Chapter 6

Guano: The White Gold of the Seabirds

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Additional information is available at the end of the chapter

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Abstract

The term "Guano" applies to natural mineral deposits consisting of excrements, eggshells and carcasses of dead seabirds found in almost rainless, hot-dry climatic regions and corresponding fertilizers. Guanos are classified according to age, genesis, geographical origin and chemical composition. Main types are nitrogen- and phosphate Guanos. Phosphate Guanos require a calcareous subsoil for the development, while nitrogen Guanos are formed only under the special climatic conditions of the subtropical-edge tropical high pressure belt with coastal deserts. The most significant nitrogen Guano is the Peru-Guano, which has been used over 2000 years as agricultural fertilizer in Peru. In Europe the application of Guano as fertilizer emerged in the 1840 as "Guano boom" and lasted until the early twentieth century when Guano was replaced by industrial manufactured fertilizers. Only a small quantity is still exported to Europe as additive to organic/mineral fertilizers, more for image boosting than for effect.

Keywords: Guano, seabird excrement, organic fertilizer, mining, history, chemical composition

1. Introduction

Bird excrements have long been highly regarded by mankind, last but not least in the holy bible where it reads in 2 Kings 6:25: "And there was a great famine in Samaria, as they besieged it, until a donkey's head was sold for eighty shekels of silver, and the fourth part of a kab of dove's dung for five shekels of silver". This is because Guanos contain mineral nutrients essential for plant growth, mainly nitrogen and phosphorous, but in fact and some only in trace amounts, also all the other chemical elements plants require for growth like sulfur, potassium, calcium, magnesium, chloride, boron, molybdenum iron, manganese, zinc and copper. Although a major nuisance to people and buildings in seaside regions (**Figure 1**), the white and acrid birds excrements [2] are still today a significant contribution to the nutrient

Figure 1. Gulls excrements blemish and destroy buildings and monuments [1].

Figure 2. Pigeon houses at SEKEM farm in Belbeis near Cairo deliver birds dung as essential fertilizer for small scale farming (photo © Schnug 2014).

balance of non-agrarian ecosystems [3] and an essential source of plant nutrients in many smallholder farming systems in developing countries, like for instance Egypt [4] (**Figure 2**).

In seabird colonies the excreta, carcasses and egg shells cover large areas which tend to cover the entire bedrock of a colony and build up to large dumps when precipitation fails to wash the debris back into the sea (**Figure 3**).

A very famous, but fictive "Guano" island was Crab Key on the shores of Jamaica where the Chinese Dr. No in a "James Bond" novel makes his money for his evil nuclear research [5].

Especially in dry and hot climates this dumps can be massive and become rock-like during aging processes. The material of such dumbs is called "Guano." The word Guano derives from the Peruvian original language Quechua; of "Huano", which means "dung to fertilize" [6]. The term Guano generally refers to deposits of excreta, carcasses and egg shells of seabirds, which transform under certain climatic conditions into the homonymous fertilizer. A speciality is

Figure 3. Like the island "Crab Key" in Ian Flemmings famous novel "Dr. No" Bass Rock in the Firth of Forth (56.0769°N 2.6410°W) is covered with white Guano produced by 150,000 gannets plus guillemots, razorbills, cormorants, puffins, eider ducks and numerous gulls (photo © Schnug 2005).

so-called "bat Guanos", which are occasionally found in large caves, especially in Asia and the Caribbean and used locally or are rarely traded as fertilizer. In this chapter the term "Guano" always refers to Guano deriving from seabirds. The writer Victor von Scheffel (1854) once wrote a hymn giving a poetic description on the genisis of Guano [7].

2. Classifications of Guanos

In the literature, there are several different criteria for Guano. Thus it can be distinguished according to its age and its genesis, its chemical composition, its geographical origin and its various animal producers.

2.1. Classification by age and genesis

A general differentiation between age and genesis distinguishes between red and white Guano. Red Guano, which is fossil, is a biogenic sediment [8]. It is a pure phosphate fertilizer with 20–30% phosphoric acid content (P_2O_5). White Guano, on the other hand, represents a recent formation and refers to the Guano, which is produced daily by animal excrements—especially by seabirds. It consists of 10–12% nitrogen, 10–12% phosphoric acid (P_2O_5) and 3% potash (K_2O) [9].

2.2. Classification by chemical composition

From a chemical point of view, Guanos can be divided according to their main constituents into phosphate and nitrogen Guanos.

Phosphate Guanos are formed under the influence of rain or sea surf, which causes soluble nitrogen and phosphate compounds to be washed out of the material. If this process takes place on a calcareous substratum (for example a coral reef, etc.), washed-out phosphates and the lime of the coral reefs produce predominantly highly compacted apatitic structures, known as so-called "rock Guanos" [10]. Mineralogically, these are secondary rock phosphate deposits. The leached Guanos on the surface of such secondary deposits are low in nitrogen but contain large quantities of low soluble mono- to tricalcium phosphates.

