IntechOpen

Seabirds

Edited by Heimo Mikkola

SEABIRDS

Edited by **Heimo Mikkola**

Seabirds
http://dx.doi.org/10.5772/intechopen.71804
Edited by Heimo Mikkola

Contributors

Juan Arizaga, Muhammad Nawaz Rajpar, Ibrahim Ozdemir, Mohamed Zakaria, Shazia Sheryar, Abdul Rab, Juan Pablo Seco Pon, Sofía Copello, Germán García, Jesica Paz, Rocío Mariano-Jelicich, Gabriel Blanco, Marco Favero, José Luis Flaminio, María Paula Berón, Arie M. Rijke, Kirsten Stoeven, Ewald Schnug, Frank Jacobs, Heimo Juhani Mikkola

First published in London, United Kingdom, 2018 by IntechOpen
eBook (PDF) Published by IntechOpen, 2019
IntechOpen is the global imprint of INTECHOPEN LIMITED, registered in England and Wales, registration number: 11086078, The Shard, 25th floor, 32 London Bridge Street
London, SE19SG – United Kingdom
Printed in Croatia

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

Additional hard and PDF copies can be obtained from orders@intechopen.com

Seabirds
Edited by Heimo Mikkola

p. cm.

Print ISBN 978-1-78923-656-9

Online ISBN 978-1-78923-657-6

eBook (PDF) ISBN 978-1-83881-614-8

Meet the editor

Heimo Mikkola has a PhD in Applied Zoology and Limnology from the University of Kuopio, Finland. He attained his Adjunct Professor title in the same university 1988 but before that enjoyed a lengthy career at the UN/FAO, first as a fisheries expert and later as a resident representative in Asia, Africa, and South America. He utilized his ocean travels and deep-sea fishing trips to observe seabirds, first during his travels to Svalbard, Norway, in 1965 and later when international fisheries consultancies took him to more than 130 countries and all oceans of the world.

Contents

Preface

The list of seabirds is somewhat in a state of flux, but most authors agree to include the following bird families: albatrosses, auks/alcids, boobies/gannets, cormorants/shags, diving petrels, frigatebirds, fulmars, gadfly petrels, giant petrels, grebes, gulls, noddies, penguins, prions, shearwaters, skimmers, skuas/jaegers, storm petrels, terns, and tropic birds [1].

Since age of 11 I have been a keen birdwatcher and have utilized my ocean travels and deep-sea fishing trips to observe seabirds, first during my travels to Svalbard, Norway, in 1965 and later in Asia, Africa, and South America. Fisheries consultancies have taken me to all oceans of the world, including places like Colombia, Comoros, Cuba, Guam, Hawaii, Hong Kong, Indonesia, Seychelles, Singapore, Papua New Guinea, Philippines, Thailand, and Uruguay. Wherever there is fishing, there is bycatch—the incidental capture of non-target species such as marine mammals, dolphins, and seabirds.

Changes in seabird populations are good indicators of large-scale and long-term change in marine ecosystems because seabird populations are relatively well monitored. Unfortunately, their populations are strongly influenced by threats like entanglement in fishing gear at sea, overfishing of food sources by humans, plastic pollution, direct exploitation, and disturbance [2]. The monitored portion of the global seabird population has declined overall by 70% between 1950 and 2010 [2]. This study analyzed data on 162 species, representing one-fifth of the global seabird population. Some families, such as the terns, have suffered an almost 90% decrease in numbers over the last 70 years [2].

Often, we can read reports that climate change and disappearance of food sources have caused a catastrophic drop in seabird numbers. Since 2000 the number of puffins (*Fratercula arctica*) in Shetland has dropped from 33,000 to only 570, a trend that has also been observed in other species such as kittiwakes (*Rissa tridactyla*), fulmars (*Fulmarus glacialis*), and guillemots (*Uria aalge*) [3].

This book aims to win additional support for seabirds. It has six chapters presenting a wide variety of global seabird-related issues, from India to Svalbard, Norway. It also gives a comprehensive history of the use and chemical content of guano and certification schemes in fisheries for seabird conservation in Argentina.

I want to thank the Publishing Process Manager Romina Rovan for her time-consuming efforts to get all the authors to deliver their chapters after corrections. Without her active attitude, some important chapters would have been left out of the book.

Heimo Mikkola
University of Eastern Finland
Finland

References

[1] Cooper, J. Annotated List of the Seabirds of the World. www.oceanwanderers.com/Seabird.Home.html. Accessed 28 June 2018

[2] Paleczny, M., Hammill, E., Karpouzi, V. & Pauly, D. Population Trend of the World's Monitored Seabirds, 1950–2010. 2015. Plos One/DOI: 10.1371/journal.pone.0129342

[3] McKie, R. Eerie silence falls on Shetland cliffs that once echoed to seabirds' cries. Birds, The Observer, The Guardian, 3 June 2018

Chapter 1

Introductory Chapter: Seabird Occurrence in the Open Arctic Sea during the Breeding Season

Heimo Mikkola

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.78533

1. Introduction

I undertook my first long sea voyage between June 21 and July 1, 1965 from Tromsø, Norway, to Spitzbergen-Svalbard (only Spitzbergen used from now onward), and back. Tromsø city is 350 km north of the Arctic Circle [1] and the southern tip of Spitzbergen is 660 km from the North Cape [2]. Bear Island is halfway between Spitzbergen and the N-Norway [3]. My destination for a 1 week stay was Kapp Linné at the entrance of Isforden, the second largest fjord in Spitzbergen. It lies on the west side of the archipelago, which is about midway between Norway and the North Pole. Kapp Linné's coordinates are 78°03′44.7″ N and 13°37′04.0″ E and it is named after the Swedish botanist Carl von Linné [4]. This site used to be the location of Isfjord radio and weather station, which operated from 1933 until 1999 when it was automated and depopulated. During my visit, however, the station still had eight staff members who proved to be extremely helpful and knowledgeable concerning the birdlife and the polar bears. Nowadays, parts of Kapp Linné are a bird sanctuary, which may not be visited between May 15 and August 15.

2. Material and methods

During the slow steamboat trip, all seabirds that were sighted around the vessel were recorded during 15-minutes/each hours [5]. The bird count was mainly undertaken by myself but during my short breaks for rest and refreshments the observations were undertaken by four of my fellow birdwatchers: E. Kotanen, J. Salokoski, P. Susiluoto, and O. Toivonen. According to the captain, the average speed of the boat was 11 nautical miles/hour (NM = nautical mile = 1852 m), which was used to calculate the distances for the seabird observations (**Table 1**). To avoid any confusion, it is important to note that **Table 1** lists only birds within the 15-minute observation periods/hour during the sea trip from Tromsø to Kapp Linné in

Species	Coastal waters of Norway (only)	Norway coast and largest distance	Bear island waters and largest distance	Spitzbergen coast and largest distance	Total number recorded
Somateria mollissima		Yes	Yes	Yes	61
Alca torda	Yes	36	None	None	69
Stercorarius parasiticus		None	60	100	12
Larus argentatus		60	None	None	151
Larus marinus		50	65	None	5
Larus hyperboreus		None	22	35	11
Larus fuscus	Yes	None	None	None	Several
Larus canus	Yes	None	None	None	Several
Sterna paradisaea		Yes	None	None	Several
Uria aalge		Yes	Yes	None	44
Uria lomvia		None	Yes	Yes	122
Uria sp.		None	Yes	None	380
Cepphus grylle		Yes	Yes	More than before	50
Fratercula arctica		80	None	A few only	465
Fulmarus glacialis		30 First seen	Yes	Yes	300
Rissa tridactyla		Yes	Yes	Yes	312
Alle alle		None	33 After first seen	Yes	277

Table 1. Occurrence of seabirds on steamship trip from Tromsø, Norway to Kapp Linné, Spitzbergen June 21–24, 1965.

Spitzbergen. Seabird species seen in Kapp Linné during the last week of June 1965 are listed in **Table 2**.

3. Results by species

Common Eider (*Somateria mollissima*) occurred only in the coastal waters, the last five were seen 2 hours after passing Fugleøya just at the beginning of the open sea. Only once was a single male seen in the open sea near the ridged ice edge between Spitzbergen and Bear Island. Although common eider was not sighted more frequently from the ship, it is a very common breeding bird in Bear Island and Spitzbergen. In Kapp Linné alone I counted 163 pairs in a lagoon area and 168 pairs close to the Isfjord radio station.

Razorbill (*Alca torda*) occurs mainly in the coastal waters and was not seen further north than 4 hours from Fugleøya, and 33 NM from the Norwegian mainland.

Arctic Skua (*Stercorarius parasiticus*) is also called the **Parasitic Jaeger**. Like the previous species, it prefers coastal waters, but it was also sometimes spotted out on the open sea. Before

Species	Kapp Linné	Bird mountain	Bird island
Gavia stellata	2 pairs		2
Fulmarus glacialis	Over 30	50	
Clangula hyemalis	4–5 pairs		1 pair +1
Melanitta nigra	1 pair +1		
Somateria mollissima	340 pairs		76 pairs
Somateria spectabilis	12 pairs		18 pairs
Anser brachyrhynchus	10		
Branta bernicla	12		
Arenaria interpres	2 pairs		
Calidris maritima	Over 100	5	
Calidris alpina	10		
Phalaropus fulicarius	10	6	5
Stercorarius parasiticus	1 pair	3	1 pair
Stercorarius pomarinus		1 pair +1	
Larus hyperboreus	13	20	15
Rissa tridactyla	Over 50	Ca. 1000	
Sterna paradisaea	100		
Alle alle		Many	
Uria lomvia		Many	
Cepphus grylle	1		2
Fratercula arctica	1	2	

Table 2. Seabird records from Kapp Linné and nearby bird mountain and bird island, Spitzbergen from June 24–28, 1965.

arriving at Bear Island, single Arctic Skuas were spotted twice in the open sea some 60 NM from land, and individual birds were even noted some 100 NM from the land between Bear Island and Spitsbergen. Arctic Skuas occurred in all study sites in Spitzbergen (**Table 2**).

European Herring Gull (*Larus argentatus*) was following the ship until 60 NM from the Norwegian mainland but did not occur within Bear Island or Spitzbergen waters.

Great Black-backed Gull (*Larus marinus*) was not seen in the waters between Bear Island and Spitzbergen but some birds were following the ship until some 50 NM from the Norwegian coast and a single gull appeared behind the ship some 65 NM from Bear Island.

Glaucous Gull (*Larus hyperboreus*) clearly replaced the great black-backed gull within Bear Island and Spitzbergen waters but it did not follow the ship as eagerly. The first Glaucous Gull was noted 22 NM from the Bear Island and 35 NM from the Spitzbergen coastline. These distances seem to indicate that the species is not too fond of the open sea.

Lesser Black-backed Gull (*Larus fuscus*) and **Common Gull** (*Larus canus*) were following the ship only in the fjord area after leaving and before arriving at Tromsø harbor.

Arctic Tern (*Sterna paradisaea*) was only sighted once from the ship some 11 NM from Tromsø when still not in the open sea. It is a common breeding bird in Bear Island and Spitzbergen but obviously sticks mostly near the shoreline during the breeding season. They are obviously not attracted to passing ships in the same manner as the gulls.

Common Guillemot (*Uria aalge*) is also called the **Common Murre**. It occurred everywhere until Bear Island and was observed in each count period but was not sighted at all in Spitzbergen waters.

Brűnnich's Guillemot (*Uria lomvia*) is also named the **Thick-billed Murre**. It lives mainly in Spitzbergen waters and was sighted in each observation period.

Common or Brűnnich's Guillemot (*Uria sp.*) seemingly filled the waters near Bear Island. Within 30–60 NM out from the island small flocks appeared to be everywhere. Single unidentified guillemots were seen all around Bear Island during each observation period.

Black Guillemot (*Cepphus grylle*) is also named **Tystie**. It was constantly sighted during the whole trip and often in pairs, even in the open sea but was clearly more common in Spitzbergen coastal waters than the open sea.

Common Puffin (*Fratercula arctica*) is also called the **Atlantic Puffin**. It was seen often beyond 80 NM from the Norwegian coast but was not recorded in the Bear Island waters and only rarely sighted on the Spitsbergen coast. However, the species breeds commonly both on Bear Island and Spitzbergen.

Northern Fulmar (*Fulmarus glacialis*) was the only bird recorded within every counting period after reaching the open sea from the Norwegian coast. The first fulmars were sighted some 30 NM from the coast and after that between 1 and 30 birds were seen in every 15-minute period until landing at Kapp Linné, Spitzbergen.

Black-legged Kittiwake (*Rissa tridactyla*) like the previous species is one that was recorded in all except one hourly count during the trip. Copious numbers were recorded near Bear Island (up to 80 birds per count) and the influence of Bear Island already started to impact the numbers some 100 NM from the island. The largest number of kittiwakes, however, was recorded during the last hour count on the coast of Spitzbergen (100 birds).

Little Auk (*Alle alle*) is also called the **Dovekie**. It was observed only shortly after the leaving the Bear Island and Spitzbergen coastal waters where the species was clearly more numerous than before. Tens of the birds started to be seen 36 NM before the coast of Spitzbergen.

Table 2 shows 21 seabird species recorded in the Kapp Linné area. In Spitzbergen, there are no real birds of prey or owls as there are no small mammals for them to eat. It is obvious that Glaucous Gull and skuas replace predatory birds in Spitzbergen as they eat other seabird eggs and young.

http://dx.doi.org/10.5772/intechopen.78533

4. Discussion

Arctic open waters, far away from any land area, is preferred by only a few seabird species, such as guillemots, kittiwakes, and fulmars, which were observed practically everywhere during the trip. It is interesting that the most common open water seabirds were guillemots, which have the highest flight cost, for their body size, of any animal [6]. Brűnnich's Guillemot, Little Auk, and Glaucous Gull were only seen within Spitzbergen waters, while Common, Herring, great and lesser black-backed gulls and Razorbill occurred in the coastal waters of N-Norway.

Author details

Heimo Mikkola

Address all correspondence to: heimomikkola@yahoo.co.uk

University of Eastern Finland, Kuopio, Finland

Reference

[1] Wikipedia. Tromsø. 2018a, https://en.wikipedia.org/wiki/Tromsø. [Accessed May 10, 2018]

[2] Wikipedia. Svalbard. 2018b, https://en.wikipedia.org/wiki/Svalbard. [Accessed May 10, 2018]

[3] Wikipedia. Bear Island (Norway). 2018c, https://en.wikipedia.org/wiki/Bear_Island_(Norway). [Accessed May 10, 2018]

[4] Stange, R. Kapp Linne. 2013, https://spitsbergen-svalbard.com/spitsbergen information/settlements- and stations/kapp-linne.html. [Accessed May 10, 2018]

[5] Mikkola, H. Merilintujen esiintymisestä avomerellä pesimisaikaan. 1965, Molekyyli 22: 107-108

[6] Elliott KH, Ricklefs RE, Gaston AJ, Hatch SA, Speakman JR, Davoren GK. High flight costs and low dive costs support the biomechanical hyphothesis for flightlessness in penguins. Proceedings of the National Academy of Sciences of the United States of America. 2013; **110**(23):9380-9384. DOI: 10.1073/pnas.1304838110

Chapter 2

Feather Structure and Behavioral Patterns in Seabirds

Arie M. Rijke

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.77729

Abstract

The structural details of the flight and contour feathers of seabirds closely match the requirements of their habitats and feeding habits. They serve a variety of functions ranging from intraspecific signaling to such physical qualities as thermal insulation, water repellency and resistance to impact. It comes as no surprise, therefore, that they are composed of an array of elements that confer these qualities to the optimal benefit of their avian bearer. In this chapter, the physical bases for these functions are provided in both mathematical and evolutionary terms. Some functions excel at the expense of others, and many species have evolved an optimal balance between functions in terms of both feather microstructure and behavioral patterns that suit their specific habitat and feeding habits. The effects of mechanical forces on feathers are presented in terms of the impact of diving, plunging and alighting, and the structural properties in seabird feathers identifiable as adaptations to these forces. Finally, the way oiling affects the water repellency and resistance of feathers is discussed. It is concluded that the flight and contour feathers exhibit morphological and mechanical features that are advantageous for specific habitats and feeding techniques.

Keywords: seabirds, feather structure, behavioral patterns, water repellency, water resistance, feather adaptations

1. Introduction

Seabirds are part of a large group of families that have made their home at open oceans, shores and estuaries inhabiting many diverse marine environments. Most of them feed in salt water, taking their prey from the surface or catching it under water by swimming, plunging and deep diving. Others exploit the skies above pursuing their prey in an unobstructed three-dimensional space without ever alighting. Among them are families that have colonized the remotest parts of our earth and have adapted to the most extremes of climatic conditions.

Indeed, seabirds can be found foraging and often breeding at all latitudes. They can truly be said to have conquered the entire marine world.

