. Returning home after 16 years, Anelio decided to become active in biodiversity conservation. He acquired one of the last patches of western Ecuador lowland rain forest close to his house, using his own hard-earned savings and a few head of cattle. He wants his young children to play in the same environment he did many years ago and called his forest *Esperanza* meaning *hope* in Spanish. He does not exploit or manage Esperanza. He just leaves it alone. However, with the support of botanists he set up a 1-hectare forest plot in his free time, measuring and identifying the plants on a regular basis just as he learned to do in *Yasuní*. Anelio has one ambition, which is to acquire the last patch of forest adjacent to his own before it is subjected to the same fate as all the other forests in the region. We said goodbye, wishing Anelio the best with his conservation efforts.

By now, we started to have a fair number of *tagua* collections from the coastal plains and lowland forests of western Ecuador. However, tagua also occurs along the Andean slopes up to 1500 m above sea level. We thus set out for the second leg of our trip, and headed towards the privately-owned reserve of Otongachi, close to Santo Domingo de los Colorados. Otongachi is in an area of montane forest on the Andean foothills at about 850 m above sea level, in which *tagua* grows abundantly. We noted an interesting morphological characteristic of this population (Fig. 5). *Tagua* leaves are generally characterized by having their segments arranged in groups and spreading in different planes (Borchsenius et al. 1998). However, in Otongachi we observed *tagua* individuals with the segments regularly inserted along the midrib and spreading in a single plane. We also found individuals with mixed characteristics (i.e. individuals with segments regularly inserted in different planes and individuals with segments grouped in one plane). It is possible that this morphological variation is an adaptation to this more humid habitat compared to what we had seen along the coastal plain. In addition to *tagua*, we observed other palms such as *Oenocarpus bataua*, *Iriartea deltoidea*, *Prestoea acuminata*, and *Chamaedorea pinnatifrons*. Here, we met with researchers from our home institutions, the *Pontificia Universidad Católica del Ecuador* (PUCE) and the *Institut de Recherche pour le Dévelopemment* (IRD) who were studying the floral biology (Figs. 6 & 7) and thermogenesis of *tagua* (Fig. 8), a trait poorly understood in this dioecious palm (Pincebourde et al. 2016).

6. Recently opened pistillate (female) inflorescence of *Phytelephas aequatorialis* at the reserve of Otongachi. Photo by S. Escobar.

7. Recently opened staminate (male) inflorescence of *Phytelephas aequatorialis* at the reserve of Otongachi visited by possible pollinators. Photo by S. Escobar.

8. Heat production of a closed staminate (male) inflorescence captured by an infrared camera at the reserve of Otongachi by researchers from the PUCE and the IRD. Photo by T.L.P. Couvreur.

For our last journey we traveled near to San Francisco de Las Pampas, a village located on the Andean slopes at 1500 m above sea level. This harbors one of the highest known populations of *tagua*. The landscape is a mosaic of remnant forest patches with *tagua* and the Andean palms *Wettinia kalbreyeri* and *Ceroxylon echinulatum*, and pastures for cattle browsing in which *tagua* individuals are left standing. We met with the Tapia family who owns a portion of land and a small patch of natural forest where we sampled leaves of *tagua*. However, Mrs. Tapia warned us to take extra precaution when sampling *tagua* with mature fruits. Why? Because mature fruits attract rodents such as agoutis, squirrels, and mice, that in turn attract predators such as snakes! Luckily, we did not see any snakes during our field trip.

After eight days of fieldwork, we had sampled 15 different *tagua* populations and driven more than 1000 km. During our field trip we could note that *P. aequatorialis* is not under risk of extinction due to its wide distribution and large populations. However, many of its populations are highly threatened by deforestation, which could compromise the genetic diversity within the species. As for many palms in western Ecuador, they are generally the last trees standing in the pastures. Since *tagua* may be undergoing incipient domestication, it is essential to secure its genetic diversity through conservation (Borchsenius et al. 1998).

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Literature Cited

Barfod, A.S., B. Bergmann and H. Borgtoft Pedersen. 1990. The vegetable ivory industry: Surviving and doing well in Ecuador. Economic Botany 44: 293–300.

Borchsenius, F., H. Borgtoft Pedersen and H. Balslev. 1998. Manual to the Palms of Ecuador. AAU Reports 37, Aarhus, Denmark.

Borchsenius, F. and M. Moraes. 2006. Diversidad y usos de palmeras andinas (Arecaceae). Pp. 412–433, in Moraes,M., B. Øllgaard, F. Bochsenius and H. Balslev (eds.). Botánica Económica de Los Andes Centrales, Universidad Mayor de San Andrés, La Paz, Bolivia.

Borgtoft Pedersen, H. and F. Skov. 2001. Mapping palm extractivism in Ecuador using pair-wise comparisons and bioclimatic modeling. Economic Botany 55: 63–71.

Brokamp, G., H. Borgtoft Pedersen, R. Montúfar, J. Jácome, M. Weigend and H. Balslev. 2014. Productivity and management of *Phytelephas aequatorialis* (Arecaceae) in Ecuador. Annals of Applied Biology 164: 257–269.

Couvreur, T.L.P., N. Billotte, A.M. Risterucci, C. Lara, Y. Vigouroux, B. Ludeña, J.L. Pham and J.-C Pintaud. 2006. Close genetic proximity between cultivated and wild *Bactris gasipaes* Kunth revealed by microsatellite markers in Western Ecuador. Genetic Resources and Crop Evolution 53: 1361–1373.

Montúfar, R., G. Brokamp and J. Jácome. 2013. Tagua: *Phytelephas aequatorialis*. Pp. 165–173. in Valencia, R., R. Montúfar, H. Navarrete and H. Balslev (eds.). Palmeras Ecuatorianas: Biología y uso sostenible. Herbario QCA de la Pontificia Universidad Católica del Ecuador, Quito, Ecuador.

Pincebourde, S., R. Montúfar, E. Páez and O. Dangles. 2016. Heat production by an Ecuadorian palm. Frontiers in Ecology and the Environment 14: 571–572.

Sierra, R. 2013. Patrones y factores de deforestación en el Ecuador continental, 1990–2010. Y un acercamiento a los próximos 10 años. Conservación Internacional Ecuador y Forest Trends. Quito, Ecuador.

Velásquez-Runk, J. 1998. Productivity and sustainability of a vegetable ivory palm (*Phytelephas aequatorialis*, Arecaceae) under three management regimes in northwestern Ecuador. Economic Botany 52: 168–182.