Well-known representatives of the phosphate Guanos were found on the coral islands in the Pacific and in the Caribbean, which were eponymous for this types of Guanos. Meyer's Great Conversation Lexicon of 1907 [11] mentions as typical Guano phosphates, e.g. Baker-Guano, Howland-Guano, Jarvis-Guano and Sydney-Iceland-Guano, which were named after the Pacific coral islands and islands in the Caribbean with sombrero Guano, navassa Guano, aves Guano and curassao Guano. Other well-known equatorial-pacific phosphate Guano deposits are the fossil Nauru Guano, Guano from the Christmas Islands and the Mejillones Guano named after the Chilean peninsula of the same name [12]. Typical of these phosphate Guanos is the lack of or very low nitrogen content. Since these varieties consist almost exclusively of tricalcium phosphates, a quick plant availability of the phosphates is guaranteed only after a sulfuric acid digestion; they were thus mainly used as raw material of the superphosphate industry [13] (**Figure 4**).

Guanos with high nitrogen content are simply called "nitrogen Guanos." They contain nitrogen in the single-digit to low double-digit percentage. However, in raw Guanos classified as

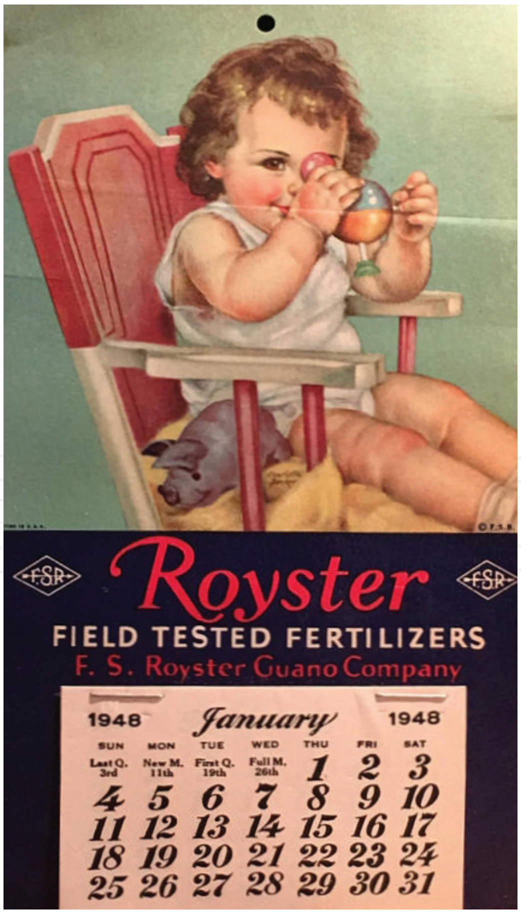

Figure 4. Fertilizer manufacturers rendered the apatitic phosphates in Guano soluble by treating with sulfuric acid. 1948 calendar sheet from the Royster fertilizer company.

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nitrogen Guanos, the content of phosphate is usually always higher than that of nitrogen. They were traded as fertilizers without further industrial processing.

The composition of Guanos from various deposits is given in **Tables 1** and **2**. The corresponding locations are shown in the overview map in **Figure 5**.

2.3. Classification by geographical origin

Another distinguishing criterion for the different varieties of Guano is their geographical origin. It is closely linked to the particular climatic conditions that are responsible for the genesis of Guano deposits.

Phosphate Guanos are found mainly on some equatorial-Pacific and Caribbean islands, since only in the tropical-subtropical region by appropriate water temperatures, the climatic

Origin	Howland Island—UM-84*	Baker Island—UM-81*	Enderbury Island—Republic of Kiribati	Jarvis Island—UM-86*	Malden Island—Republic of Kiribati	Mejillones—Chile	Curacao—the Netherlands
Location in **Figure 5**	A	B	C	D	E	F	G
H_2O	12	11	12	12	5	10	1
C_{org}	12	9	7	8	2	8	1
N	n/a	0.5	n/a	0.5	n/a	0.7	n/a
P_2O_5	33	33	37	23	37	38	40
K_2O	n/a	n/a	n/a	0.5	n/a	n/a	n/a
CaO	40	40	42	35	49	34	50

*The United States Minor Outlying Islands—UM—country code.
Source: [14, 15].

Table 1. Composition of phosphate Guanos from various deposits (%).

Origin	Peru	South Africa	Namibia	Egypt	Bat
Location in **Figure 5**	H	I	J	K	L
H_2O	7.8	<LOD	<LOD	<LOD	22
C_{org}	45	18–44	<LOD	39	79
N	8–15	3–9	5–7	11	8–13
P_2O_5	8–15	7	12–14	9	2–5
K_2O	2–4	3	n/a	n/a	2
CaO	<LOD	<LOD	<LOD	<LOD	<LOD

n/a: not applicable.
LOD: limit of detection.
Source: [14].

Table 2. Composition of nitrogen Guanos from various deposits (%).