Such widespread occurrence has exposed seabirds to a great variety of evolutionary forces that have shaped their anatomy and behavioral patterns to optimally suit their specific environment. In this chapter, we show how the feathers of seabirds, in particular the contour feathers, vary among families and exhibit a range of properties that function, among other things, to regulate body temperature, repel water, prevent water from penetrating to the skin and resist the impact forces of diving, plunging and alighting. Some of these functions excel in extreme environmental conditions or in relation to specific feeding techniques, frequently at the expense of other functions. Others represent a balance between two or more opposing functions. In consequence, many of these functions are expressed in an array of feather characters that confer these qualities to the optimal benefit of the avian bearer.

To study these functions in some detail, a closer look at the structural composition of feathers is in order. The morphology of feathers has been well described in the ornithological literature [1, 2] and is reproduced here only to the extent necessary for the purpose of this chapter. All feathers, whether flight or contour feathers, are composed of essentially the same elements, only their relative prominence is different. At the base of the spine (or rachis), we find the downy or plumulaceous feathers, only a tuft in flight and tail feathers, but extensively present alongside the proximal two-thirds of the rachis of contour feathers. These are thought to function as a means to regulate body temperature by entrapping air [3, 4]. More distally, they show a highly structured pattern with rami extending from the rachis in the plane of the feather, each sprouting barbules of which the distal ones have hooks that catch upon the curled proximal barbules of the barb next more distal. This continuous-looking, hook-and-flange arrangement provides this pennaceous part of the feather with the rigidity so critical for its mechanical properties. It also confers water repellency and resistance to water penetration to the body plumage.

In flight and tail feathers, the pennaceous part is by far the most dominant part, but in contour feathers, it occupies only the distal one-third of the length of the feather. The proximal two-third is made up of downy elements that work as structural reinforcements limiting the bending of the downy barbules. They may also function to catch other barbules and keep them from becoming entangled, thereby allowing the entrapment of more air and serve as a better thermal insulator [5]. Nodes in downy barbules, seen in some families including seabirds, may also contribute to a thick fluffy plumage resulting in even better thermal insulation [6]. Apart from conserving heat by air convection, feathers with downy texture also show adaptations for the conservation of body heat radiation emitted from the skin of all warm-blooded animals. Part of this radiation is absorbed by the feather keratin and, in turn, converted into convection heat and partially re-emitted from the keratin or lost to the surrounding environment [7].

Contour feathers are arranged in an overlapping fashion like shingles on a roof having their distal dorsal aspect exposed to air or water. It is at this interface that the physical interaction with the external world occurs and where adaptations to environmental factors can be found.

http://dx.doi.org/10.5772/intechopen.77729

2. Water repellency and resistance to water penetration

One of the major functions of feathers is to prevent water from reaching the skin or weighing down the remiges and tail feathers in flight. With very few exceptions, all birds benefit from a plumage that optimally repels and resists the penetration of water. However, the manner in which this optimum is realized for each seabird family is closely associated with its behavior and interaction with its habitat and, as a result, the feather characters responsible for water repellency and resistance vary accordingly. To understand the way, a water-repellent/resistant structure functions, certain aspects of surface physics should be made clear.

The water repellency of feathers and other biological porous structures, such as the stomatal apparatus of leaves and the spiracles of insects, is governed by the fundamental principles of surface physics that apply to *all* porous surfaces whether natural or manmade. It is determined by the relative areas of solid-water and air-water interface and their respective interfacial energies regardless of the actual architecture of the repellent structure itself [8]. If the surface of the solid is coated with another material, such as paint or preening oil, it will assume the properties of the coating material. For feathers coated with uropygial gland oil, the feather-water interface is, in fact, an interface between gland oil and water.

When a drop of water is placed on a smooth feather surface such as the rachis, it will pearl up and roll off easily. The surface is then said to be water repellent, the actual extent of which is determined by the contact angle θ, defined as the angle between the tangent to the curved water surface at the point of contact with the solid surface and the plane of the surface on which the drop is resting, measured through the water. When the drop is placed on the porous vane of the feather, it will entrap air in the hollows and interstices, forming additional air-water interfaces, which will cause considerable increase in the contact angle, according to

$$\cos\theta_a = f_1 \cos\theta - f_2 \tag{1}$$

where f_1 is the area of solid-water interface and f_2 is the area of the air-water interface per unit of apparent surface area. For water drops on barbs, f_1 and f_2 can be expressed as

$$f_1 = (\pi - \theta) r/(r + d) \tag{2a}$$

and

$$f_2 = 1 - r\sin\theta/(r + d) \tag{2b}$$

where $2r$ represents the diameter of the rami measured in the plane of the long axes of the rami separated by distance $2d$ [8, 9].

Note that the increase in apparent contact angle is ascertained only by the parameter $(r + d)/r$ and not by the separate values of r and d. Thus, θ_a for values of this parameter ranging between 2.4 (penguins, *Spheniscidae*) and 10 (land birds) would vary between about 126° and

154°, roughly correct by experimental verification [10]. These values are significantly higher than those attained for the most repellent of smooth surfaces which equal about 114° [9].

Eq. (1) has been derived solely from basic physicochemical principles without reference to parameters pertaining to any specific dimensions of the porous surface. In addition, the values of f_1 and f_2 are determined only by the areas of solid–liquid and air-liquid interface per unit of macroscopic surface areas without dictating the shape, curvature or configuration of these interfaces. Therefore, the relationship between the dimensions of a porous surface provided in terms of f_1 and f_2 and its ensuing contact angle as represented by Eq. (1) is a rigorous one, not an empirical one, and is of general validity. Eq. (1) has been tested experimentally and was found to be correct by Cassie and Baxter and Rijke using paraffinated stainless steel wire cages and grids [8, 11]. For these particular models, calculations for the values of f_1 and f_2 could be made according to Eqs. (2a) and (2b). Many other studies including recent ones have reported contact angle measurements on porous substrates including feathers and consistently confirmed the correctness of the above premises [9, 11–13].

In order to measure contact angles on smooth or porous surfaces correctly, certain experimental conditions have to be met, such as: the drop has to be small enough so as not to be perturbed by gravitational forces, but large enough to cover a representative area of the porous surface. The drop should be prevented from evaporation which would turn the advancing contact angle into a receding one. Feather specimens should be covered with fresh preening oil, not rinsed with an ethanol wash [12]. When these conditions are met, the correct contact angle is usually found to be within one degree error as observed by multiple authors [8, 11, 14–17]. These results have shown conclusively that contact angles can be reliably calculated from and represented by the dimensions of the porous surface alone.

An expression for the pressure (P), required to force water between the rami and barbules, can be derived from similar premises and reads

$$P = \gamma/r\left\{\cos\theta + \sqrt{[(r+d)/r]^2 - \sin^2\theta}\right\} \tag{3}$$

here, γ represents the surface tension of the water. This equation shows P to be inversely proportional to r and $(r + d)/r$. As a result, the requirement of relatively large values for $(r + d)/r$ to provide sufficient water repellency is opposed by the need for small values for this parameter to attain good resistance to water penetration. Thus, the structural characteristics compatible with optimal water repellency are, at least in part, in conflict with the requirements of resistance to water penetration. This conflict has important implications for seabirds, which must realize a balance between these two opposing functions to cope with their respective habitats and behavioral patterns as indeed they do [10].

Experimental data on water repellency and resistance to water penetration for Double-crested cormorants (*Phalacrocorax auritus*) and Anhingas (*Anhingidae*) have shown that results can be satisfactorily interpreted in terms of ramus diameter and spacing only without recourse to barbules. Their $(r + d)/r$ values for barbules are in the approximate range of 4.5–5.5 as found for almost all bird families regardless of their feeding habits or interaction with open water [10]. This suggests that the contribution of barbules to water resistance is real, but not based on the same mechanism as applies to rami. Barbules provide an interlocking mechanism by preventing the rami from separating under the increasing water pressure while increasing their own separation by their hooks sliding in the flanges, a process that can be verified under a low-powered light microscope. Similarly, water drops being repelled by the rami and not involving the barbules can be observed with a magnifying glass.

The contact angle θ of water drops on smooth feather surfaces, such as the rachis or on a microscopic slide covered with preening oil, measures about 90° as established by various authors [8, 9, 17]. The same value was found for water drops on polyethylene foil [14] and this is no coincidence: polyethylene almost exclusively consists of methylene groups ($-CH_2-$) which are the predominant chemical component of preening oil [18, 19].

Note that when θ is 90°, cosθ equals zero and sinθ equals one, which reduces Eq. (1) to $\cos\theta_a = -f_2$ and Eq. (2b) to $f_2 = 1 - r/(r + d)$. These fortuitous circumstances allow the investigator to determine the apparent contact angle from the value of $(r + d)/r$ alone. For instance, Cassie and Baxter [8] found $(r + d)/r$ for their duck feathers to be 5.9, which corresponds to a θ_a of 147° in good agreement with their experimental value of 150°. These results, corroborated by other workers [20], have shown that for feathers coated with fresh preening oil, both the water repellency in terms of the apparent contact angle θ_a and the balance between water repellency and resistance expressed by the value of $(r + d)/r$, can be correctly predicted from the micro-structure of the feather alone. Furthermore, the value of 5.9 for duck feathers, when compared with 4.8 for the White-breasted Cormorant (*Phalacrocorax carbo*) [21] and 7.1 for the European Starling (*Sturnus vulgaris*) [22], suggests that the duck, and probably all dabblers, are more water repellent than cormorants, but less so than starlings. On the other hand, cormorants show a superior resistance to water penetration, particularly when compared with starlings.

Measurements on more than 160 species of about 45 bird families [20, 21, 23–25] have shown that $(r + d)/r$ values vary from about 2.3 for penguins to about 6.5 for gulls (*Laridae*) and up to 10 for most terrestrial birds (**Table 1**). This range in values for this parameter suggests that each seabird family, and indeed each water bird family, has evolved a balance between water repellency and resistance to water penetration that suits its particular habitat and behavioral pattern.

The data on barb diameter, spacing, and $(r + d)/r$ values published in the peer-reviewed literature are far from a complete inventory of bird plumage, but on the basis of what is available, the following observations can been made and tentative conclusions reached.

First, the distal one-third of breast, abdominal, and back feathers shows the patterned structure that confers the water repellency and resistance to penetration. The proximal and medial parts show no such structure. The tail feathers and remiges, on the other hand, are structured over essentially the entire length of the feather and have values of $(r + d)/r$ that are generally small, which prevent these feathers from becoming waterlogged. Among water bird families, contour feathers vary more in values of $(r + d)/r$, which range from 2 to 10, than rectrices and remiges both of which vary little and range from 2 to 4 [20, 24, 26].

Second, within most families, the contour feathers that protect the skin from coming in contact with water have, on the whole, very similar values for $(r + d)/r$, exceptions seen only when

Family/species	$2r$ (μm)	$(r + d)/r$	Behavior/habitat
Penguins (*Spheniscidae*)	70	2.3	Swimmer/diver
Diving Petrel (*Pelecanoididae*)			Swimmer/diver
Common	42	5.0	
Cormorants (*Phalacrocoracidae*)			
Double-crested, White-breasted, Reed	~50	4.3–4.9	Wing-spreader/diver
Flightless	36	7.2	Wing-spreader/diver
Blue-eyed Shag	?	3.8	Wing-spreader in Chilean population
Darters (*Anhingidae*) African Darter	28	9.1	Wing-spreader/Under water stalker
Auks (*Alcidae*)	61	3.4	Swimmer/diver
Gannets (*Sulidae*)	50	3.8	Plunge-diver
Petrels (*Procellariidae*)	51	4.6	Surface feeder
Storm Petrels (*Hydrobatidae*)	~35	6.9–7.4	Swimmer
Pelicans (*Pelecanidae*)	~53	4.9–5.4	Swimmer
Brown Pelican	37	5.9	Surface feeder
Frigatebirds (*Fregatidae*)	54	5.7	Surface feeder
Gulls (*Laridae*)	~53	6.5–6.9	Occasional swimmer/Surface feeder
Skuas (*Stercorariidae*)	51	5.8	Occasional swimmer
Terns (*Sternidae*)	36	6.0	Surface feeder
Albatrosses (*Diomedeidae*)			
Yellow-nosed	61	4.3	Surface feeder/swimmer

Table 1. Summary of seabird families and species, barb diameter ($2r$) and $(r + d)/r$ values of contour feathers, habitat/behavior.

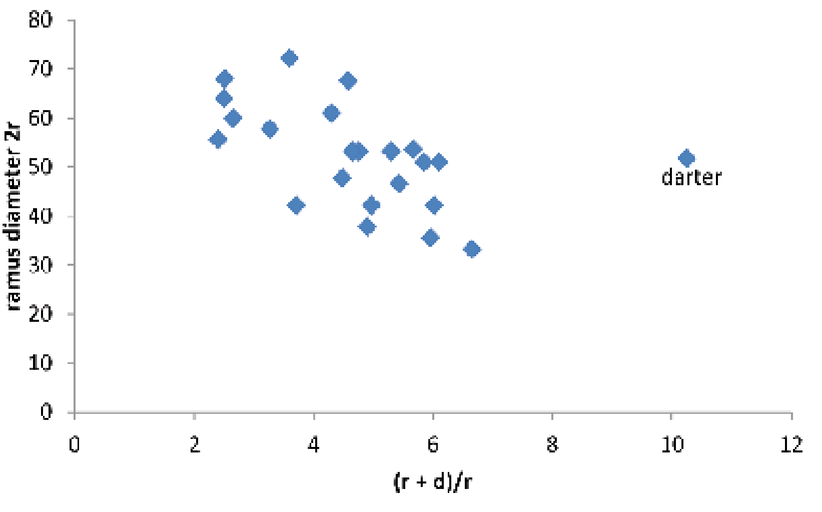

Figure 1. Plot of ramus diameter against wettability parameter $(r + d)/r$ for 23 species of seabirds showing barb width decreases with decreasing resistance to water penetration. The values for the darter, which benefits from water penetration, are shown for comparison.

a species within a family behaves differently from its relatives. A typical example is the Brown Pelican (*Pelecanus occidentalis*), which, unlike its congeners, dives for its prey from the air.

Third, these data sets on feather structure suggest a relationship between barb diameter $2r$ and $(r + d)/r$ values (**Figure 1**). Families such as the penguins and other diving water birds have wide barb diameters and small values for $(r + d)/r$, whereas the opposite holds true for terrestrial families such as the starlings and nightjars (*Caprimulgidae*). Birds that come into occasional contact with open water such as herons (*Ardeidae*) and gulls have intermediate values. Penguins have excellent resistance to water penetration but poor water repellency as shown by their 'wet' appearance when they exit the water. The breast feathers of terrestrial birds, on the other hand, are very water repellent but promise little in the way of resistance to water penetration. Those of herons and gulls fall somewhere in between.

3. Water repellency, water resistance and spread-wing postures

The first effort to correlate the value of the parameter $(r + d)/r$—that is, the balance between water repellency and resistance to water penetration—with behavioral patterns was made almost 50 years ago [27]. In that paper, the well-known habit of cormorants of spreading their wings to the sun or breeze after a period in the water, a feature commonly referred to as "wing-drying," was proposed to follow from the poor water repellency of their breast feathers, as evidenced by their low value for $(r + d)/r$ in comparison to that for the Mallard (*Anas platyrhynchos*) and presumably other dabblers that do not spread their wings. Only four species of cormorants and one species of anhinga had been examined with little attention paid to the important differences in the water-repellent structures between contour feathers and flight feathers. In addition, no systematic comparison was made with other water bird species that do not show spread-wing behavior, such as the penguins and divers (*Gaviidae*). In spite of these limitations, the conclusion that the poor water repellency of the cormorant's breast feathers is the proximate cause of its characteristic habit of wing-spreading has been generally accepted in the ornithological literature [2, 23, 28–39]. Since then, further studies on the "wing-drying" of cormorants have overwhelmingly supported the notion that its function is the drying of contour feathers and not thermoregulation, balancing, intraspecific signaling or an aid to swallowing fish [25]. However, the relation between the cormorant's feather structure, specifically its parameter $(r + d)/r$, and this behavior has remained elusive and has been criticized by Elowson [24]. However, the underlying issues have since been resolved in the light of new information that has become available since 1985. One of these issues was the necessity to select samples with only perfectly latched barbules with rami parallel. Damaged regions will yield values for $2d$ that are too large and, consequently, values for $(r + d)/r$ that are too large. Unfortunately, these inaccuracies in the $(r + d)/r$ values have introduced uncertainties large enough to negate a meaningful correlation between this parameter and species that do and do not wing-spread. It is still possible, though, to draw a number of conclusions if only uncontested data are considered and if more recent data recorded with modern imaging software are included.