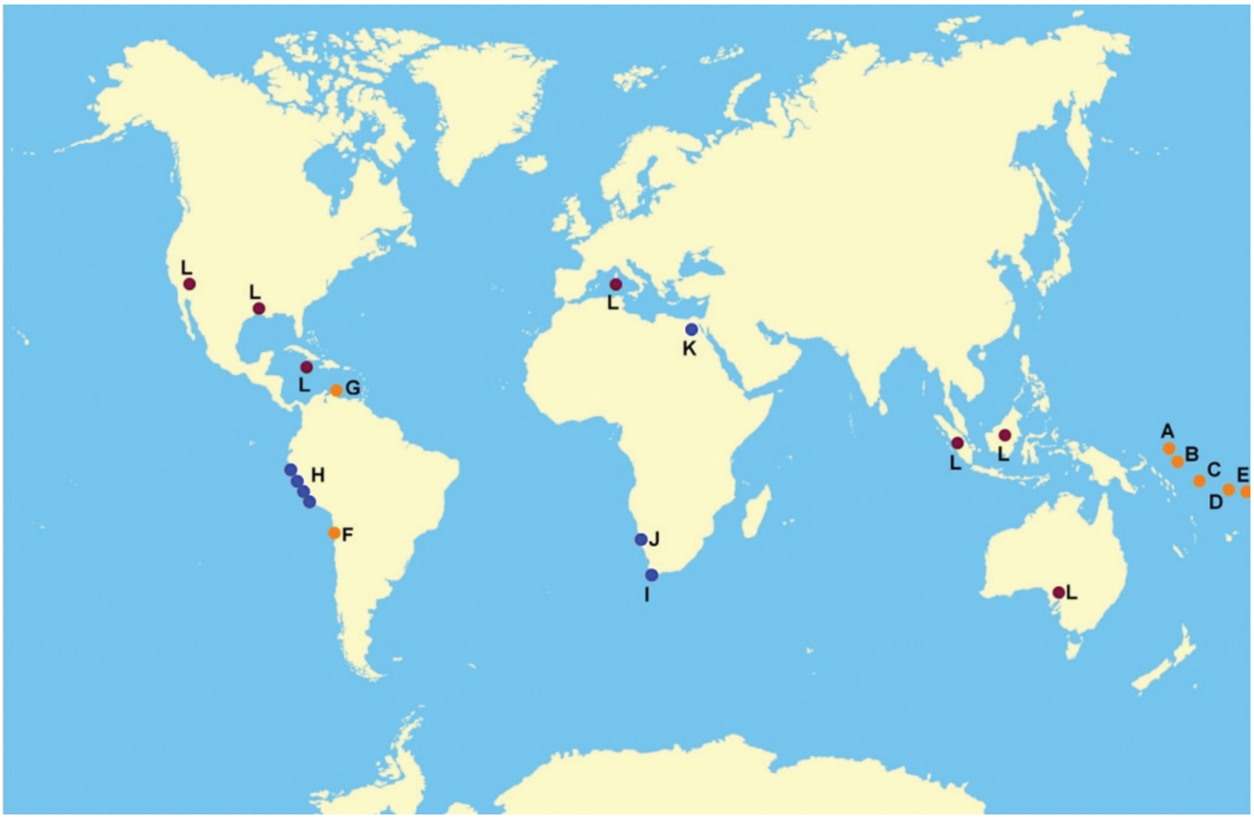

Figure 5. Important deposits of phosphate Guanos (A-G), nitrogen Guanos (H-K) and bat Guanos (L).

conditions for the growth of coral reefs are given, which represent the calcareous substrate for the formation of phosphate Guanos.

Different climatic conditions apply to the formation of phosphorus-rich nitrogen Guanos. Decisive for their formation is a sufficiently large seabird population, which in turn depends on a rich nutrient supply to produce enough excrement. These excrements are deposited in several decimetral strata on the islands and promontories populated by seabirds. Another basic prerequisite for the formation of such nitrogen-Guano deposits is extreme low precipitation or dryness, since otherwise the excrements are subject to precipitation-related scavenging and then cannot form massive Guanol deposits. Such special climatic conditions can be found in the subtropical high-pressure belt with its coastal deserts, whose formation is characterized by cold and very nutrient-rich buoyant waters [16].

Significant nitrogen Guano deposits of great thickness are therefore found mainly in the Pacific on islands off the west coast of South America, Peru, Chile and Bolivia. There flows the cold, plankton and fish-rich Humboldt Current, which feeds large populations of seabirds. The counterpart is the Benguela River, which is also fed from Antarctic waters of origin, off the coast of Namibia (formerly Southwest Africa) with the Namib Desert and South Africa. Here is the approximately 6.5-acre island Ichaboe (Namibia) to call, on which was up to 12 m thick Guano deposit.

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However, the commercially most important Guano deposits in the past were found in South America between the 8th and 15th degrees south latitude on the Peruvian coast and the offshore islands, the so called Peru Guano.

The most famous and significant and up to 30 m thick Peru Guano deposits were on the Chincha Islands - a group of three small, consisting of granite rock, on all sides by steep cliffs limited islands about 21 km off the Peruvian southwest coast near the city of Pisco.

2.4. Differentiation according to the different animal producers

Another distinction of Guanotypes can be made according to its various animal producers. By far the most important Guano producers are exclusively fish-feeding seabird species that live in large colonies on the Guano Islands off the coasts of Africa and South America. They are very similar in their ecological claims as well as in their food and reproductive behavior. In South America, the most important Guano producers are the Guanay cormorant or Guanay shag (*Leucocarbo bougainvillii* or *Phalacrocorax bougainvillii*), the Peruvian pelican (*Pelecanus thagus*), the Peruvian booby (*Sula variegata*)—(**Figure 6**), the Peruvian diving petrel (*Pelecanoides garnotii*) and various albatross species (*Diomedeidae*).

In South Africa, the Bank cormorant or Wahlberg's cormorant (*Phalacrocorax neglectus*), the Cape gannet (*Morus capensis*), the Cape cormorant or Cape shag (*Phalacrocorax capensis*) and various albatross species (*Diomedeidae*) are the most important Guano producers [17]. For the equatorial-pacific and Caribbean islands, various species of boobies (*Sulidae*), frigatebird species (*Fregatidae*) and terns (*Sternidae*) are the most important Guano producers.

Compared to the far superior number of seabirds, other Guano producers are junior penguins (*Spheniscidae*), although they are well known as Guano animals (**Figure 7**). Here are the Humboldt penguin (*Spheniscus humboldti*) and Galápagos Penguin (*Spheniscus mendiculus*) for South America and the African Penguin (*Spheniscus demersus*) for South Africa.

Figure 6. Young Peruvian boobies (*Sula variegata*). Nests of this species can be found on all slopes of Guañape Norte, no other is so common on the island. (photo © Tomás Munita).

Figure 7. The penguin as a trademark in Guano advertising for compo® garden plant fertilizer.

The bats (*Chiroptera*) are a special case of animal Guano producers. Recent bat Guano (*Chiropterite*) [18], which is often produced in large quantities from the excrement of the animals in caves, is currently being exploited in Italy (Sardinia), Spain (Andalusia), Hungary, Egypt, the United States (Arkansas, Texas), Mexico and Jamaica, as well as South West Africa and the Indian Pacific (Ceylon, Indonesia/Sumatra/Borneo) [19] and more valuable nitrogen fertilizer (so-called "Bat-Guano") marketed. In Germany, the native *Microchiroptera* species produce the bat Guano [20].

In contrast to seabird Guano, bat Guano does not have a strong inherent odor, because the bats that serve as Guano producers feed on fruits and insects [2, 6]. Bat Guano is therefore visually recognizable by the chitin residues of the indigestible outer skeletal parts (wings) of the consumed prey insects. The marketed bat Guano contains between 3 and 8.5% nitrogen and 2–19% phosphoric acid and is characterized by its almost neutral pH around 7.5. The urea contained gives the plants an instant "nitrogen boost", while the chitin residues of the insects act as an N-depot and supply the plants with nitrogen only through the microbial decomposition process in the soil [6]. However, the commercial exploitation of bat Guano is on a grand scale not uncontroversial, as it can lead to a considerable disturbance of the bats.

The practice of harvesting bat Guano practiced in Germany is limited to small quantities used by hobby gardeners (up to a few 100 kg), which are obtained mainly from church roof chairs by manual collection of the bat decoy. The Bavarian State Office for the Environment classifies bat Guano produced in Germany as hygienically harmless [21].

The production of bat Guano in Germany is already reported in 1866. In an article in "Westermann's Monatshefte" it says: "The bats Guano has not been completely overlooked as a usable fertilizer; in the Nassau, many truckloads of it have already been obtained from old church stores and sold as fertilizer" [22].

2.5. Alternative Guano

Due to constantly increasing demand and rapidly decreasing supplies, in the last quarter of the nineteenth century cheap alternatives were sought for the expensive "genuine Peru Guano", which dominated the fertilizer market. As a substitute, artificial mixtures of penguin and seal feces of inferior quality were exported to the European market. Also in Germany, one worked with alternative fertilizers. Fish and fish wastes treated with sulfuric acid were dried and marketed in powdered form as “Helgoland fish Guano”. Also “Altona algae Guano” and appropriately treated whale waste were marketed as “whale Guano”. Particularly exotic was the processing of cockchafers to Guano for fertilization purposes [6].

3. Origin and structure of the deposits

As a result of the natural aging process, all Guanol deposits have a typical layer structure and a striking three-layered leveling [12].

The uppermost layer of the youngest deposit of Guano has a white or whitish-gray color, which becomes grayish yellowish brown with increasing thickness. It used to deliver the much appreciated white Guano (Huano blanco). The top layers are similar to fresh clay, of a tough, soft consistency. This top layer, which is most strongly influenced by the environmental influences, has a relatively low nitrogen content and high phosphorus content because it is permanently kept moist by spray from the sea surf and fog. As a result, a part of the N and P compounds dissolved and shipped to the middle layer.

The middle layer therefore has a high N content and fewer phosphate compounds. Since the N compounds are more soluble, nitrogen accumulation occurs in this low-phosphorus layer, causing significant yellowing of the middle layer. With increasing depth, this middle layer becomes darker and the yellowing becomes increasingly brownish. Since the water content in the Guano continuously decreases towards the bottom, the deposited mass in the middle layer becomes increasingly looser and more powdery.

The bottom layer contains only traces of nitrogen, which is liberated as volatile ammonia during the mineralization of organic compounds and accumulated again in the middle layer. As a result of this sequestration one third remains as low soluble, brownish colored tricalcium phosphate [23]. This lowermost layer is almost anhydrous and highly compacted and already shows typical rock character with crystalline fracture and is therefore quite difficult to process [15, 23, 24].

The chemical composition of Guanos is directly related to the abundance of protein and phosphate in seabirds. Depending on the location, depth and age of storage and climatic influences, the Guano has large differences and variations in its chemical composition. This is shown by the analysis data published in the nineteenth and twentieth centuries in the literature for Peru-Guano. It should be noted that these Guano analyzes are not horizon-oriented values, but the Guano ingredients are summarily summarized as a mixture of all three horizons described above.

The nitrogen occurs in Peru Guano predominantly in the ammonium oxalate and in the ammonium urea; wherein the ammonium as well as the oxalic acid are decomposition products of uric acid from the nitrogenous end product of the metabolism of the birds. A small part of the nitrogen (about 1%) still occurs in guanine, an organic nuclein base (DNA component). The phosphate is only slightly soluble in water, the insoluble remnant of Peru Guano consists of undecomposed uric acid and tricalcium phosphates.