Seabirds that regularly spread their wings include several species of cormorants, such as the Reed Cormorant (*P. africanus*), Bank Cormorant (*P. neglectus*), Cape Cormorant (*P. capensis*), White-breasted Cormorant and the Double-crested Cormorant, most of which have $(r + d)/r$ values for their contour feathers between 4.3 and 4.9 (**Table 1**). Families and species with parameters under about 4.2, such as the divers (4.0), gannets (*Sulidae*) (3.8), auks (*Alcidae*) (3.4), penguins (2.3) and the Antarctic Blue-eyed Shag (*P. atriceps*) (3.8) never show wing-spreading behavior. Pelicans (*Pelecanidae*) (4.9–5.4), including the Brown Pelican (5.9), do so only very occasionally, but all other water birds do not with the notable exception of the darters (10 to 11). Darters have contour feathers that promote water to penetrate to the skin in order to reduce their buoyancy [40, 41] so their very large $(r + d)/r$ value comes as no surprise. It is reasonable to assume that, with the exception of the darters, all water birds benefit from a plumage with good water repellency and equally good resistance to water penetration. However, as we have seen, the structural requirements for these two qualities are partly opposed, so it is to be expected that each family or species will have struck a balance that suits its specific demands of habitat and behavior. Spread-wing postures can then be explained as being part of a behavioral pattern in those birds that dive frequently and therefore require good resistance to water penetration, but this resistance comes at the expense of a measure of water repellency, which is compensated for by "wing-drying."

The question as to whether it is the wings or the body plumage that is being dried by wing spreading was raised by Sellers [25] and can be addressed by considering the difference in $(r + d)/r$ values between flight and contour feathers. Values for flight feathers, in particular the outer coverts, measure 2 to 4 for both water and terrestrial birds, and these are therefore well protected from becoming waterlogged. Those for contour feathers, on the other hand, show much difference between these two groups of birds, with those of water birds that spend much time in the water and dive frequently ranging from about 2 to 4 and those of terrestrial birds ranging from about 7 to 10. Other water birds, including cormorants, have values that fall somewhere in between (**Table 1**). Contour feathers with $(r + d)/r$ values higher than about 4 are at risk of becoming waterlogged, which suggests that it is the exposed contour feathers rather than the flight feathers that need drying in cormorants and in darters.

Apart from $(r + d)/r$ values, weather may also influence wing-spreading behavior. Cormorants reduce the extent to which their wings are spread with increasing wind speed, and at speeds of 4 on the Beaufort scale Sellers never saw birds to extend their wings more than about 50%. Wind speeds may also be the reason why spread-wing postures are unknown in the Antarctic populations of the Blue-eyed Shag [23], but common in birds of this species breeding in Chile [42]. The persistent strong winds at high latitudes may well be the cause for the absence of wing-spreading behavior in the Antarctic populations.

Other than wind speed, the relative temperatures of water and air may be a factor in wing-spreading. A case in point is the Flightless Cormorant (*P. harrisi*) of the Galapagos, which is known to spread its stubby wings after a dive in the cool waters of the archipelago and, in this respect, behaves no different from other cormorants. However, whereas most other cormorants have contour feather with barb diameters between 48 and 54 μm and $(r + d)/r$ values between 4.3 and 4.9, those for the Flightless Cormorant are 31–41 μm and 7.1–7.4, respectively

[21]. These numbers suggest that the Flightless Cormorant suffers a measure of water penetration through the barbs of its contour feathers, a feature that is more reminiscent of darters than of cormorants. As with darters, increased water penetration is thought to assist the underwater bottom-feeding habits of *P. harrisi* for which too much buoyancy would prove to be a disadvantage. Simple calculations appear to support this notion: the pressure that a surface-swimming Flightless Cormorant exerts on the water ranges between 630 and 780 N m^{-2}, whereas only 550–590 N m^{-2} pressure is required to force water between the barbs [43, 44]. For other cormorants, the maximum weight for no water penetration between the barbs lies well above the bird's weight range [20]. So, unlike those of other cormorants, the Flightless Cormorant's contour feathers are waterlogged after a dive in cold water, but the bird can then proceed to dry its plumage in the warm tropical breezes on the lava rocks, an advantage denied to cormorants inhabiting high latitudes.

4. Water repellency, water resistance, and other behavioral patterns

In the previous section, we attributed the occurrence or absence of spread-wing postures to the need for a balance between water repellency and resistance as reflected in the value of the parameter $(r + d)/r$. Therefore, it is to be expected that other behavioral patterns, directly or indirectly, relate to this parameter in a similar manner.

As an example of the relationship between $2r$, $(r + d)/r$, and behavioral pattern, gannets, cormorants, and shearwaters (*Procellariidae*) all have about the same barb diameter (50–51 μm), but gannets have a value for $(r + d)/r$ of 3.8, which lies at the low end of the range (3.8–4.9), indicating a greater resistance to water penetration. This may well be an adaptation to the gannet's habit of diving from the air (with associated high pressure at impact) and then pursuing prey under water, as seen in the 1998 BBC documentary *The Life of Birds.* Brown Pelicans also dive from the air, but unlike gannets do not pursue their prey under water. Their breast feathers have smaller barb diameters and higher $(r + d)/r$ values than those of gannets, producing an increased water repellency. American White Pelicans (*Pelecanus erythrorhynchos*), on the other hand, find their prey while swimming on the surface and have smaller values for $(r + d)/r$. Apparently, plunge-divers and birds that swim underwater benefit mostly from an increased resistance to water penetration, whereas surface feeders, such as the Brown Pelican, gulls and storm petrels (*Hydrobatidae*), profit from an increased water repellency (**Table 1**). Similar findings were recorded for the five species of Dippers (*Cinclidae*), which among them show a slightly different water repellency and resistance in their contour feathers as an adaptation to their different feeding habits and river habitats [22]. Certain species of cranes (*Gruidae*) and rails (*Rallidae*) can also be regarded as having attained structural characters in their plumage that relate to their specific interaction with their watery feeding grounds [44–46].

It is likely that many more examples of contour feather structure correlating with specific behavior/habitat will be found once more data have been gathered. However, the abovementioned examples suffice to suggest that each feather substructure represents an evolutionary adaptation to a specific set of behavioral patterns and habitat conditions. It should be borne in mind that feather structure relates in the first place to behavior and habitat and secondarily to family identity and then only to the extent that family members behave in essentially the same way and inhabit similar habitats. As we have shown, congeners with different behavior/habitat patterns show a correspondingly different value for the structural parameter. That this behavior difference occurs in conjunction with a structural difference supports the existence of a correlation between feather structure and the habitat and behavior of its avian bearer.

5. Do seabird feathers show adaptations to the impact forces of diving, plunging and alighting?

Unlike terrestrial birds, seabirds and other birds that have access to open water physically interact with water at the interface between feather coat and water. Water is about 800 times denser than air and, as a result, the impact forces of diving, plunging and alighting are so much more severe than when operating in air. Therefore, it is no surprise that seabird feathers are composed of stiffer elements to cope with these conditions. However, since each family interacts with water in its own specific way, variations in feather stiffness among families are to be expected for this reason alone.

All feathers are built from beta-keratin the elastic modulus of which is an inherent property of the keratin material itself. However, the actual stiffness of the various feather elements, rachis, rami and barbules, is determined by the respective shapes and sizes of these elements. The mechanical forces involved in diving, plunging and alighting are not accessible to direct measurement in any reliable or representative way. Any such data would not be meaningfully correlated to the resulting yield or flexure of barbs and vanes during forceful interaction with water. However, the bending and flexing of materials of different shapes and sizes have been well described in engineering physics and it is from these considerations that a number of conclusions can be drawn.

When a force F is applied over the length of a single barb, the barb will bend in the direction of the applied force with its tip flexing over a distance S. This relates to the barb length l and barb radius r as

$$S = F \cdot l^3 / 2\pi \cdot r^4 \cdot E \tag{4}$$

where E stands for the Young's elastic modulus of the feather keratin. When the force is applied to the vane, the flexural displacement of the tips of the vane per repeating unit $2(r + d)$ can be written as

$$S_v = F_v . l^3 \cdot 2(r + d) / 2\pi \cdot r^4 \cdot E \tag{5}$$

where the subscript v refers to the repeating unit of the vane. Rearrangement of Eq. (5) then yields

$$\pi.E.S_v/F_v = (l/r)^3 \cdot (r + d)/r \tag{5a}$$

Apart from π and the elastic modulus E, the left-hand side of Eq. (5a) represents the extent of flexing of the tips of barbs per unit of force applied over the lengths of the barbs and measured over a distance $2(r + d)$. For the bending of the entire vane, F_v needs to be considered for the number of repeating units per vane. Note that the right-hand side of the equation is made up of the feather variables l, r and d, which, unlike S_v and F_v, are easily and directly accessible to measurement. These considerations allow us to semi-quantitatively predict the bending of the vane under an applied force from the dimensions and spacing of the barbs alone.

The role of the barbules in resisting bending of the vane has been considered in the light of their primary function, that is, keeping the barbs from separating under an applied force and doing so by their hooks sliding in the flanges of the barbule next more distal. Therefore, as well as for their small size, they are assumed to make only a minimal, if any, contribution to the overall resistance to bending.

To test the above premises, the contour feathers of 23 species belonging to 15 families of seabirds were examined (**Table 1**). The values for r and d of these contour feathers had been measured for the purpose of a 1970 study using a transmission light microscope equipped with a calibrated scale ocular. However, there is no reason to suspect the accuracy and precision of these data to be anything less than of those collected with electronic imaging techniques such as used in more recent studies [22, 47]. Values for l of the closed pennaceous portion of the contour feather were measured at the mid-part of the vane to the nearest half millimeter using a traveling microscope. At least three feather specimens of each species were examined.

Apart from feather stiffness, the resistance to impact forces is also determined by the extent of contour feather overlap and body feather density. To estimate the former, the length of the rachis L_f was measured to the nearest millimeter. The extent of overlapping can be approximated by the product of L_f and the square root of the number of feathers per surface area. To estimate the latter, we made use of the data on number of feathers and body weights as reported by several authors [48–54]. By fitting a second-order polynomial to these data, an estimate of the number of contour feathers as a function of the mass of the bird could be obtained. For the relationship between body surface area and body mass, expressions proposed by Perez et al. [55] and by Mitchell [56] were used to estimate surface area as a function of body weight. Combining the results of these two sets of calculations, contour feather densities expressed in number of feathers per surface area were found to be about 100,000 to 150,000 per m^2 for seabirds weighing less than 1.2 kg for all families studied. This number increases with weight to 200,000/m^2 at about 7 kg. The extent of feather overlaps, according to these calculations, yields about 10–15 feathers in a stack for families in the lower weight range with twice that number for heavier birds. Apparently, feather overlapping is the same for seabirds in the lower weight range regardless of family identity and, as a result, the restriction that stacking provides to bending is also the same. Only for birds weighing more than 1.2 kg do we find an increase in feather density and overlap with weight up to 250,000 per m^2

Cat.	Description	Stiffness parameter range l/r	Deflection parameter (avg.) $(l/r)^3\,(r + d)/r$ (10^6)	Standard deviation (10^6)
1	**Deep divers**	59–108	1.6	0.92
	Dive/pursue prey under water			59%
	Penguins			
2	**Swim and dive**	188–237	49	24.5
	Pursue prey under water, extended time swimmers			50%
	Common diving petrel, cormorants			
3	**True plungers**	301–381	194	71
	Petrels, gannets, auks,			37%
4	**Large surface feeders**	377–410	387	14
	Pelicans, frigatebirds, skimmers			4%
5	**Shorebirds**	539–1009	839	260
	Skuas, gulls, terns			31%
6	**Large birds of open ocean**	689	1403	—
	Yellow-nosed albatross			

Table 2. Stiffness and deflection parameters for six seabird categories.

and stacks of 18 for a pink-backed Pelican (*P. rufescens*) weighing 9.6 kg. This is in line with expectation as impact forces are directly proportional to mass [57].

The above findings may be explained by any of two or both possibilities: (1) the feather density and number of feathers in a stack for the lower-weight families are sufficiently large to prevent feather bending regardless of behavioral pattern and (2) barb stiffness and resistance to water penetration of the contour feathers of each of these families are large enough to prevent water from reaching the skin on their own account and do not benefit from a further increase in feather density or stacking. Other than preventing water from reaching the skin, thermoregulatory adaptations can also be expected to affect feather density. Lowe [53] counted 48/cm^2 on a young Gentoo penguin (*Pygoscelis papua*).

According to Eq. (5a), the bending of the vane of a contour feather under the impact of forces associated with diving or landing on water surfaces consists of two factors: (1) the ratio of the length to the thickness of the barbs expressed as l/r and (2) the wettability parameter $(r + d)/r$. The first factor indicates that short and thick barbs make the vane stiff resisting bending, whereas long and thin barbs favor flexibility that promotes bending. The appearance of the wettability parameter in the equation shows that feathers resistant to water penetration also help prevent their bending, whereas highly water repellent feathers do not. Note that l/r enters the equation in the form of a third power which markedly enhances its contribution in the equation and dwarfs that of the other factor: over its range of 2.5 to about 7, $(r + d)/r$ increases by only a factor of 3, whereas $(l/r)^3$ does so by about three orders of magnitude.

http://dx.doi.org/10.5772/intechopen.77729

The *l*/*r* values for the 15 families of the 23 seabird species have been assorted into six more or less distinct ranges listed in **Table 2** as categories. As shown, 'deep divers,' represented here by four species of penguins and characterized by their habit of diving and pursuing prey under water, fall in the lowest range (59–108) and therefore have the highest vane stiffness. The next range is made up of birds that 'swim and dive' in pursuit of their prey and spend much time in and on the water. This range includes the Common Diving Petrel (*Pelecanoididae*) with an *l*/*r* value of 237 and the cormorants (188). Category 3 covers the range 301–381, into which fit the 'true plungers' such as petrels (*Procellariidae*), gannets and auks. Large surface feeders, such as pelicans, frigatebirds (*Fregatidae*) and skimmers (*Rhynchopidae*), form the next category with a range of 377–410. Category 5, the 'shore birds,' includes skuas (*Stercorariidae*), gulls, and terns (*Sternidae*) that have the lowest vane stiffness with a range of 450–550. These birds are not extended time swimmers, do not pursue their prey under water and spend much time in flight or on shore. Albatrosses (689) are mostly airborne and alight only to take food from the surface or slightly below. In this respect, they behave much like category 5 families. Not listed are the Flightless Cormorant in category 2 and the Brown Pelican in category 4, because, as mentioned above, these species behave in a different way from their congeners, a feature expressed in the dimensions of their feather structure (**Table 1**).

The large differences in contour feather stiffness for the six categories of seabirds are borne out by a wide range in deflection parameter $(l/r)^3 \cdot (r + d)/r$. Averaged for each category, this parameter runs from 1.6×10^6 for penguins in category 1 to 1403×10^6 for albatrosses in category 6. By averaging the deflection parameters for each category, a large 'standard deviation' is introduced, but since the range of parameter values is very large, this does not affect the conclusions.

From these data, it can be concluded that the contour feathers of penguins, the most aquatic of families, are about 30 times stiffer than those of diving petrels and cormorants, and 120 times more so than those of plungers like gannets. Similarly, penguin feathers are 250 times more resistant to bending than those of surface feeders like pelicans, over 500 times more so than those of shorebirds such as skuas, gulls and terns and almost three orders of magnitude stiffer than albatross feathers. These large differences are directly related to feeding habits and interaction with water. Penguins find their prey exclusively under water and dive to great depths to catch it. Diving petrels and cormorants also dive, but spend more time on the surface and in the air. Plungers dive from the air with associated high pressure on impact, but catch their prey at lesser depths. Surface feeders do not dive and do not pursue their prey under water (brown pelicans dive from the air, but do not pursue under water). Shore birds feed from the water surface and are not extended time swimmers. Albatrosses, one of the most aerial of seabirds, alight only to feed from the surface and may occasionally dive at feeding frenzies.

5.1. The following pattern of feather structure in relation to feeding habits/behavior emerges

Barb width and spacing determine the relative water repellency and resistance to water penetration of feathers. Diving birds, and in particular deep diving birds, benefit from a mostly water resistant plumage with little in the way of water repellency. Less aquatic families, such as gannets and to a greater extent cormorants, show more repellency, but at the expense of some of their water resistance. Some cormorants compensate for this by their habit of wing spreading. Swimming and hovering birds that catch their prey from the surface, shore birds and those operating mostly in the skies show a predominantly water repellent plumage.

The length and diameter of the rami of contour feathers vary widely among seabirds. Barb stiffness varies with barb length and width and is the largest for deep diving birds, less so plungers and very much less so for surface feeders ranging over three orders of magnitude. These structural differences in the feather plumage are believed to represent evolutionary adaptations to feeding habits and, in some cases, environmental conditions.

One of the greatest threats to the lives of seabirds is oil spills. In spite of heroic rescue operations, it is clear that the vast majority of seabirds perish at sea. In the context of this chapter, it may be useful to consider the potential role of the feather micro-structure in the demise of the victim. All components of petroleum, including the residues, are inherently hydrophobic and as such could be considered water repellent and perhaps even helpful in shedding water from the feather coat. However, it is the fine microstructure with its regular array of parallel rami and barbules latched together that is destroyed by the stickiness of the oil residues. This renders the resistance to water penetration nil, allowing seawater to reach the skin with the bird exposed to hypothermia. This mechanism is somewhat analogous to the infamous experiment in which the uropygial gland of ducks was extirpated whereupon the feathers did not so much lose their water repellency as their water resistance as a result of brittleness and lack of coherence [58]. Bird rescuers have long realized that removing the oil is only the first step in the recovery of the victim to be followed by restoration of the normal feather microstructure. This is eventually achieved by the bird's preening habits if the oil gland is functional, a very time-consuming process.

Author details

Arie M. Rijke

Address all correspondence to: amr@virginia.edu

University of Virginia, Charlottesville, Virginia, USA

References

[1] Thomson LA. A New Dictionary of Birds. London: Nelson; 1964

[2] Stettenheim PR. The integument of birds. In: Farner DS, King JR, editors. Avian Biology. Vol. 2. New York: Academic Press; 1972. pp. 1-63

[3] King JR, Farner DS. Energy metabolism, thermoregulation and body temperature. In: Marchall AJ, editor. Biology and Comparative Physiology of Birds. New York and London: Academic Press; 1961. pp. 215-288

[4] Lucas AM, Stettenheim PR. Avian Anatomy. Integument. Agricultural Handbook 362. Washington: US Dept. Agr., DC; 1972

[5] Stettenheim PR. The integumentary morphology of modern birds – An overview. American Zoologist. 2000;**40**:461-477

[6] Lei FM, Qu YH, Gan YL, Kaiser M. The feather microstructure of passerine sparrows in China. Journal für Ornithologie. 2002;**143**:205-213

[7] Dove CJ, Rijke AM, Wang X, Andrews LS. Infrared analysis of contour feathers. The conservation of body heat radiation in birds. Journal of Thermal Biology. 2007;**32**:42-46

[8] Cassie ABD, Baxter S. Wettability of porous surfaces. Transactions of the Faraday Society. 1944;**40**:546-551

[9] Moilliet JL, editor. Water Proofing and Water Repellency. New York: Elsevier; 1963

[10] Rijke AM, Jesser WA. The water penetration and repellency of feathers revisited. The Condor. 2011;**133**:245-254

[11] Rijke AM. The liquid repellency of a number of fluoro-chemical finished cotton fabrics. Journal of Colloid Science. 1965;**20**:205-216

[12] Bormashenko E, Bormashenko Y, Stein T, Whyman G, Bormashenko E. Why do pigeon feathers repel water? Hydrophobicity of Pennae, Cassie-Baxter wetting hypothesis and Cassie-Wenzel capillarity-induced wetting transition. Journal of Colloid and Interface Science. 2007;**311**(1):212-216

[13] Ma M, Hill RM. Superhydrophobic surfaces. Current Opinion in Colloid & Interface Science. 2006;**11**:193-202

[14] Adam NK, Elliot GEP. Contact angles of water against saturated hydrocarbons. Journal of the Chemical Society. 1962;**424**:2206-2209

[15] Shafrin EG, Zisman WA. The spreading of liquids on low-energy surfaces IV: Monolayer coatings on platinum. Journal of Colloid Science. 1952;**7**:166-177

[16] Shafrin EG, Zisman WA. The adsorption on platinum and wettability of monolayers of terminally fluorinated octadecyl derivatives. Journal of Physical Chemistry. 1957;**61**:1046-1053

[17] Rijke AM, Jesser WA, Mahoney SA. Plumage wettability of the African darter (*Anhinga melanogaster*) compared with the double-crested cormorant (*Phalacrocorax auritus)*. Ostrich. 1989;**60**:128-132

[18] Elder WH. The oil gland of birds. Wilson Bulletin. 1954;**66**:6-31

[19] Odham G, Stenhagen E. On the chemistry of preen gland waxes of water fowl. Accounts of Chemical Research. 1971;**4**:21-128

[20] Rijke AM. Wettability and phylogenetic development of feather structure in water birds. Journal of Experimental Biology. 1970;**52**:469-479

[21] Rijke AM, Burger EH. Wettability of feathers and behavioural patterns in water birds. Proceedings of the Pan-African Ornithological Congress. 1985;**6**:153-158

[22] Rijke AM, Jesser WA. The feather structure of dippers: Water repellency and resistance to water penetration. Wilson Journal of Ornithology. 2010;**122**:563-568

[23] Bernstein NP, Mason SJ. Absence of wing-spreading behavior in the Antarctic blue-eyed shag (*Phalacrocorax atriceps bransfieldensis*). The Auk. 1982;**99**:588-589

[24] Elowson AM. Spread-wing postures and the water repellency of feathers: A test of Rijke's hypothesis. The Auk. 1984;**101**:371-383

[25] Sellers RM. Wing-spreading behaviour of the cormorant, *Phalacrocorax carbo*. Ardea. 1995; **83**:27-36

[26] Mahoney SA. Plumage wettability of aquatic birds. The Auk. 1984;**101**:181-185

[27] Rijke AM. The water repellency and feather structure of cormorants, Phalacrocoracidae. Journal of Experimental Biology. 1968;**48**:185-189

[28] Clark GA. Spread-wing postures in Pelecaniformes, Ciconiiformes, and Falconiformes. The Auk. 1969;**86**:136-139

[29] Kennedy RJ. Directional water-shedding properties of feathers. Nature. 1970;**227**:736-737

[30] Kennedy RJ. Preen gland weights. Ibis. 1971;**113**:369-372

[31] Kahl MP. Spread-wing postures and their possible function in the Ciconiidae. The Auk. 1971;**88**:715-722

[32] George WC, Casler CL. Subalular apterium in birds. The Auk. 1972;**89**:245-262

[33] Stettenheim PR. Structural adaptations in feathers. Proceedings of the International Ornithological Congress. 1976;**16**:385-401

[34] Siegfried WA, Williams AJ, Frost PGH, Kinahan JB. Plumage and ecology of cormorants. Zoologica Africana. 1975;**10**:183-192

[35] Rhijn JG van. Processes in feathers caused by bathing in water. Ardea. 1977;**65**:126-147

[36] Schreiber RW. Maintenance behavior and communication in the Brown Pelican. Ornithological Monographs. 1977;(22):1-78

[37] Jones PJ. A possible function of the "wing-drying" posture in the reed cormorant *Phalacrocorax africanus*. Ibis. 1978;**120**:540-542

[38] Winkler H von. Das Flugelspreitverhalten der Mohrenscharbe, *Phalacrocorax niger.* Journal für Ornithologie. 1983;**124**:177-186

[39] Hennemann WW. Energetics and spread-winged behavior of Anhingas in Florida. Condor. 1982;**84**:91-96

[40] Owry OT. Adaptations for locomotion and feeding in the Anhinga and double-crested cormorant. Ornithological Monographs. 1967;(6):60-63

[41] Mahoney SA. Some aspects of the thermal physiology of Anhingas (*Anhinga anhinga*) and Double-crested Cormorants (*Phalacrocorax auritus*). In: Cooper J, editor. Proceedings

of the Symposium on Birds of the Sea and Shore, 1979. Cape Town: African Seabird Group; 1981. pp. 461-470

[42] Rasmussen PC, Humphrey PS. Wing-spreading in Chilean blue-eyed shags (*Phalacrocorax atriceps*). Wilson Bulletin. 1988;**100**:140-144

[43] Brudis J, Bass F. Report to the Charles Darwin Research Station, Santa Cruz, Galapagos. Punta Espinosa, Fernandina Island: Field work; Oct 25–Nov 8; 1979

[44] Rijke AM. Wettability and Feather Structure of Endemic Galapagos Water Birds. Puerto Ayora, Santa Cruz Island, Galapagos, Ecuador: Report to the Charles Darwin Research Station; 1986

[45] Tarboton WR. The Complete Book of Southern African Birds. Cape Town: Struik Winchester; 1990

[46] Rijke AM, Jesser WA. Plumage wettability of African cranes. Proceedings of the Pan-African Ornithological Congress. 1993;**8**:533-537

[47] Rijke AM, Jesser WA, Schaal SFK. Can the substructure of fossil feathers provide taxonomic information? Journal of Ornithology. 2013;**154**(3):663-667

[48] Wetmore A. The number of contour feathers in passeriform and related birds. The Auk. 1936;**53**:159-169

[49] Hutt FB, Ball L. Number of feathers and body size in passerine birds. The Auk. 1938;**55**:651-657

[50] Dwight J. The sequence of plumages and moults of the passerine birds of New York. Annals of the New York Academy of Sciences. 1900;**13**:118-119

[51] McGregor RC. Cited in: Wetmore A. The number of contour feathers in passeriform and related birds. The Auk. 1936;**53**:159-169

[52] Knappen P. Number of feathers on a duck. The Auk. 1932;**49**:461

[53] Lowe PR. 1933. Cited in: Wetmore A. The number of contour feathers in passeriform and related birds. The Auk. 1936;**53**:159-169

[54] Kuhn O, Hesse R. Die postembryonale Pterylose bei Taubenrassen verschiedener grosse. Z Morphol Oekol Tiere. 1957;**45**:616-655

[55] Perez CR, Moye JK, Pritsos CA. Estimating the surface area of birds: Using the homing pigeon (*Columba livia*) as a model. Biology Open. 2014;**3**:486-488

[56] Mitchell HH. The surface area of single comb white leghorn chickens. The Journal of Nutrition. 1930;**2**:443-449

[57] Rijke AM, Jesser WA. Contour feathers of water birds. How do they resist the impact forces of diving, plunging and alighting? Poster presented at 14 PAOC, Dakar, Senegal. 16-21 October, 2016

[58] Hou HC. Studies on the glandula uropygialis of birds. Chinese Journal of Physiology. 1928;**2**:345-378

Chapter 3

Certification Schemes in Argentine Fisheries: Opportunities and Challenges for Seabird Conservation

Juan Pablo Seco Pon, Jesica A. Paz,
Rocío Mariano-Jelicich, Germán García,
Sofía Copello, María P. Berón, Gabriel Blanco,
José Luis Flaminio and Marco Favero

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.74784

Abstract

In Argentina, one major factor playing a significant role in the implementation of better fishing practices is related to the advent of the *Marine Stewardship Council* (MSC) certification schemes in marine fisheries, given that one of its component addresses the impact of fishing operations on the ecosystem (e.g. effects on the environment, related species, bycatch). In recent years, several fisheries in Argentina—ranging from coastal ice trawlers targeting the Argentine anchovy *Engraulis anchoita* to freezer trawlers targeting the Patagonian scallop *Zygochlamys patagonica* and the Patagonian grenadier or Hoki *Macruronus magellanicus* have been certified under the MSC scheme. Although these processes are not driven by the Government certainly creates opportunities to develop better fishing practices including in the agendas of fishermen not only target species but also other management issues affecting the marine environment. In this chapter, we will review the current status of the certification schemes implemented in the latter referred fisheries regarding seabird conservation discussing challenges and opportunities from the seabird perspective.

Keywords: certification schemes, argentine fisheries, bycatch, albatrosses, penguins, petrels, shearwaters, seabird conservation

IntechOpen

1. Introduction

This chapter offers an overview of the status of the certification schemes implemented in three Argentine fisheries certified under the *Marine Stewardship Council* scheme regarding seabird conservation. The first section of this review considers the nature of interactions between pelagic seabirds (albatrosses and petrels) and fisheries, particularly in the Southwest Atlantic Ocean. The second section seeks to define the key features of certified Argentine fisheries providing a summary of the certification process per fishery and extant fishery regulation and management measures related to both certified and non-certified species/fisheries. The third section explores up-to-date scientific, legal, and political actions taken to protect seabirds in Argentine waters, referring to possible steps for implementing an ecosystem approach to national fisheries within the frame of Argentina's National Plan of Action—seabirds and its interaction with current certification schemes.

2. Commercial fisheries and their impacts on marine top predators

2.1. Gloom of fisheries and impacts on marine ecosystems and their fauna

Since the past century, human population and technological skills at sea, as well as the demand for marine products, have grown on a large scale. Favored by a combination of several factors, namely increase in production, reductions in wastage, better utilization, improved distribution channels and growing demand linked to population growth, rising incomes and urbanization, the global fish food supply has grown substantially in the past five decades. Global total capture fishery production (by 2014) was 93.4 million tons, 87% of which came from marine waters [1]. Affecting not only fishery resources globally, this increase has also altered the structure of marine ecosystems, resulting in severe depletion of populations of marine megafauna, such as seabirds, marine mammals, sea turtles and highly migratory fish, and spreading throughout communities of interacting species through indirect effects [2–5]. This has led to a current scenario where almost 60% of the world fish stocks are considered fully fished, nearly 30% overfished and the remaining 10% moderately exploited [1], strongly implying that the approach of modern day fisheries management (focused in target species) has failed to provide the necessary framework for protecting fish populations and related/dependent species and their environments. Though the industry has been making global efforts to improve the size and quality of commercial landings, minor attention has been given to the ecosystem implications of these extractive activities until recent years, including the magnitude and fate of bycatch and discarded target and non-target species (both benthic and pelagic, including marine megafauna) [6, 7], indirect effects such as the removal of one species leading the profit or detriment of another and habitat impacts [2, 4]. To end with, the growing concern over the state of the marine environment, and the fisheries sustainability, has led to a shift in the focus of fisheries management, from a single-stock approach to management which considers the entire ecosystem, including humans [8–11]. This means that the ecosystem effects of fishing should contemplate a wide range of biological interactions, including changes in predator-prey relationships and nutrient dynamics, effects on non-target species through incidental capture, "cascading" effects mediated by food-web interactions and the loss or degradation of habitats, among others [4, 5, 10].

2.2. The Patagonian Shelf: its importance to marine megafauna

In the Southern Hemisphere, the Patagonian Shelf extends along the southern Atlantic Coast of South America from the Río de la Plata to southern Patagonia and Tierra del Fuego, thus extending throughout coastal and shelf waters of Argentina, Uruguay and Southern Brazil [12, 13]. Two major wind-driven currents influence the Patagonian Shelf: the cold, rich in nutrients, northward flowing Malvinas/Falkland Current and the warm, southward flowing Brazil Current. Extensive mixing of the above-mentioned currents in the La Plata region (~35°S) results in a highly productive confluence zone, affecting mainly oceanic areas and to certain extent the continental shelf. This mixing has biological, physical, and meteorological consequences that impact the entire Patagonian Shelf [14, 15]. The outflow from the Río de la Plata, the second largest drainage basin in South America, and upwelling of cold Antarctic waters caused by the prevailing westerly winds, also contributes to the high biological productivity on the continental shelf and slope [16, 17]. Particularly, the region covered by the Argentine Continental Shelf is one of the most extensive areas of the world with 1.7 million km^2, largely comprised a relatively shallow (<100 m deep) underwater plateau and bathed by waters whose temperatures range from to 6 to 18°C. The relative influence of the Malvinas/Falkland and Brazilian currents over the Argentine Continental Shelf coupled with other processes operating at a smaller scale such as tides, winds and river discharge generates several fronts promoting the production and/or concentration of phytoplankton and zooplankton, and the consequent development of major communities of fish, crustaceans and squid [16, 17]. Overall, this is a rich marine ecosystem of global importance with an outstanding biodiversity endemism and high biomass of certain species from warm, temperate and cold waters, offering plentiful food for a diverse number of local and migratory marine megafauna (e.g. seabirds, marine mammals, sea turtles and fish) [14, 18–22]. Squids are important components of the Argentine Continental Shelf ecosystem, for ecological and socioeconomic reasons [23]. The fish diversity of the Argentine Sea and adjacent waters between 34 and 55°S is very important, being composed of 522 species out of which about 60–70 are commercially exploited (with seven species representing more than 70% of the total national catch) [24].

2.3. Spatial and temporal overlap between seabirds and fishing activities: implications to bycatch

As mentioned in the previous section, the waters off Argentina and its shelf break constitute an ecosystem of global importance due to the high abundance and diversity of marine invertebrates and vertebrates. Considering the marine megafauna (seabirds, marine mammals and sea turtles), about 150 species inhabit the region [25]. Of these, roughly 40% encompass seabirds, with 17 breeding species and 40 non-breeding species [20]. Overall, Procellariiformes (albatrosses and petrels) contribute with the highest number of species, some of them showing extreme life history traits including low fecundity and productivity, late age at maturity and long-life expectancy [26]. Many of these species show small breeding populations and many are in decline, as their demographic characteristics severely limit their rate of recovery (especially those species breeding biennially). The reasons for these declines are largely anthropogenic since humans have been killing (intentionally or incidentally) albatrosses since they went out into the oceanic region. Of all the albatrosses (and some petrels), demographic parameters, changes in adult and juvenile survival via incidental mortality in fisheries have the most immediately important factor influencing population trend. Consequently, at sea, threats for these birds are of higher concern when compared with those affecting populations in the breeding grounds such as introduced predators [27, 28].