Peruvian bird Guano contains 8–22% water, 42–70% organic matter, 3–11% lime (CaO), 6–13% phosphoric acid (P_2O_5), 11–17% N. In this young Guano, the nitrogenous compounds are gradually leached or volatilized, resulting in a slow, relative increase of the P content.

The higher quality varieties of the ancient, almost completely degraded Peru Guanos contained 20–30% easily absorbed calcium phosphate and 10–15% bound nitrogen, e.g. as uric acid and ammonium oxalate [18].

Stutzer (in [23]) mentions 11–16% nitrogen, 8–12% phosphate and 2–3% K_2O for Peru-Guano. According to [23] gives in **Table 3** the variation range of the composition of Peru Guano as follows:

Water soluble phosphate (% P_2O_5)	2.2–5.3
Citric acid soluble phosphate (% P_2O_5)	1.8–4.9
Total nitrogen (% N)	8.2–14.6
NH_4^+-N (% N)	1.9–7.2
NO_3^--N (% N)	0.05–0.1
N in organic substance	1.4 - 12.8
Potash (% K_2O)	2.0–4.3

Table 3. Range of nitrogen and phosphate in Peru Guano [23].

A summary analysis of Guano based on its individual substances is shown in **Table 4**.

Ammonium oxalate	17.7
Ammonium urate	12.2
Magnesium ammonium phosphate	11.7
Ammonium chloride	2.3
Ammonium phosphate	6.9
Ammonium carbonate	0.8
Ammonium humate	1.1
Calcium phosphate	20.2
Calcium oxalate	1.3
Calcium carbonate	1.7
Other organic substances (urea, guanin, parine, keratine, etc., p.p.)	8.3
Potassium sulfate	4.0
Sodium sulfate	4.9
Sodium chloride	0.4
"Miscellaneous" and water	6.7

Table 4. Chemical composition (%) of Peru-Guano to Stutzer [12, 23]. Compared to rock phosphates [49] Guanos have a much lower cadmium (Cd 0,2 - 2,0 ppm) and uranium (U 1 - 10 ppm) concentration.

Before the start of industrial agriculture and the associated exclusive use of artificial fertilizer only fertilization with concentrated nutrients (feces) was common. That changed only with the use of Peru Guano. Large differences in the nutrient contents of the individual shiploads, high water content, which made the application difficult, the volatility of the ammonium carbonate and the poor solubility of some of the phosphates, however, make it necessary to digest the Guano. For this purpose, the Guano was mixed with sulfuric acid at 22–25% of its weight and comminuted again after solidification. As a result, the tricalcium phosphate was converted into water-soluble monobasic phosphates in analogy to superphosphate production, and the volatile ammonium carbonate was converted into the stable ammonium sulfate. By mixing lots of different nutrient contents, a homogeneous product with 6% N, 12% P_2O_5 and 2% K_2O was produced. Today, however, the use of Guano as a raw material of the superphosphate industry due to the long regeneration times, the difficult mining conditions and the transport routes economically are non-sustainable.

4. Peru Guano: from the fields of the Incas to the fields of Europe

Archeological studies show that already at the beginning of Nazca culture in the period between the third and fifth centuries BC. Bird dung was used as a natural fertilizer on the west coast of South America. The first written description of the use of Guano by the Incas to fertilize crops was provided by Cieza de Leon in 1553 [12].

The fact that Guano degradation by the Incas was designed for sustainability in the mid-fifteenth century is already documented by the records of the Inca chronicler Garcilaso de la Vega in the work "Comentarios reales" from 1604 [25]. In order to ensure a constant renewal of the valuable manure, entry into the strictly guarded bird islands during the breeding season of the birds was prohibited under penalty of death. To protect the god of Guanos Huamancantac, the Incas deposited offerings on the Guano Island before each dismantling, including valuable silver objects [6].

Guano arrived in Europe for the first time around 1700 via Cadiz by the Spanish colonial rulers. However, only in very small quantities and without recognizing its value for fertilization [26, 27]. Of travelers who visited Peru at the beginning of the eighteenth century, Father Ludwig Feuillee, monk of the Order of Saint Francis of Paula (1714), Frezier (1713) and Ulloa (1740) mentioned the Guano in their travelogues. Feuillee describes for the first time an "excellent fertilizing effect," but lamented the "unfamiliar stench."

On the occasion of his research trip to America, the Prussian natural scientist Alexander von Humboldt became aware of Guano in 1802 in Lima, where it was used by the indigenous population to fertilize fields [28]. On his return in 1805, Humboldt brought a small amount of Guano to Europe and sent samples to Paris for chemical analysis to two of the most important chemists of his time: Antoine François Comte de Foucroy and Louis Nicolas Vauquelin. Both scientists identified uric acid in the sample, providing the first scientific proof that it was an animal excrement [25]. The English chemist and agricultural chemist Sir Humphry Davy also received samples and examined it. However, the Guano sample brought in by Humboldt was far from large enough to conduct field trials in order to proof its fertilizing effect [29].

The first successful field trials with Guano outside of South America took place in July 1808 on the island of St. Helena, at that time the East India Company and in the middle of the South Atlantic between Africa and South America by the Scottish military engineer and "experimental agriculturist" Alexander Beatson [29]. For his fertilization experiments on potato plants he used horse manure, pig manure and Guano, which he moved from neighboring Egg Island to St. Helena. Beatson examined the differences in the fertilizer effect of different fertilizers on the basis of crop yields in a study that was already very complex for the time [30].