Several studies in the Patagonian Shelf using tracking methodologies such as satellite transmitters had been used to assess the distribution at sea, define foraging ranges, and identify the overlap between seabirds and human activities such as fisheries at different spatial and temporal scales. In other marine regions of the world, the foraging distributions of several seabird species strongly overlap throughout their entire annual cycle with commercial fisheries globally [29]. This spatial overlap is a necessary precondition for direct interactions (such as bycatch) between seabirds and fisheries; thus, it can be used as a proxy of risk faced by the birds interacting with fisheries [30, 31] (see Section 3.1).

In the case of albatrosses and petrels in the Argentine Continental Shelf, studies on breeders of southern giant petrels *Macronectes giganteus* and adults of the black-browed albatross *Thalassarche melanophris* during the non-breeding period had showed that the core foraging areas were overlapped with the fishing grounds of trawlers [32, 33]. Similarly, southern giant petrels (adults and juveniles) during the wintering period showed plasticity in the selection of their foraging environments being distribution of fisheries one of the main variables influencing their distribution [34, 35]. On the other hand, fisheries management may impact on a range of seabirds' traits such as foraging behavior [36, 37]. For example, southern giant petrels and black-browed albatrosses may show certain differences in their foraging behaviors with respect to areas inside and outside the permanent Argentine hake *Merluccius hubbsi* fishing closure in the Patagonian Shelf (see Section 3.2). The bulk of the core foraging areas of these species were concentrated in waters adjacent to the fishing closure where the fishing effort is higher than in other areas of the shelf [38]. Besides, this fishing closure produced a redistribution of the seabird bycatch creating a "boundary effect" due to the concentration of the fishing effort in the limits of the closure. This high fishing effort most likely brings an increase of discard availability and fish facilitated during hauling and the consequent attractiveness of fishing vessels for birds.

Coastal seabirds, such as the Magellanic penguin *Spheniscus magellanicus* and the Imperial cormorant *Phalacrocorax atriceps* breeding in the Argentinean continental coast, also showed a clear overlap with commercial hake and Argentine red shrimp *Pleoticus muelleri* trawl fisheries operating within waters of the San Jorge Gulf [39]. Moreover, incidental mortality of these species has been regularly recorded in both fisheries [40, 41], and Magellanic penguins were incidentally captured in the pelagic trawl fishery operating in southern Buenos Aires province [42].

The at-sea mortality of adults and juveniles in fisheries were linked to the global population declines of many seabirds' populations mainly albatrosses and petrels, which have been extensively recognized as one of the most threatened group of birds [29]. The information gathered from remote sensing technologies is relevant to identify risk areas for seabirds at sea and also into the framework of the ecosystem-based fishery management which has as their main goal to maintain ecosystems in a healthy, productive and resilient condition so they can provide the services humans want and need [29, 30].

3. Certification schemes in commercial fisheries

3.1. Improving fishing practices from the seabird conservation perspective

Interactions between pelagic seabirds (albatrosses, petrels, shearwaters) and fisheries occur in all oceans of the globe, virtually in all fisheries, and are dominated by the effect of fishing on birds. Despite the fact that the provisioning of fishery discards and offal to birds can be viewed as beneficial, as was mentioned above incidental mortality in fisheries is by far the main at-sea threat albatrosses and petrels are facing nowadays, and certainly the main cause of declinations in populations recorded in modern days [2, 43–45]. Longline fisheries have for many decades been responsible for the deaths of large numbers of seabirds worldwide. This is primarily due to the fact that (1) after high seas gillnets were banned in international waters (United Nations Resolution 46/215), much of the fishing effort subsequently shifted its approach to the use of longlines and (2) though longline was long considered as highly selective practice [46] seabird bycatch in these fisheries occur when baited hooks deployed onto the sea surface attract seabirds to fishing vessels leading to attacks on baits, capture and death by drowning [47, 48]. The species most affected include surface-feeding scavengers (like albatrosses), surface-divers (such as *Procellaria* petrels) or opportunists, which assemble behind boats and try to steal the bait off of hooks (e.g. albatross, petrels, skuas and gulls). In a recent global review, it was estimated that 160,000 seabirds were killed globally each year in at least 69 longline fisheries reviewed [49]. In spite of great efforts made to mitigate seabird mortality in longline fisheries [45, 50], incidental mortality in commercial longline fisheries threatens the continued existence of seabird populations in many regions of the world and is a key reason why 15 of the 22 species of albatrosses are listed as “threatened” by the International Union for Conservation of Nature [51].

3.1.1. Plan of action: seabirds

In view of the detrimental effects of longline fishing activities on several seabird species, in March 1997, the Committee on Fisheries on its 22nd season pursued FAO (Food and Agriculture Organization of the United Nations) to develop guidelines leading to a Plan of Action aimed at reducing the incidental catch of seabirds. The International Plan of Action for Reducing the Incidental Catch of Seabirds in Longline Fisheries (IPOA-Seabirds) was formally adopted by the 23rd session of the Committee on Fisheries in 1999. This document was elaborated within the framework of the Code of Conduct for Responsible Fisheries, agreements from the 1995 United Nations Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks and any applicable rules of international law. Briefly, the FAO Code of Conduct for Responsible Fisheries (adopted in 1995 and hereinafter refereed as to the Code) establish principles and standards applicable to tile conservation, management and development of all fisheries, also taking into account the biological features of these resources and their environment and the interest of consumers and other users [52]. Although the Code is voluntary, all stakeholders concerned with the management of fisheries, and the conservation of fishery resources, are encouraged to adopt it.

The development of the IPOA-Seabirds provided a framework that allowed the delineation of principles and guidelines to improve the fishing practices and to promote the development of National Plans to reduce this source of mortality in seabirds. As far as 2014, at least 12 States and other entities have completed their National Plan of Action-Seabirds (NPOA-Seabirds) or broadly equivalent documents. As an example of transboundary international efforts, a European Community Plan of Action-Seabirds has already been evoked so as to reduce the incidental mortality of seabirds wherever its longline vessels operate [53]. Finally, due to the nature of the IPOA-Seabirds guidelines (flexible and capable of evolving as new information becomes available), they may be further revised and complemented by other guidelines on specific matters. Consequently, FAO updated in 2009 its previous technical document and extended it to include other fisheries such as trawling once the later were identified as a serious threat to top predators including seabirds [54].

3.1.2. Fisheries certification

Managing the common resource of the world's fisheries has become an activity involving a great deal of risk, with many vested interests. It is by far a highly politicized problem, as not surprisingly, many nations compete for the shared fisheries resources. Deciding how to share these resources sometimes leads to political strains which indirectly affect attempts to protect seabirds. Market-based approaches relying on economic incentives and property rights have won favor in the past two decades when compared to mandate and control regulations [55]. In this context, private standards and related certification schemes are becoming significant features of international fish trade and marketing [56]. Fisheries certification is an instrument that recognizes desirable fisheries practices, while ecolabeling provides information to the consumer about the environmental impact caused by the product [57, 58]. Together, these initiatives aim to create market incentives for improved fisheries management [59]. There is a range of sponsors or developers of standards and certification schemes for fisheries sustainability, including private companies, industry groups, non-governmental organizations (NGOs) and even some combinations of stakeholders. A relatively new development is government-sponsored national ecolabels (e.g. in France and Iceland). It is worth pointing out that a range of ecolabeling and certification schemes exists in the fisheries sector, each with its own criteria, assessment processes, levels of transparency and sponsors. What is covered by the schemes can vary considerably: incidental mortality (bycatch) issues, fishing methods and gear, sustainability of stocks, conservation of ecosystems and even social and economic development [57].

The development of the Marine Stewardship Council (hereafter MSC) in 1997 went further ahead in the sense that it certifies an actual fishery as being both sustainable and sustainably managed. In this context, the MSC certification attempts to recognize producers using responsible fisheries practices [60–63]. Initially developed by Unilever and the WWF, the

MSC has operated independently of those two parents since 1999 [60, 61]. The MSC program is designed to be voluntary and meet the guidelines issued by FAO and be international in scope. By March 2015, 255 fisheries were and further 121 were at different stages of the assessment process, together accounting for about 10% of the global wild-caught seafood [64], thus turning MSC as the most worldwide fisheries certification program [65]. Briefly, the MSC's fishery certification process is an assessment to determine whether a fishery meets certain environmental standards for sustainable fishing. The MSC standard is composed of three core principles and a set of performance indicators and scoring guidelines, known as the "default assessment tree" [66]. Such principles are (1) sustainable target fish stocks, (2) environmental impact of fishing, and (3) effective management. The certification process has two stages: a confidential pre-assessment that identifies the characteristics and limitations of the fishery in question and a complete public assessment in which a third-party certification body (known as certifier or Conformity Assessment Body) evaluates whether a fishery meets the standard. The certification process implies a pre-assessment evaluation, a full-assessment and further annual surveillance [66].

Regarding seabird conservation and taking into account the three principles described above, in Principle 2, seabirds appear in the components dealing with the bycatch of Endangered, Threatened and Protected (ETP) species and the ecosystem function component. Within Principle 3, seabirds and their conservation might be addressed through any of several information-related performance indicators which relate to the needs for information of the management system and enforcement of the certification requirements, to planning and decision performance indicators, and to enforcement of any regulation related to seabird bycatch. In a recent review, of the 138 MSC certified fisheries, 38 were assessed to potentially pose a significant risk to seabirds. An additional 22 fisheries were selected for exhaustive review because of uncertainty about the information available for them. The remaining 78 fisheries were considered low risk given the little threat pose to seabirds, including gears such as collection of shellfish, handlines, or harpooning [67]. A remaining concern is the fairly large number of fisheries for which filling information gaps on bycatch is a condition of certification, meaning that the certification was given without full information. It should be stressed though that the impact of MSC certification on seabird conservation is somewhat limited, because few of the fisheries that have high seabird bycatch are likely to apply and invest the significant sums required for assessment, only to be turned down. These fisheries, therefore, remain beyond the reach of MSC. One of the issues in the MSC fishery certification process is that it relies on undocumented and virtually impossible to document expert opinion. Even when the experts are knowledgeable in the various aspects of the fishery, different experts may interpret the same data differently or place different importance on different aspects of a given conservation issue [67].

3.2. Argentine commercial fisheries: status of targeted stocks, fishery regulations, and management measures

As referred in earlier sections of this chapter (see Section 2.2), commercially targeted fish species in Argentine waters range from 60 to 70 species. However, the main target species comprise a handful of species including the Argentine hake (c. 33% of the total catch), followed by the Argentine shortfin squid *Illex argentinus*, the Argentine red shrimp, and the

Patagonian grenadier or Hoki *Macruronus magellanicus* (c. 23, c. 12, and c. 7% of the total catch, respectively) [68]. Another targeted species playing an important role in the food web of the Argentinean marine ecosystem though with lowered captures is the Argentine anchovy (*Engraulis anchoita*; c. 2% of the total catch). With the exception of the Patagonian grenadier and the Argentine anchovy, the three remaining targeted species/fisheries are not certified. Nevertheless, given the importance of these on overall landings, we will briefly comment about their status along with those certified resources/fisheries.

With regards to the status of main target species in the argentine commercial fisheries, during the 1990s landings of the Argentine hake increased from 435,000 to 645,000 tons. In response to the growing risks of collapse, the *Consejo Federal Pesquero* (CFP, Federal Fisheries Council) reduced the total allowable catch to 189,000 tons in 1999. However, ineffective surveillance and control led to continued overexploitation of the fishery. As a result, the total biomass of the species continued to decline, a scenario worsened by increased discards of juveniles, representing between 11 and 24% of total landings during the period 1990–1997 [69]. The current status of the resource "hake" (both northern and southern stocks combined) is considered as "recruitment overfishing" meaning that the reproductive biomass of the species is in such low level that jeopardizes the animals' ability to reproduce and recover above equilibrium levels previous to 1997, a period in which the resource descended below the species minimum critical level [*Resolución Auditoría General* (Resolution Audit General's Office) 09/2011]. Attempts to reduce the bycatch of juvenile hake or increase the escape of undersized fish through the nets began using the ice-trawl fleet as study case and finalized with the development of a bycatch reduction device called DEJUPA (*Dispositivo para el Escape de Juveniles de Peces en las redes de Arrastre* or Juvenile Fish Bycatch Reduction Device for Trawl Net). The use of DEJUPA (along with the use of certain mesh size in the cod-end) is in current days mandatory for all bottom-demersal trawlers targeting hake under Resolution CFP N° 08/2010, though compliance is still partial. In addition, a fishing closure issued by Provision *Subsecretaría de Pesca y Acuicultura* (SSPyA, Under Secretariat of Fishing and Agriculture) N° 136 was established in 1997 at protecting juvenile hake in high seas waters, covering c. 119,000 km^2. A modification to the previous fishing closure took place in 2000 (Resolution SAGPyA N° 265) further revised by the establishment of a committee for the management of the hake (Resolution SAGPyA N° 12/2001). Since then, the core area of the fishing closure aimed at protecting juvenile hake has remained stable, though partial openings and closures at its margins have occurred mainly driven by the hake spawning biomass estimated from scientific surveys leaded by *Instituto Nacional de Investigación y Desarrollo Pesquero* (INIDEP, National Institute for Fisheries Research and Development) and to political and socio-economic shifts [70]. During 2012, another fishing closure was established by Resolution *Comisión Técnica Mixta del Frente Marítimo* (CTMFM, Argentine-Uruguayan Joint Technical Commission of the Maritime Front) N° 08 for the protection of juvenile hake in the vicinity of the Argentine-Uruguayan Common Fishing Zone.

On the other hand, the Patagonian grenadier or Hoki is the most abundant fishery resource on the southern shelf and slope south of 45°S. During the last years, the biomass catches for this species declined at least 4% (from c. 124,500 to c. 55,000 tons) [68]. Considering commercially important invertebrates, the Argentine shortfin squid is a neritic-oceanic species that can be found from 54 to 23°S of Argentina [23]. Its abundance is difficult to estimate due to its short lifespan, complex population structure, and the high inter-annual variability in its population size chiefly due to variable environmental conditions [71]. The Argentine red shrimp is mainly distributed in the San Jorge Gulf. There are difficulties with this stock in linking the spawning biomass to the magnitude of subsequent recruitment. Hence, the fishery operates under continuous monitoring and is closed when necessary to protect the spawning process and minimize overfishing during growth and recruitment. Shrimp fishing trawlers have the sole authority to operate in areas of permanent closure for hake fishing. The main impact of this fishery is through its bycatch, involving 80 species of fish, the most common of which being juvenile hake [72]. The Argentine anchovy is an under-exploited species and is commonly used for filleting and canning. There is a protected area for reproduction purposes, which is closed to fishing within the Common Fishing Zone Argentinean-Uruguayan (ZCPAU).

In relation to fishery regulations and management measures, the Argentine Constitution provides the general national framework to protect marine wildlife in the country. The National policy relevant to wildlife protection is also defined by the *Ley Federal del Ambiente* (Federal Environmental Law) (N° 25.675) enforced by the *Consejo Federal del Medio Ambiente* (Federal Environment Council), the highest environmental authority. The *Ley Federal de Pesca* (Federal Fisheries Law) (N° 24.922) is the central norm in fisheries issues within Argentina at the federal level. However, the regulation of maritime fisheries presents a clear degree of dispersive rules, with different extent range between provincial jurisdictions, and at the federal level, the Federal Fisheries Council is the governance practical body that has federal and provincial representation.

3.3. Certification schemes in argentine commercial fisheries

The incorporation of Argentine commercial fisheries into certification schemes started in 2006 with the certification of the Patagonian Scallop *Zygochlamys patagonica* fishery. Since that time four other fisheries had been involved in certification processes, all under the Marine Stewardship Council (MSC) normative. Two of them are still certified: Argentine Anchovy (Bonaerense stock) certified in 2011 and the Patagonian grenadier or Hoki certified in 2012. While other two fisheries, formerly certified had withdrawn from the MSC assessment process: Southern King Crab *Lithodes santolla* in 2014 and the Argentine Patagonian Toothfish *Dissostichus eleginoides* in 2015.

The second Principle of the MSC Standard, "Minimizing environmental impacts," has been highlighted by researchers involved in certification processes as the main drawback for most Argentinean fisheries to meet the MSC standard [73]. In particular, Argentina has developed several National Plans of Action (NPOA) based on FAO Plan of Action for the conservation and management of chondrichthyes (*Plan de Acción Nacional-Tiburones* or NPOA-Sharks, since 2009) and to reduce the interaction of seabirds (*Plan Nacional de Acción-Aves Marinas* or NPOA-Seabirds, since 2010) and marine mammals (*Plan de Acción Nacional-Mamíferos Marinos* or NPOA-Marine Mammals, since 2015) with fisheries. Furthermore, the CFP under Resolution N° 3/2001 have instructed the *Instituto Nacional de Investigación y Desarrollo Pesquero* (INIDEP, National Institute for Fisheries Research and Development) through the Onboard Observers Program to carry out actions and methodologies required for the proper quantification of bycatch of reptiles, birds, and marine mammals and implement them during commercial fishing operations. This context provides a favorable legal and regulatory framework for the consideration of these taxa in any fishery certification. The assessment against MSC principles and criteria of certificated commercial fisheries envisage this type of evaluation as unwanted catch in the categories "Endangered, Threatened and Protected species (ETP)" or "Secondary species" (out-of-scope species but not considered ETP). However, the impact of certified commercial fisheries on seabirds, mammals, and reptiles has been unequally treated in the certification scheme of Argentine certified commercial fisheries. In the Argentine anchovy (Bonaerense stock) [74] and Patagonian grenadier fisheries [75], this aspect has been, and it is actually being evaluated, while in the Patagonian Scallop fishery [76], it is underestimated. The final document on the Patagonian Scallop assessment states that seabirds are rare along the shelf break front where the fishery takes place, and so, the interaction between these fleet and seabirds is minimized [76]. However, recent reports inform the association of at least 14 seabird species during the fishing operations [77]. Moreover, five of the attending species are listed in any category of global threat [51].

The certification process has been highlighted by all stakeholders (chiefly industry and certification bodies) as a good decision for many reasons. From the researchers, academics, and NGOs point of view, it implies the enforcement of authorities to conduct research, engagement of stakeholders, and the commitment to carry out action plans [73]. Regardless of whether fisheries meet the MSC standards, not all enterprises in the fishing industry share the financial and administrative capacity to comply with the certification requirements, nor the necessity to participate in the MSC program. Argentine fisheries participating in the MSC program meet this profile, but profound asymmetries exist in terms of onboard observers' coverage among them. While the degree of the observer programme coverage in the case of the Patagonian Scallop since its certification has been of 100% (4 vessels involved in the certification process from a total of 4 operative vessels in the period 2006–2016), the coverage in other fleets has been variable and far from ideal. Observer coverage onboard vessels fishing for Argentine anchovy has ranged from 11 to 13% during the period 2012–2016 in a fleet ranging from 24 to 66 operative vessels. The coverage in vessels targeting Patagonian grenadier has fluctuated between 8 and 36% during the period 2011–2016 in a fleet ranging from 37 to 117 operative vessels [73–76, 78, 79].

4. Seabird conservation in the context of certification schemes

4.1. Improving seabird conservation and fisheries management

It is widely recognized that albatrosses and petrels are one of the most threatened group of birds [44, 45]. Therefore, it is paramount to reduce and prevent pelagic seabird bycatch. Moreover, the incidental mortality of seabirds (chiefly albatrosses and petrels) does not only have devastating consequences for them (and other marine megafauna) but also may turn fishing operation less efficient [80]. The Code of Conduct for Responsible Fisheries developed by FAO [81] encouraged the maintenance and conservation of biodiversity through the reduction of the effects of fishing on non-target species. As a consequence, in recent years, a number of techniques or measures to mitigate incidental mortality of seabirds have been developed, particularly in longline fisheries [82], as these been the first fisheries to be tackled the issue of bycatch of albatrosses and petrels globally. Apart from being effective in reducing the bycatch of birds, mitigation measures should be practical and easy to apply in commercial fisheries, preferably not reducing the catches of the target species, and ideally, provide incentives for fishermen for their use.

As current Argentinean certified fisheries use towed nets as main gears, for reducing seabirds' interactions with trawl fisheries, best practices include protecting the warp cables, managing offal discharge and discards, and reducing the time the net is exposed on the surface of the water [82]. Mitigation measures aimed at avoiding or reducing interactions between seabirds and Argentinian certified trawl fishing gear are solely taken place in the large high-seas freezer trawl fishery that targets Patagonian grenadier. The Albatross Task Force of Aves Argentinas has designed bird scaring lines—and assessed its efficacy at reducing seabird mortality—to protect the warp cables in this fleet in coordination with the INIDEP [83]. It was in this context that the CPF issued Resolution N° 3/2017 for the mandatory use of tori-lines (for trawl cables) in demersal freezer trawlers commencing in May 2018. Despite the progress achieved and that mitigation measures are included in the plan of action of the certified Argentine anchovy fishery, issues dealing with the development and at sea trailing of mitigation measures tailored for certified trawlers targeting this resource are far from realization.

Both inspectors and observers are the key personnel in charge of monitoring the use and compliance of mitigation measures to reduce the incidental capture of seabirds onboard Argentinean commercial fishing vessels (certified and non-certified vessels combined). The main distinction between these bodies is that the area of intervention of inspectors corresponds to national waters and they also have the capacity of applying the law by means of performing acts of infringement under Provision *Subsecretaría de Pesca y Acuicultura* (SSPyA, Under Secretariat of Fishing and Agriculture) N° 424/2004. There are both national and provincial observers' programs in Argentina. The former monitors national waters belonging to the INIDEP, while the provinces of Rio Negro, Chubut, Santa Cruz, and Tierra del Fuego have their own observers' programs to monitor its coastal waters [84]. Though programs differ in administrative, jurisdictional, and type of fleets issues, in recent years, several workshops took place aimed at standardizing protocols for data collection by either national and provincial observers' programs. There is no distinction between protocols for data collection on seabird-related issues in certified and non-certified fisheries.

4.2. Opportunities and challenges in seabird conservation: the case of certified Argentinean fisheries

In the case of the Argentine anchovy fishery (Bonaerense stock), during the 2011 certification pre-assessment, the main interacting seabird species (including records of incidental mortality) comprised Procellariiformes such as the Great and Sooty shearwaters (*Ardenna gravis*, listed by the IUCN as Least Concern and *A. grisea*, Near Threatened) and the White-chinned petrel *Procellaria aequinoctialis* (Vulnerable). According to the MSC evaluation team, these species were considered as Unwanted catch and listed in the category "Endangered, Threatened and Protected species" [85]. These preliminary results were studied in greater detail during the certification stage and informed in the corresponding audits. In order to achieve such goal, observers belonging to the INIDEP were tasked onboard vessels so as to record seabird abundance and interactions following standardized protocols already in place [86]. During a period of 3 years of research (2011–2013), the species interacted the most included shearwaters (chiefly *A. gravis*), the kelp gull *Larus dominicanus* (Least Concern), the black-browed albatross (Least Concern), and the white-chinned petrel. The highest mortalities included 101 shearwaters and 12 penguins. A great proportion of the contacts (92%) and all mortalities were recorded taking place with the net [87].

The fishery targeting Patagonian grenadier was certified in 2012 and is currently in the process of being recertified. At the time of certification, several studies had already identified high interaction rates and mortalities of seabirds with high-seas demersal trawlers operating in southern Patagonian Shelf (chiefly black-browed albatross, kelp gull, southern royal albatross *Diomedea epomophora*, southern giant petrel, and white-chinned petrel). In this case, the main recorded contacts were collisions with the warp cables [86, 88]. For this reason, during the certification period, the main goal was to research and implement mitigation measures available in the literature [82]. In modern days, the MSC evaluation team considers that is highly likely that seabirds fall within the biological limits given that the conservation status of most captured seabird species is considered as minor concern. In addition, it is mandatory for vessels to task onboard observers to ensure compliance with regulations. By the time of finishing this chapter, the fishery was in the process of receiving a new certification [89].

As for the fishery targeting Patagonian scallop, the former was certified in 2006 and recertified in 2012 and again in 2017. Though the impact of this commercial fishery on "ETP species" including seabirds is recorded by onboard observers with 100% coverage since its certification, it seems to have negligible effects on such marine megafauna [76, 90, 91]. Still, new information shows that there is an important attendance of seabirds (chiefly Procellariiformes) in different management areas of the fishery, though no contacts (consequently incidental mortality) have been recorded [77].

To resume with, the interactions (including bycatch) of seabirds with the Argentine anchovy and the Patagonian grenadier fisheries can be considered high. Despite this, such fisheries have been certified and recertified based on claimed issues related to (i) the conservation status of species involved in the bulk of the interactions not qualify for any IUCN threatened category, (ii) a complete lack of information regarding the at-sea abundance of the species involved, and (iii) a presumable high compliance on the use of mitigation measures (e.g. streamer lines), among others. Despite this, some essential aspects need to be taken into account: firstly, that threatened seabird species do interact with vessels [39–42, 83, 86–88, 92] although possible to a lesser degree than non-threatened species. However, this may be related to the lowered observer coverage during fishing activities of certified fisheries, as observers are tasked to perform seabird counts (and associated levels of interactions) once per haul per day, thus underestimating attending seabird assemblages and consequently the species composition and their conservation status. It has to be stressed that observers are not fully dedicated to seabird-related issues onboard certified (and non-certified) vessels. Secondly, there are no mitigation measures currently in place for fishing vessels targeting pelagic school fish such as the Argentine anchovy, therefore interactions with the latter could be sustained and/or increase. Thirdly, the levels of compliance with regards to the use of mitigation measures have not been fully assessed in vessels targeting demersal fish such as the Patagonian grenadier.

http://dx.doi.org/10.5772/intechopen.74784

4.3. Argentina's National Plan of Action-Seabirds and the interaction with current certification schemes

The approval of the National Plan of Action-Seabirds (NOPA-S) by the CPF in 2010 constituted a critical milestone in Argentina, marking the end of a long-term process aimed to understand the basics of the seabird bycatch in commercial fisheries and establishing a framework to guide conservation and management actions to minimize seabird bycatch in commercial fisheries. As referred in Section 3.1, the Argentinean NPOA-S follows the guidelines provided in the FAO International Plan of Action-Seabirds further expanding to include trawl and other fisheries known to affect the conservation status of seabirds [46, 54]. The above referred process covered about a decade of work and collaboration between governmental agencies, the academia, and NGOs and allowed the implementation of further detailed research in a range of fisheries (including semi-commercial) and the development of conservation advise and management regulations, including one binding conservation measure approved in 2008 calling for the use of seabird bycatch mitigation methods in demersal longline fisheries [Resolution CPF N° 08/2008], and a more recent conservation measure approved in 2017 for freezer trawlers [Resolution CPF N° 03/2017]. Another important milestone in this process was the accession of Argentina to the Agreement on the Conservation of Albatrosses and Petrels (www.acap.aq) in 2006, providing the international framework to the domestic initiatives and leading to international action and engagement with relevant counties worldwide. Although significant progress can be seen since the inception of the process that started in the late 1990s, there is still much more to do in Argentina to effectively bring the number of seabirds killed in fisheries down to acceptable levels. That should include the full implementation of current binding measures, monitoring of compliance and the development of additional regulations to address the bottom ice-trawl and other fisheries known to impact seabirds in the Patagonian Shelf.

As commented in a Section 3.1, a bit more than a decade ago, FAO developed a set of voluntary guidelines for the ecolabeling of fish and fishery products from marine capture fisheries [56]. These guidelines primarily address issues related to the sustainable use of fishery resources and refer to principles, minimum requirements and criteria, and procedural and institutional aspects of ecolabeling. There are already several national, international, industry sponsored, NGOs-led and consumer-supplier partnership certification, and standards schemes under development in the fisheries sector [56–58]. However, it is apparent that the only fisheries-specific scheme that adheres to the FAO guidelines is the MSC Responsible Fisheries Scheme [93]. Although certification and branding are only aspects of product promotion for the fishery, it must be pointed that any given fishery under such scheme must comply with certain minimum standards of data collection and implementation of measures to minimize the impact on the ecosystem, hence providing a benefit beyond the actual management of a given fish stock. In Argentina, and most likely in many other states, the advent of fisheries certification schemes has created opportunities for improving databases, the better understanding conservation issues such as bycatch of top predators, and generated improved conditions for the dialog between different stakeholders (industry included). Domestic examples can be taken from the freezer trawlers targeting the Patagonian scallop, the freezer trawlers targeting Patagonian grenadier, and the coastal ice-trawlers targeting the Argentine anchovy, all of them fisheries certified under the MSC scheme.

Although certification processes are not driven by governments, certainly open windows for partnerships and ultimately create opportunities to develop better fishing practices at an ecosystem level. For example, the certification process in the Patagonian grenadier fishery allowed the implementation of an outreach program for crew in freezer trawlers, substantially improving the onboard conditions for the implementation of seabird bycatch mitigation measures. The anchovy trawl fishery operating in northern Patagonia offers another example of improved conditions for data collection aboard and the understanding of seabird bycatch in coastal fisheries. From the Government perspective, the important matter to address seabird bycatch in fisheries in a strategic fashion is to have available a framework to guide the implementation of conservation actions, and that tool is provided by a NPOA-S that is periodically reviewed and updated by a group of experts. The reciprocal action between the implementation of the NPOA-S (as well as other national plans) and the certification schemes, creating opportunities for research and development, must be accompanied by the monitoring of compliance and enforcement fulfilled by the local authorities.

Acknowledgements

This study was financially supported by the *Universidad Nacional de Mar del Plata*, Argentina (National University of Mar del Plata, 15/E975 EXA 842/17), the *Agencia Nacional de Promoción Científica y Tecnológica*, Argentina (National Agency for Scientific and Technological Promotion, PICT 2012-0295 S. Copello, PIP 2011-070 and PICT 2013-0711 M. Favero, PICT 2015-0262 J. P. Seco Pon), and the *Instituto Nacional de Investigación y Desarrollo Pesquero*, Argentina (INIDEP, National Institute for Fisheries Research and Development).

Conflict of interest

The authors declare no conflict of interest.

Author details

Juan Pablo Seco Pon[1*], Jesica A. Paz[1], Rocío Mariano-Jelicich[1], Germán García[1], Sofía Copello[1], María P. Berón[1], Gabriel Blanco[2], José Luis Flaminio[2] and Marco Favero[1]

*Address all correspondence to: secopon@mdp.edu.ar

1 Marine and Coastal Research Institute (National University of Mar del Plata – National Research Council, Argentina), Mar del Plata, Argentina

2 National Institute for Fisheries Research and Development, Mar del Plata, Argentina

References

[1] United Nations Food and Agriculture Organization (FAO). The State of World Fisheries and Aquaculture. 1st ed. Rome: Food and Agriculture Organization of the United Nations; 2016. 200 p

[2] Dayton PK, Thrush S, Agardy MT, Hofman RJ. Environmental effects of marine fishing. Aquatic Conservation: Marine and Freshwater Ecosystems. 1995;**5**:202-232. DOI: 10.1002/aqx.3270050305

[3] Montevecchi WA, Kirk DA. The great auk (*Pinguinus impennis*). In: Poole A, Gill F, editors. The Birds of North America. 1st ed. Washington, DC: The Academy of Natural Sciences and The American Ornithologists Union; 1996. pp. 1-20

[4] National Research Council (NRC). Dynamic Changes in Marine Ecosystems: Fishing, Food Webs, and Future Options. 1st ed. Washington, DC: The National Academies Press; 2006. 168 p

[5] Pauly D. 5 Easy Pieces: How Fishing Impacts Marine Ecosystems. 1st ed. Washington, DC: Island Press; 2010. 193 p

[6] Hall MA, Alverson DL, Metuzals KI. By-catches: Problems and solutions. Marine Pollution Bulletin. 2000;**41**:204-219. DOI: 10.1016/S0025-326X(00)00111-9

[7] Moore G, Jennings S. Commercial Fishing: The wider Ecological Impacts. 1st ed. London: Cambridge University Press; 2000. 66 p

[8] Browman HI, Konstantinos IS. Perspectives on ecosystem-based approaches to the management of marine resources: Introduction section. Marine Ecology Progress Series. 2004;**274**:269-303

[9] Piatt JF, Harding AM, Shultz M, Speckman SG, van Pelt TI, Drew GS, Kettle AB. Seabirds as indicators of marine food supplies: Cairns revisit. Marine Ecology Progress Series. 2007;**352**:221-234. DOI: 10.3354/meps07078

[10] United Nations Food and Agriculture Organization (FAO). Fisheries management. 2. The ecosystem approach to fisheries: The human dimensions of the ecosystem approach to fisheries. FAO Technical Guidelines for Responsible Fisheries. 2009;**4**:2

[11] Hobday AJ, Smith ADM, Stobutzki IC, Bulman C, Daley R, Dambacher JM, Deng RA, Dowdney J, Fuller M, Furlani D, Griffiths SP, Johnson D, Kenyon R, Knuckey IA, Ling SD, Pitcher R, Sainsbury KJ, Sporcic M, Smith T, Turnbull C, Walker TYI, Wayte SE, Webb H, Williams A, Wise BS, Zhou S. Ecological risk assessment for the effects of fishing. Fisheries Research. 2011;**108**:372-384. DOI: 10.1016/j.fishres.2011.01.013

[12] Sherman K. Sustainability, biomass yields, and health of coastal ecosystems: An ecological perspective. Marine Ecology Progress Series. 1994;**112**:277-301

[13] Duda AM, Sherman K. Applications of the large marine ecosystem approach toward world summit targets. In: Hennessey T, Sutinen J, editors. Sustaining Large Marine Ecosystems: The Human Dimension. 1st ed. Amsterdam: Elsevier; 2005. pp. 297-318

[14] Bastida R, Rodríguez D, Scarlatto N, Favero M. Marine biodiversity of the South-Western Atlantic Ocean and main environmental problems of the region. In: Miyazaki N, Adeel Z, Ohwada K, editors. Mankind and the Oceans. 1st ed. New York: United Nations University Press; 2005. pp. 172-207