However, these studies by Beatson as well as the findings of Humboldt and all previous rapporteurs, did not lead a widespread use of Guano as a fertilizer in Europe. This was mainly due to the fact that local conventionally produced manure and euphemistically referred to as "Night Soil" (latrine content) were still very cheap and readily available, while the cost of transport for Peru Guano were high and the transport logistics was complicated. The ship transport from Peru to Great Britain took at least 3–4 months. As a rule, about 8 months passed between the order and the arrival of the goods in an English port. Only after Peru was able to assert its independence from Spain in 1824 did the Peruvian government decide to establish Guano as an export product and sought ways to make it popular in Europe for centuries as well known in South America for its excellent fertilizing action. For this purpose one used the existing good contacts to British merchants, who were represented in all Spanish colonies in South America already starting from the eighteenth century. Guano samples were sent to the UK via these commercial agencies from the 1830s [31]. Thus, for the first time in 1826, a large amount of Guano was sent to England for initial field trials, but the attempts were unsuccessful [32]. Further field trials with Guano imported to England again in 1832 proved to be a failure, as it was not yet possible to estimate the correct dosage of this very concentrated fertilizer [25]. But not only in England, but also in France, the interest in the fertilizer from South America grew. The Guano once again came into the focus of public perception by the naturalist Alcide Dessalines d'Orbigny. In 1826 the famous French traveler and naturalist became aware of the exceptionally positive fertilizing effect of Guanos on his trip to South America [27] and later published his findings in Paris in his work Voyage dans l'Amérique Méridionale (1835).

A decisive turning point came in 1838 when two Franco-Spanish merchants sent samples of the Peru Guano to William Myers, a successful businessman from Liverpool, who was also interested in agriculture. The fertilization trials he has carried out with these samples must have been so successful that Myers invested in Guano trading and ordered a larger quantity for the first time. On July 23, 1839, 30 bags of Guano reached the port of Liverpool with the ship "Heroine" from Valparaiso, and Myers distributed the Guano to other interested farmers for experimental purposes [33].

Crop yields skyrocketed and the bird fertilizer proved to be far superior to the hitherto common manure and the "Night Soil" harvested from the city latrines. At the instigation of importer William Myers, his local Peruvian business partner and companion, Don Francisco Quirós, in Lima, signed a treaty with the Peruvian state on November 10, 1840, for the monopoly on all Guano mining. The demand for Guano rose rapidly in England and shortly thereafter in the rest of Europe. The Guano boom began [25].

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The handling of the fertilizer was initially getting used to and not without risk because of its corrosive properties. When the first Guano ships arrived in Southampton, “the stench was so miserable” wrote the English historian Frederick Pike, “that the entire urban population has fled to the nearby hills” [25].

The profit margins for the new fertilizer were very high. Quirós, Myers and their associates alone earned around £ 100,000 in the first large quantities of Guano supplies, which, according to current purchasing power, amounts to around €10 million [25]. As demand on the European mainland also increased strongly, not only the British ports but also Antwerp, Bordeaux and Hamburg developed into hubs for Guano trade. Due to high demand and tight supply, prices remained at a consistently high level.

Guano from Chile, Bolivia, Patagonia, Colombia and Mexico has now been exported to Europe as alternatives to Peru’s monopoly Guano, although it was lower in quality compared to Peru Guano. In 1843, the British discovered lucrative Guano deposits on the island of Ichaboe in Lüderitz Bay off the coast of what is now Namibia. The climatic and ecological conditions were just as advantageous there as on the Guano Islands off Peru and also the Guano was of equally good quality. Within just 15 months, the British mined about 300,000 tonnes of Guano [25].

In the following years, the export trade of the coveted nitrogen and phosphate fertilizer continued to boom. Main buyers for Guano were England, followed by France, Germany and Belgium [6].

5. Guano: a fertilizer with potential for conflict

The immense demand and the unconditional depletion led to conflicts. A point of contention was the rights and conditions in the Guano promotion. This eventually led to the so-called “First Guano War,” in which Spain fought against Peru and Chile between 1864 and 1866, followed by Bolivia and Ecuador. In April 1864, Spanish troops occupied the Chincha Islands to profit from the Guano mining. As a result of the armed conflict, most of Peruvian Guano exports collapsed and the Peruvian economy suffered severe damage [16].

Through reckless exploitation, as early as 1861, 376,667 tonnes of Peruvian Guano worth nearly US $ 17 million were loaded. Regardless of the breeding season of the seabirds, the mining yield continued to increase. As early as 1867, the first major deposits were exhausted. In 1870, 520,000 tonnes of Guano were exported to Germany alone [6]. The unchecked further progressive degradation had the result that the natural reserves in the Peruvian Guano islands were already almost completely exhausted in 1871. Since 1874, the Guano deposits on the Chincha Islands were completely degraded.