[15] Guerrero RA, Piola AR. Masas de agua en la Plataforma Continental. In: Boschi EE, editor. El Mar Argentino y sus recursos pesqueros. Tomo 1: Antecedentes históricos de las exploraciones en el mar y las características ambientales. 1st ed. Mar del Plata: INIDEP; 1997. pp. 101-118

[16] Acha ED, Mianzan HW, Guerrero RA, Favero M, Bava J. Marine fronts at the continental shelves of austral South America: Physical and ecological processes. Journal of Marine Systems. 2004;**44**:83-105. DOI: 10.1016/j.jmarsys.2003.09.005

[17] Balech E, Ehrlich MD. Esquema biogeográfico del Mar Argentino. Revista de Investigación y Desarrollo Pesquero. 2008;**19**:45-75

[18] Campagna C, Sanderson EW, Coppolillo PB, Falabella V, Piola AR, Strindberg S, Croxall JP. A species approach to marine ecosystem conservation. Aquatic Conservation: Marine and Freshwater Ecosystems. 2007;**17**:S122-S147. DOI: 10.1002/aqc.918

[19] Croxall JP, Wood AG. The importance of the Patagonian Shelf to top predators species breeding at South Georgia. Aquatic Conservation: Marine and Freshwater Research. 2002;**12**:101-118. DOI: 10.1002/aqc.480

[20] Favero M, Silva Rodríguez MP. Estado actual y conservación de aves pelágicas que utilizan la plataforma continental Argentina como área de forrajeo. El Hornero. 2005;**20**:95-110

[21] Gónzalez Carman V, Álvarez KC, Prosdocimi L, Inchaurraga MC, Dellacasa RF, Faiella A, Echenique C, González R, Andrejuk J, Mianzan HW, Campagna C, Albareda DA. Argentinian coastal waters: A temperate habitat for three species of threatened sea turtles. Marine Biology Research. 2011;**7**:500-508. DOI: 10.1080/17451000.2010.528772

[22] Boltovskoy D, Correa N, Boltovskoy A. Marine zooplanktonic diversity: A view from the South Atlantic. Oceanologica Acta. 2002;**25**:271-278. DOI: 10.1016/S0399-1784(02)01199-4

[23] Brunetti NE, Ivanovic ML, Sakai M. Calamares de importancia comercial en Argentina. Biología, distribución, pesquerías y muestreo biológico. 1st ed. Mar del Plata: Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP); 1999. 45 p

[24] Cousseau MB, Perrotta R. Peces marinos de Argentina: Biología, distribución, pesca. 1st ed. Mar del Plata: Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP); 2004. 167 p

[25] Falabella V, Campagna C, Croxall JP. Atlas del Mar Patagónico: Especies y espacios. 1st ed. Buenos Aires: Wildlife Conservation Society & BirdLife International. Buenos Aires; 2009. 305 p

[26] Warham J. The Behaviour, Population Ecology and Physiology of the Petrels. 1st ed. Vol. 1996. London and San Diego, Academic Press. 612 p

[27] Gurevitch J, Padilla DK. Are invasive species a major cause of extinctions? Trends in Ecology and Evolution. 2004;**19**:470-474. DOI: 10.1016/j.tree.2004.07.005

[28] Croxall JP, Butchart SHM, Lascelles B, Stattersfield AJ, Sullivan B, Symes A, Taylor P. Seabird conservation status, threats and priority actions: A global assessment. Bird Conservation International. 2012;**22**:1-34. DOI: 10.1017/S0959270912000020

[29] BirdLife International. Tracking Ocean Wanderers: The Global Distribution of Albatrosses and Petrels. 1st ed. Gordon's Bay: BirdLife International; 2004. 100 p

[30] Delord K, Cotté C, Péron C, Marteau C, Pruvost P, Gasco N, Duhamel G, Cherel Y, Weimerskirch H. At-sea distribution and diet of an endangered top predator: Relationship between white-chinned petrels and commercial longline fisheries. Endangered Species Research. 2010;**13**:1-16. DOI: 10.3354/esr00309

[31] Tuck GN, Phillips R, Small CJ, Thomsom RB, Klaer N, Taylor F, Wanless RM, Arrizabalaga H. An assessment of seabird-fishery interactions in the Atlantic Ocean. ICES Journal of Marine Science. 2011;**68**:1628-1637. DOI: 10.1093/icesjms/fsr118

[32] Copello S, Quintana F. Spatio-temporal overlap between Southern Giant Petrels and fisheries at the Patagonian Shelf. Polar Biology. 2009;**32**:1211-1220. DOI: 10.1007/s00300-009-0620-7

[33] Copello S, Seco Pon J, Favero M. Spatial overlap of Black-browed albatrosses with longline and trawl fisheries in the Patagonian Shelf during the non-breeding season. Journal of Sea Research. 2014;**89**:44-51. DOI: 10.1016/j.seares.2014.02.006

[34] Blanco G, Sánchez-Carnero N, Pisoni JP, Quintana F. Seascape modeling of southern giant petrels from Patagonia during different life-cycles. Marine Biology. 2017;**164**:53. DOI: 10.1007/s00227-017-3094-0

[35] Blanco G, Pisoni JP, Quintana F. Characterization of the seascape used by juvenile and wintering adult Southern Giant Petrels from Patagonia Argentina. Estuarine, Coastal and Shelf Science. 2015;**153**:135-144. DOI: 10.1016/j.ecss.2014.12.007

[36] Pichegru L, Ryan PG, van Eeden R, Reid T, Grémillet D, Wanless R. Industrial fishing, no-take zones and endangered penguins. Biological Conservation. 2012;**156**:117-125. DOI: 10.1098/rsbl.2009.0913

[37] Regular P, Montevecchi W, Hedd A, Robertson G, Wilhelm S. Canadian fishery closures provide a large-scale test of the impact of gillnet bycatch on seabird populations. Biological Letters. 2013;**9**:20130088. DOI: 10.1098/rsbl.2013.0088

[38] Copello S, Blanco G, Seco Pon J, Quintana F, Favero M. Exporting the problem: Issues with fishing closures in seabird conservation. Marine Policy. 2016;**74**:120-127. DOI: 10.1016/j.marpol.2016.09.008

[39] Yorio P, Quintana F, Dell'Arciprete P, Gonzalez Zevallos D. Spatial overlap between foraging seabirds and trawl fisheries: Implications for the effectiveness of a marine protected

area at Golfo San Jorge, Argentina. Bird Conservation International. 2010;**20**:320-334. DOI: 10.1017/S0959270910000286

[40] González Zevallos D, Yorio P. Seabird use of discards and incidental captures at the Argentine hake trawl fishery in Golfo San Jorge, Argentina. Marine Ecology Progress Series. 2006;**316**:175-183. DOI: 10.3354/meps316175

[41] González-Zevallos D, Yorio P, Svagelj WS. Seabird attendance and incidental mortality at shrimp fisheries in Golfo San Jorge, Argentina. Marine Ecology Progress Series. 2011;**432**:125-135. DOI: 10.3354/meps09146

[42] Paz J, Seco Pon J, Favero M, Blanco G, Copello S. Commercial trawl pelagic fisheries in Argentina: Seabird attendance and interactions with the vessels. Aquatic Conservation: Marine and Freshwater Ecosystems

[43] Montevecchi WA. Interactions between fisheries and seabirds. In: Schreiber EA, Burger J, editors. Biology of Marine Birds. 1st ed. Boca Raton: CRC Press LLC; 2002. pp. 527-557

[44] BirdLife International. State of the world's birds [Internet]. 2017. Available from: http://datazone.birdlife.org/sowb [Accessed: 2017-01-03]

[45] Agreement on the Conservation of Albatrosses and Petrels (ACAP). The ACAP Species Assessments [Internet]. 2017. Available from: https://acap.aq/en/acap-species/307-acap-species-list/file [Accessed: 2017-01-03]

[46] Brothers NP, Cooper J, Lokkeborg S. The incidental catch of seabirds by longline fisheries: Worldwide review and technical guidelines and mitigation. FAO Fisheries Circular. 1999;937

[47] Brothers N. Albatross mortality and associated bait loss in the Japanese longline fishery in the Southern Ocean. Biological Conservation. 1991;**55**:255-268. DOI: 10.1016/0006-3207(91)90031-4

[48] Robertson G. The culture and practice of longline fishing: Implications for seabird by-catch mitigation. Bird Conservation International. 1998;**8**:211-221. DOI: 10.1017/S095927090000188X

[49] Anderson ORJ, Small CJ, Croxall JP, Dunn EK, Sullivan BJ, Yates O, Black A. Global seabird bycatch in long-line fisheries. Endangered Species Research. 2011;**14**:91-106. DOI: 10.3354/esr00347

[50] Bull LS. Reducing seabird bycatch in longline, trawl and gillnet fisheries. Fish and Fisheries. 2007;**8**:31-56. DOI: 10.1111/j.1467-2979.2007.00234.x

[51] International Union for the Conservation of Nature (IUCN). The IUCN Red List of Threatened Species. Version 2017-3 [Internet]. Available from: http://www.iucnredlist.org/ [Accessed: 2017-01-03]

[52] Garcia SM. The FAO definition of sustainable development and the code of conduct for responsible fisheries: An analysis of the related principles, criteria and indicators. Marine and Freshwater Research. 2000;**51**:535-541. DOI: 10.1071/MF00030

[53] Dunn E. The Case for a Community Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries: A Report from BirdLife International's Global Seabird Programme. 1st ed. Cambridge: BirdLife International; 2007. 20 p

[54] United Nations Food and Agriculture Organization (FAO). Fishing operations. 2. Best practices to reduce incidental catch of seabirds in capture fisheries. FAO Technical Guidelines for Responsible. Fisheries. 2009;**1**:2

[55] Mansfield B. Assessing market-based environmental policy using a case study of North Pacific fisheries. Global Environmental Change. 2006;**16**:29-39. DOI: 10.1016/j.gloenvcha.2005.10.001

[56] Washington S, Ababouch L. Private standards and certification in fisheries and aquaculture: Current practice and emerging issues. FAO Fisheries and Aquaculture Technical Paper. 2001;**553**. 203 p

[57] Wessells CR, Cochrane K, Deere C, Wallis P, Willmann R. Product Certification and Ecolabelling for Fisheries Sustainability. FAO Fisheries and Aquaculture Technical Paper 422. 2001;422. 83 p

[58] Potts T, Haward M. International trade, eco-labelling, and sustainable fisheries–recent issues, concepts and practices. Environment, Development and Sustainability. 2007;**9**:91-106. DOI: 0.1007/s10668-005-9006-3

[59] Ward T, Phillips B. Ecolabelling of seafood: The basic concepts. In: Ward T, Phillips B, editors. Seafood Ecolabelling: Principles and Practice. 1st ed. London: Wiley-Blackwell; 2008. pp. 1-37

[60] Constance DH, Bonanno A. Regulating the global fisheries: The World Wildlife Fund, Unilever, and the Marine Stewardship Council. Agricultural Human Values. 2000;**17**:125-139. DOI: 10.1023/A:1007625606243

[61] Peacey J. The marine stewardship council fisheries certification program: Progress and challenges. In: Johnston RS, Shriver AL, editors. Microbehavior and Macroresults: Proceedings of the Tenth Biennial Conference of the International Institute of Fisheries Economics and Trade. 1st ed. Corvallis, Oregon: International Institute of Fisheries Economics and Trade (IIFET); 2000. pp. 1-5

[62] Gulbrandsen LH. The emergence and effectiveness of the Marine Stewardship Council. Marine Policy. 2009;**33**:654-660. DOI: 10.1016/j.marpol.2009.01.002

[63] Ponte S. The Marine Stewardship Council (MSC) and the making of a market for 'Sustainable Fish'. Journal of Agrarian Change. 2012;**12**:300-315. DOI: 10.1111/j.1471-0366.2011.00345.x

[64] Marine Stewardship Council (MSC). Marine Stewardship Council: Global Impacts Report 2015. 1st ed. London: Marine Stewardship Council; 2015. 52 p

[65] Agnew DJ, Gutiérrez NL, Hoggarth D, Stern-Pirlot A. The MSC experience: Developing an operational certification standard and a market incentive to improve fishery sustainability. ICES Journal of Marine Science. 2013;**71**:216-225. DOI: 10.1093/icesjms/fst091

[66] Marine Stewardship Council (MSC). MSC Fisheries Certification Requirements and Guidance. 1st ed. London: Marine Stewardship Council; 2014. p. 25

[67] Wiedenfeld DA. Analysis of the Effects of Marine Stewardship Council Fishery Certification on the Conservation of Seabirds. 1st ed. American Bird Conservancy: The Plains; 2012. 40 p

[68] Navarro G, Rozycki V, Monsalvo M. Estadísticas de la Pesca Marina en la Argentina. Evolución de los desembarques 2008-2013. Ministerio de Agricultura, Ganadería y Pesca de la Nación: Buenos Aires; 2014. 144 p

[69] Dato C, Bambill G, Cañete G, Villarino M, Aubone A. Estimación cuantitativa del descarte en la pesquería de merluza realizado por la flota comercial argentina. In: INIDEP Documento Científico 6. Mar del Plata: Instituto Nacional de Investigación y Desarrollo Pesquero; 2006. pp. 31-38

[70] Alemany D, Iribarne O, Acha EM. Effects of a large-scale and offshore marine protected area on the demersal fish assemblage in the Southwest Atlantic. ICES Journal of Marine Science. 2012;**70**:123-134. DOI: 10.1093/icesjms/fss166

[71] Basson M, Beddington J, Crombie J, Holden S, Purchase L, Tingley G. Assessment and management techniques for migratory annual squid stocks: The *Ilex argentines* fishery in the Southwest Atlantic as an example. Fisheries Research. 1996;**28**:3-27. DOI: 10.1016/0165-7836(96)00481-X

[72] Góngora ME, Bovcon NE, Cochia PD. Ictiofauna capturada incidentalmente en la pesquería de langostino patagónico *Pleoticus muelleri* Bate, 1888. Revista de Biología Marina y Oceanografía. 2009;**44**:583-593. DOI: 10.4067/S0718-19572009000300006

[73] Pérez-Ramírez M, Lluch-Cota S, Lasta M. MSC certification in Argentina: Stakeholders' perceptions and lessons learned. Marine Policy. 2012;**36**:1182-1187. DOI: 10.1016/j.marpol.2012.03.011

[74] Prenski LB, Sesar G, Landa PA, Medina Foucher CA, Laco ML. Assessment against MSC Principles and Criteria for: Argentine Anchovy (*Engraulis anchoita*), Bonaerense Stock, Semi-Pelagic Mid-Water Trawl Net Fishery. Final Report. Certificate Code: F-OIA-P-0200. Buenos Aires: Organización Internacional Agropecuaria (OIA); 2016. 235 p

[75] Morsan EM, Campodónico I, Sesar G, Medina Foucher CA. Assessment against MSC Principles and Criteria for: Argentine Hoki Bottom and Mid-Water Trawl Fishery in Argentine Sea (*Macruronus magellanicus*). Final Report. Certificate Code: F-OIA-P-0300. Buenos Aires: Organización Internacional Agropecuaria (OIA); 2017. 199 p

[76] Morsan EM, Sesar G, Medina Foucher CA, Laco ML. Assessment against MSC Principles and Criteria for: Patagonian Scallop Bottom Otter Trawl Fishery in Argentine Sea (*Zygochlamys patagonica*). Final Report. Certificate Code: F-OIA-P-0101. Buenos Aires: Organización Internacional Agropecuaria (OIA); 2017. 163 p

[77] Bastida J, Campodónico MS. Aves marinas asociadas al recurso Vieira patagónica (*Zygochlamis patagonica*) en el frente de talud durante las campañas de evaluación 2015-2016. INIDEP Informe técnico N°3; 2017. 15 p

[78] Prosdoscimi L, Monsalvo M. Informe anual 2014. Informe GP N° 8/2015. Coordinación Gestión de Pesquerías – DNPP, Subsecretaría de Pesca y Acuicultura. Ministerio de Agroindustria; 2015

[79] Prosdoscimi L, Monsalvo M. Informe anual 2016. Informe GP N° 05/2017. Coordinación Gestión de Pesquerías – DNPP, Subsecretaría de Pesca y Acuicultura. Ministerio de Agroindustria; 2017

[80] Gandini P, Frere E. The economic cost of seabird bycatch in Argentinean longline fisheries. Bird Conservation International. 2012;**22**:59-65. DOI: 10.1017/S0959270911000219

[81] United Nations Food and Agriculture Organization (FAO). Code of Conduct for Responsible Fisheries. 1st ed. Rome: Food and Agriculture Organization of the United Nations; 1995. 41 p

[82] Agreement on the Conservation of Albatrosses and Petrels (ACAP). Report of the Tenth Meeting of ACAP's Advisory Committee [Internet]. 2017. Available from: https://acap.aq/en/advisory-committee/ac10/3130-ac10-report/file [Accessed: 2017-01-03]