Unlike the Europeans, most notably the English trading houses, who had secured their Guano supplies early through long-term contracts, the United States noted that they had completely failed to safeguard their interests in the Guano. Nevertheless, to participate in coveted Guano, the US Congress passed the “American Guano Islands Act” in 1856, granting every citizen of the United States the right to seize every uninhabited and stateless island on which Guano was found as the property of the Guano Islands Declare USA. The discoverer himself thereby obtained the exclusive Guano-mining rights. Guano scouts found 94 islands with Guano deposits. The State Department found Guano mining profitable on 66 islands and declared it American owned. On 24 islands began a large Guano mining [25]. Much of the islands were later ceded again, but nine islands are still attributed today as "United States Minor Outlying Islands" the United States—inter alia the Johnston Atoll and the Midway Islands [34].

By the turn of the century, the Guano yield was already only 68,000 tons/year and by 1909/10 could be reduced from the Guano Islands even only 48,000 tons per year.

5.1. Insight and rescue at the last moment

The ever-waning Guano stocks eventually led the Peruvian government, with regard to its own agriculture, to quota Guano mining and enact laws to protect Guano birds. With the establishment of the "Compania Administradora del Guano (CAG)", the Guano Islands were placed under state administration from 1909 and strict protective regulations were issued [17]. The export of Peru Guano was initially completely stopped [35].

In order not to disturb the breeding season of the birds and to allow a regrowth of Guano, the Guano degradation was prohibited for half the year. Fishing around the Guano Islands has also been limited to ensure adequate food supplies for the birds. Protected areas were also established on the mainland, where the birds were safe from enemies. As a result of these protective measures, the amount of Guano has steadily increased over time [36]. The population of Guano-producing seabirds rose again in the following period from a few hundred thousand in 1909 to over 30 million in 1957 [37].

But the heyday of Guano production finally came to an end at the beginning of the twentieth century and was gradually replaced by the use of industrially produced fertilizers.

The Guano depletion in 1971 was therefore only one twentieth of the record income from the previous century. In addition to decreasing demand, there was also a reduced rate of Guano regeneration due to the flourishing anchovy fishery of the fishmeal industry, which challenged seabirds from the mid-twentieth century onwards. On the other hand, the population of Guano-producing seabirds was decimated by the recurrent natural disaster El Niño. The birds starved because the shoals of fish followed the plankton in the cold water under the atypically heated water surface. The surface water off the coast warmed up so much that the upper layer of water no longer mixed with the cool and nutrient-rich deep water. The El Niño phenomenon causes the nutrient-rich, cold water layers to shift to depths that are no longer accessible to Guano-producing seabirds [6].

In 1997, the Government of Peru, through the Ministerio de Agricultura for the protection of the Guano Islands and for the sustainable management of natural resources, launched the project "Proabonos" (Special Project to Promote the Use of fertilizers from Seabirds). This special program, anchored in the law, protects seabirds and preserves marine biodiversity. For example, 22 Guano islands and 11 coastal beaches / stretches along the Peruvian coast from Piura to Tacna, with a total area of 140.833 ha, are designated as a National Reserve System and are permanently under state control [38].

http://dx.doi.org/10.5772/intechopen.79501

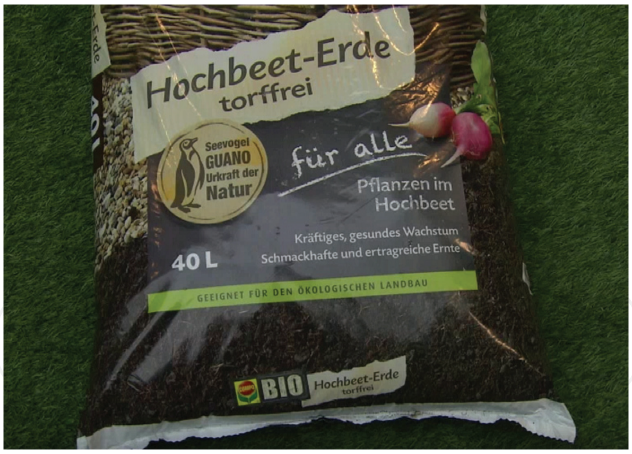

Figure 8. The Guano logo provides commodities with a glorious nimbus [42, 43].

The project "Proabonos" promotes ecologically compatible Guano mining and targeted Guano marketing at preferential prices to small farmers and indigenous peasant communities. These measures should contribute to a sustainable increase in agricultural yields as a contribution to overcoming poverty, taking into account ecological considerations. From 1986 to 2007, the state-owned Proabonos fertilizer Company harvested 342,637 t of Guano. Almost the same amount was harvested in Peru in 1861 within a year [29].

In 2008, the former Proabonos program became part of the National Agricultural Rural Development Program "AGRORURAL" [39]. Peru continued to lead the world in Guano production in 2010, with 30,000 tons per year [40].

Even though government subsidy programs are currently using most of the mined Guano in Peru's domestic agriculture, about 20% of Guano production is exported [41].

In 2008, the most important buyer country for Peru-Guano was Germany with 41% of the total export of Guano, followed by the USA (38%), Israel (9%), Italy (8%) and Spain with 4% [16].

Today the term GUANO alone rather than the amounts of bird crap added provides simple horticultural commodities like composts with a glorious but unspecific nimbus of superiority (**Figure 8**).

6. Guano extraction in Peru: working conditions like a hundred years ago

During the Guano boom, almost exclusively recruited Chinese human traffickers were employed in Guano production, working under slave-like conditions. Numbered is the use of 30,000 Chinese "coolies" on the Chinchainseln between 1835 and 1865 [44].

The work processes of the Guano harvest have not changed since the past until today. The entire mining is still done manually and without mechanical use, because to protect the environment and bird colonies, the Guano Islands are basically uninhabited and with the exception of canteen, office and sleeping barracks almost free of modern infrastructure.

Figure 9. Guano extraction on the Peruvian island Guañape Norte (photo © Tomás Munita).

The Guano extraction always takes place after the same dismantling steps. First, the raw Guano is swept out of the rock crevices or scraped together (**Figure 9**). Hard-baked Guano is loosened with pickaxes.

Harvested on all accessible areas, including on the sloping cliffs of the islands. In steep slopes, isohypses-parallel stone walls revolve around the islands to prevent rinsing during heavy rainfall (**Figure 10**).

The raw Guano obtained in this way is—to avoid confusion—shoveled into dark-colored sacks, which are carried by the workers to a sieve. There, the raw Guano is screened over a grid to remove contaminants such as carcasses, bones and feathers (**Figure 11**).

The overburden remaining on the gratings is dumped into the sea. The powdered sieved end product is shoveled into white plastic bags of 50 kg capacity printed with Probonas emblem. Since no heavy equipment can be used for transport on the Guanofelsen to protect the environment, the entire transport of the bags is also carried out by physical force. For loading, the sacks are usually transported to the edge of the cliffs and then transferred to ships with a simple cable pull (**Figure 12**).

Figure 10. Century-old isohypses-parallel stone walls for protection against ragging of the raw Guano (photo © Tomás Munita).

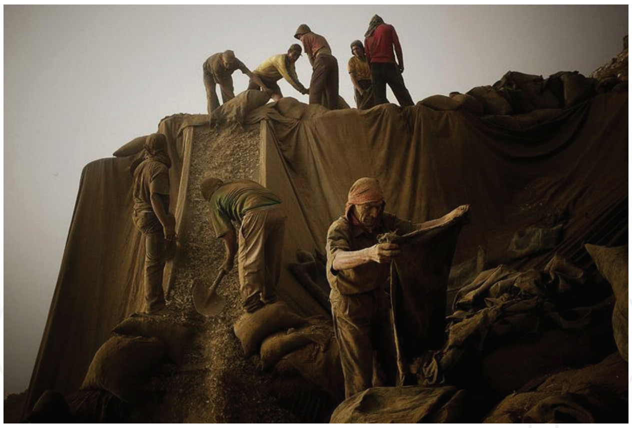

Figure 11. Sieving of the raw Guano (photo © Tomás Munita).

Figure 12. Loading the final product (photo © Tomás Munita).

Each worker shoulders 125 sacks per day—this corresponds to a total weight of 6.25 t. In order to be able to sustain this extremely strenuous work in the long run, the different working positions are occupied in rotation. Due to extreme climatic conditions, working hours usually start at 4 am and end at 12 noon to avoid high temperatures in the afternoon of more than 35°C. The usual working rhythm is 3 months without rest days.

Despite the physical strain and isolated working conditions far away from civilization, a job on the Guano Islands is very popular. With free accommodation and meals, workers in the Guano Islands earn almost double the statutory minimum wage in Peru at around € 325 a month.

Nevertheless, the work on the Guano Islands harbors health risks, in particular due to the ammonia contained in the bird droppings, which can lead to eye irritation and inhalation lead to lung acid burns. A high level of dust is produced by screening the raw Guano by means of gratings and then depositing the pulverulent end product. In addition, human pathogenic spores of feces-borne microorganisms may be present in Guanosium dust [16, 41, 45, 46].

Guano degradation on the islands is subject to strict state surveillance and regulation for sustainable protection of bird populations. Therefore, game guards live on some Guano islands throughout the year. During the breeding season of the birds a strict prohibition of removal applies. Guano degradation is followed by a 10- to 20-year regeneration phase. The decisive factor for their duration is the different Guano regeneration rate for each island, which depends on the bird species, surface and weather conditions. The Peru Cormorant, as one of the main producers, delivers an average of 43 g of feces per day—equivalent to a Guanomenge of 15.7 kg per year per bird [18, 25]. Knickmann [23] puts the annual growth rate at 180 kg/m^2.

7. Concluding remark

Currently, original Guano is given priority to the Peruvian rural population at preferential rates [47]. Only a very small proportion is exported. In Germany Guano comes in mixtures with other natural fertilizers such as horn and rock flour as flower and garden fertilizer in the trade. Mixture ratios are usually lacking in these Guano-refined fertilizers for hobby gardeners. The reference to the proportion of Guano emphasizes but effective its naturalness [48].

Although Guano has the advantage over artificial fertilizers that it works slower, but longer-term [41], it still has no significance as an industrial fertilizer. This is due to the long regeneration times and the associated low efficiency and the difficult mining conditions. If one considers that all Guano birds are exclusively fish eaters and they require almost 10 tons of fish for the production of about 1 ton of Guano, the use as fertilizer in agriculture alone would be ecologically questionable.

Industrial fishing for fishmeal production is the cause of overfishing in this marine area and deprives the seabirds of their food base. This competitive situation is intensified by the phenomenon "El Niño," which was formerly only episodic but now occurs almost regularly and increasingly as a result of intensifying climate change, which additionally limits the remaining fish stocks and also significantly reduces them further for a short time.

If even in a starving world, the transformation of high-quality fish protein over fish meal as animal feed in pork chops and chicken eggs is a morally questionable thing, how much more is the transformation of the fish protein on the bird stomachs to Guano and finally to European allotment garden cultures.

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