[83] Tamini LL, Chavez LN, Góngora ME, Yates O, Rabuffetti FL, Sullivan B. Estimating mortality of black-browed albatross (*Thalassarche melanophris*, Temminck, 1828) and other seabirds in the Argentinean factory trawl fleet and the use of bird-scaring lines as a mitigation measure. Polar Biology. 2015;**38**:1867-1879. DOI: 10.1007/s00300-015-1747-3

[84] González-Zevallos D, Tamini L, Seco Pon JP, Góngora ME, Blanco G. Aportes de la ornitología marina a la visión ecosistémica del manejo pesquero. El Hornero. 2012;**27**:117-126

[85] Prenski LB, Morales-Yokobori M, Bridi J, Gasalla MA, Minte-Vera C. Argentinean Bonaerense Anchovy (*Engraulis anchoita*) Industrial Semi-pelagic Mid-water Trawl Net Fishery. Assessment against MSC Principles and Criteria. Public Certification Report. Buenos Aires: Organización Internacional Agropecuaria (OIA); 2011. 276 p

[86] Favero M, Blanco G, García G, Copello S, Seco Pon JP, Frere E, Quintana F, Yorio P, Rabuffetti F, Cañete G, Gandini P. Seabird mortality associated with ice trawlers in the Patagonian Shelf: Effect of discards on the occurrence of interactions with fishing gear. Animal Conservation. 2011;**14**:131-139. DOI: 10.1111/j.1469-1795.2010.00405.x

[87] Paz J. Interacciones entre aves marinas y la pesquería de arrastre pelágico dirigido a anchoíta (*Engraulis anchoita*) en el Mar Argentino [thesis]. Mar del Plata: Universidad Nacional de Mar del Plata; 2015

[88] Sullivan B, Reid T, Bugoni L. Seabird mortality on factory trawlers in the Falkland Islands and beyond. Biological Conservation. 2006;**131**:495-504. DOI: 10.1016/j.biocon.2006.02.007

[89] Prenski LB, Morales-Yokobori M, Minte-Vera C, Bridi J, Landa P, Di Giacomo E, Perier M. Argentine hoki (*Macruronus magellanicus*) bottom and semi pelagic trawl net fishery. Assessment against MSC Principles and Criteria. Public Certification Report. Buenos Aires: Organización Internacional Agropecuaria (OIA); 2012. 822 p

[90] Pottinger RP, Curelovich J, Morsan E, Cranfield HJ, Mendo J. MSC Assessment Report Patagonian Scallop Fishery. Organización Internacional Agropecuaria (OIA): Assessment against MSC Principles and Criteria. Public certification report. Buenos Aires; 2006. 281 p

[91] Morsan EM, Cranfield HJ, Bridi RJ, Prenski LB, Sánchez de Bock M. MSC assessment report Patagonian scallop fishery (*Zygochlamys patagonica*). Re-Assessment against MSC Principles and Criteria. Public Re-Certification Report. Buenos Aires: Organización Internacional Agropecuaria (OIA); 2012. 263 p

[92] Seco Pon JP, Copello S, Tamini L, Mariano-Jelicich R, Paz J, Blanco G, Favero M. Seabird conservation in fisheries: Current state of knowledge and conservation needs for Argentine high-seas fleets. In: Mahala G, editor. Seabirds and Songbirds: Habitat Preference, Conservation and Migratory Behavior. 1st ed. New York: Nova Science Publishers, Inc.; 2015. pp. 45-88

[93] Macfayden G, Huntington T. Potential Costs and Benefits of Fisheries Certification for Countries in the Asia-Pacific Region. Asia-Pacific Fishery Commission. 1st ed. Bangkok: Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific; 2007. 59 p

Chapter 4

Seabirds as Bioindicators of Marine Ecosystems

Muhammad Nawaz Rajpar, Ibrahim Ozdemir,
Mohamed Zakaria, Shazia Sheryar and Abdu Rab

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.75458

Abstract

Seabirds are those waterbirds that directly or indirectly depend on the marine environment over the waters, i.e., they foraged at sea either near shore or offshore and inhabit in coastal areas, islands, estuaries, wetlands, and ocean islands. They are mostly aerial waterbirds sailing above sea spending much of their time (weeks, months, and even years) in marine environments or floating on the water surface or diving in deep sea in search of food. Seabirds encompass of 65 genera, 222 marine, and 72 partially marine bird species. Seabirds have been used as good indicators (i.e., bioindicators) of marine ecosystems due to cause-effect association with different microclimate and habitats. They exploit broad scale of habitat, quickly respond to environmental changes, they can be detected easily (i.e., they showed their presence through vocalization), easy to identify, can be surveyed efficiently over large spatial scale, e.g., presence, abundance, and influenced by surrounding habitats as compared to other animals. Employing seabird as bioindicators is a cost-effective and informative tool (well defined matrix) to determine the effects of disturbances, contamination, i.e., effects of pollutants, organic substances, and oil-spills of the marine environment. Seabirds are top predators in the marine food chain and key component of the food web. Seabirds may indicate the status of habitat, reduction in food occurrence and abundance, rate of the predation, an effect of weather (climate change), and threats. The other reason could be that, seabirds often closely associate with inter-site more distinctly than other animals and may breed in the same site each year, easy to catch while incubating and during rearing chicks. Hence, it is crucially important to use seabirds as bioindicators within the context of ecological and spatial parameters to determine the effects of disturbances in the marine environment and for effective conservation and better management of seabirds in the future.

Keywords: seabirds, bioindicators, marine, habitat, threats, ecology

1. Introduction

Marine is the largest and highly productive aquatic ecosystem of the world which covers 70% earth surface and encompasses of salt marshes, intertidal zones, estuaries, lagoons, mangroves, coral reefs, and deep sea. They are suitable home, (i.e., living place, food, shelter, and breeding grounds) for a wide array (i.e., millions of species) of invertebrate, e.g., corals, crustaceans, molluscs, etc., and vertebrate animal species, e.g., birds, reptiles, mammals, and fishes. Despite being a highly productive ecosystem, it faces significant threats due to human interaction. Marine ecosystem has substantial linkages with coastal and inland waters which are important habitats for numerous species. For example: sandy beaches, estuaries, and mangroves are nurseries and breeding grounds for a diversity of birds, reptiles, and fishes [1]. In addition, marine ecosystem is a major source of economic wealth for human being, i.e., it provides a wide range of active ingredient resources such as raw material for medicine, staple food for human as well as wildlife, and gene bank for basic as well as applied research [2].

1.1. Current status of marine areas

Presently, only 1.2% marine areas of the world within exclusive economic zones, 4.3% areas of the continental shelf, and 0.9% areas of offshore waters have been protected [3, 4]. Marine areas are the most productive ecosystem for seabird species, i.e., they provide a wide array of habitat rich in food resources that had attracted a diversity of seabird species to be utilized year around. Identifying the ideal foraging and breeding sites of the seabird is highly crucial to declare marine protected areas and manage them on the sustainable basis to ensure the breeding success and to enhance population of seabirds.

The coastal and island areas offer heterogeneous habitat and highly productive foraging sites that had attracted a wide array of seabirds to forage year-round in these areas to fulfill their requirements (**Figures 1–3**). These areas attracted congregate numbers of loons, gulls,

Figure 1. Least tern—*Sternula antillarum.* Source: This picture was taken from short natural film "A Puffin Paradise: The Seabirds of the Farne Island".

http://dx.doi.org/10.5772/intechopen.75458

and cormorants during winter season to forage in rich up dwelling areas. In addition, an island within the proximity to rich foraging sites also provide ideal nesting sites for Gulls, Guillemots, Cormorants, and Oystercatchers (**Figures 4–10**).

Figure 2. Whiskered tern—*Childonias hybrid*. Photo by Rajpar in Marudu Bay coastal area Malaysia.

Figure 3. Greater flamingo—*Phoenicopterus ruber*. Photo by Rajpar in the coastal area of Sindh, Pakistan.

Figure 4. Atlantic puffin—*Fratercula arctica.* Source: This picture was taken from short natural film "A Puffin Paradise: The Seabirds of the Farne Island".

Figure 5. Common Murres—*Uria aalge.* Source: This picture was taken from short natural film "A Puffin Paradise: The Seabirds of the Farne Island".

Figure 6. Great black-backed Gull—*Larus marinus.* Source: This picture was taken from short natural film "A Puffin Paradise: The Seabirds of the Farne Island".

Figure 7. Red-footed Booby—*Sula sula.* Source: This picture was taken from short natural film "A Puffin Paradise: The Seabirds of the Farne Island".

Figure 8. Artic tern—*Sterna paradisaea.* Source: This picture was taken from short natural film "A Puffin Paradise: The Seabirds of the Farne Island".

Figure 9. Ringed-billed Gul—*Larus dilawarensis.* Source: This picture was taken from short natural film "A Puffin Paradise: The Seabirds of the Farne Island".

Figure 10. White tern—*Gygis alba.* Source: This picture was taken from short natural film "A Puffin Paradise: The Seabirds of the Farne Island".

2. Seabirds

The term "seabirds" has been applied to waterbirds that directly or indirectly depend on the marine environment over the waters [5]. Seabirds comprised of five orders, namely; Sphenisciformes (i.e., Penguins), Procellariiformes (i.e., Albatrosses, Petrels, Storm-Petrels, Fulmars, Shearwaters), Ciconiiformes (i.e., Herons, Egrets, Storks, Ibis, Spoonbills), Pelecaniformes (i.e., Pelicans, Frigatebirds, Gannets, Boobies, Cormorants, Anhingas), and Charadriiformes (i.e., Shorebirds, Skuas, Jaegers, Skimmers, Auks, Guillemots and Puffins) are a major component of the marine environment and often exhibit distinct association with the sea environment (**Table 1**).

Family	**Scientific name**	**Common name**	**Reference**
Alcidae	*Alca torda*	Razorbill	[6]
Laridae	*Anous minutus*	Black noddy	[7]
Procellariidae	*Ardenna bulleri*	Buller's shearwater	[8]
Procellariidae	*Ardenna creatopus*	Pink-footed shearwater	[9]
Procellariidae	*Ardenna gravis*	Great shearwater	[8]
Procellariidae	*Calonectris leucomelas*	Streaked shearwater	[10]
Stercorariidae	*Catharacta antarctica*	Brown skua	[10]
Stercorariidae	*Catharacta chilensis*	Chilean Skua	[10]
Stercorariidae	*Catharacta maccormicki*	South polar skua	[10]
Stercorariidae	*Catharacta skua*	Great skua	[10]
Alcidae	*Cephphus grylle*	Black guillemot	[6]
Laridae	*Creagrus furcatus*	Swallow-tailed gull	[9–11]
Procellariidae	*Daption capense*	Cape petrel	[9]
Diomedeidae	*Diomedea exulans*	Wandering albatross	[8]
Diomedeidae	*Diomedea sanfordi*	Northern royal albatross	[8, 9]
Alcidae	*Fratercula arctica*	Atlantic Puffin	[6]
Fregatidae	*Fregata andrewsi*	Christmas frigatebird	[10]
Fregatidae	*Fregata aquila*	Ascension frigatebird	[10]
Fregatidae	*Fregata ariel*	Lesser frigatebird	[10]
Fregatidae	*Fregata magnificens*	Magnificent frigatebird	[10]
Fregatidae	*Fregata minor*	Great frigatebird	[10]
Oceanitidae	*Fregetta grallaria*	White-bellied storm petrel	[8]
Procellariidae	*Fulmarus glacialis*	Northern fulmar	[6, 12]
Procellariidae	*Hydrobates pelagicus*	European storm petrel	[6]
Laridae	*Larus argentatus*	Herring gull	[6, 10]
Laridae	*Larus armenicus*	Armenian gull	[10]
Laridae	*Larus brunnicephalus*	Brown-headed gull	[10]
Laridae	*Larus cachinnans*	Yellow-legged gull	[10]
Laridae	*Larus canus*	Mew gull	[6]
Laridae	*Larus fuscus*	Lesser black-backed gull	[6, 10]

Family	Scientific name	Common name	Reference
Laridae	*Larus glaucescens*	Glaucous-winged gull	[10]
Laridae	*Larus kumelieni*	Kumlien's gull	[10]
Laridae	*Larus marinus*	Great black-backed gull	[6]
Laridae	*Larus ridibundus*	Black-headed gull	[6]
Laridae	*Larus schistisagus*	Slaty-backed gull	[10]
Laridae	*Larus scopulinus*	Red-billed gull	[13]
Laridae	*Larus thayeri*	Thayer's gull	[10]
Procellariidae	*Macronectes giganteus*	Southern giant petrel	[9]
Procellariidae	*Morus bassanus*	Northern gannet	[6]
Procellariidae	*Oceanites oceanicus*	Wilson's storm petrel	[8]
Procellariidae	*Oceanites gracilis*	Elliott's storm petrel	[9]
Pelecanoididae	*Oceanodroma leucorhoa*	Leach's storm petrel	[6, 14]
Procellariidae	*Pacronectes halli*	Northern giant petrel	[9]
Laridae	*Pagophila eburnean*	Ivory gull	[21]
Procellariidae	*Pelagodroma marina*	White-faced storm petrel	[8, 9]
Procellariidae	*Pelecanoides garnotii*	Peruvian diving petrel	[9]
Procellariidae	*Pelecanoides urinatrix*	Common diving petrel	[8]
Pelecanidae	*Pelecanus occidentalis*	Brown pelican	[10, 21]
Phaethontidae	*Phaethon aethereus*	Red-billed tropicbird	[8–10]
Phaethontidae	*Phaethon lepturus*	White-tailed tropicbird	[10]
Phaethontidae	*Phaethon rubricauda*	Red-tailed tropicbird	[15] [16]
Phalacrocoracidae	*Phalacrocorax aristotelis*	European shag	[6]
Phalacrocoracidae	*Phalacrocorax carbo*	Great cormorant	[6]
Scolopacidae	*Phalaropus lobatus*	Red-necked phalarope	[9]
Scolopacidae	*Phalaropus fulicarius*	Red phalarope	[9]
Alcidae	*Pinguinnis impenni*	Great auk	[10]
Procellariidae	*Procellaria aequinoctiallis*	White-chinned petrel	[8]
Procellariidae	*Procellaria parkisoni*	Parkinson's petrel	[8]
Procellariidae	*Procellaria westlandica*	Westland petrel	[9]
Procellariidae	*Pterodroma deflippiana*	De Filippin's petrel	[9]
Procellariidae	*Pterodroma externa*	Juan Fernandez petrel	[9]
Procellariidae	*Puffinus gravis*	Great shearwater	[6, 10]
Procellariidae	*Puffinus griseus*	Sooty shearwater	[6, 10]

Family	Scientific name	Common name	Reference
Procellariidae	*Puffinus puffinus*	Manx shearwater	[6]
Procellariidae	*Puffinus tenuirostris*	Short-tailed shearwater	[10]
Procellariidae	*Pufnus assimilus*	Little shearwater	[8]
Procellariidae	*Pufnus pufnus*	Manx shearwater	[8]
Stercorariidae	*Rhodostethia rosea*	Ross's gull	[10]
Laridae	*Rissa tridactyla*	Black-legged kittiwake	[6, 17]
Rhynchopidae	*Rynchops niger*	Black skimmer	[18]
Spheniscidae	*Spheniscus mendiculus*	Galapagos penguin	[10]
Stercorariidae	*Stercorarius chilensis*	Chilean skua	[8]
Stercorariidae	*Stercorarius longicaudus*	Long-tailed jaeger/skua	[6, 19]
Stercorariidae	*Stercorarius maccormicki*	South polar skua	[9]
Stercorariidae	*Stercorarius parasiticus*	Parasitic jaeger/Arctic skua	[6, 9]
Stercorariidae	*Stercorarius pomarinus*	Pomarine skua	[6, 20]
Stercorariidae	*Stercorarius skua*	Great skua	[6]
Sternidae	*Sterna bengalensis*	Lesser crested tern	[7]
Sternidae	*Sterna dougallii*	Roseate tern	[21]
Sternidae	*Sterna hirundo*	Common tern	[6, 21]
Sternidae	*Sterna paradisaea*	Arctic tern	[6]
Sulidae	*Sula leucogaster*	Brown booby	[21]
Sulidae	*Sula sula*	Red-footed booby	[22]
Diomedeidae	*Thalassarche bulleri*	Buller's/Pacific albatross	[9]
Diomedeidae	*Thalassarche chrysostoma*	Gray-headed albatross	[9, 23]
Diomedeidae	*Thalassarche eremite*	Chatham albatross	[9]
Diomedeidae	*Thalassarche melanophris*	Black-browed albatross	[9, 10, 23]
Diomedeidae	*Thalassarche salvini*	Black-browed albatross	[9]
Diomedeidae	*Thalassarche salvini*	Salvin's albatross	[9]
	Uria aalge	Common murres	[6]
Laridae	*Xema sabini*	Sabine's gull	[10]

Table 1. List of seabird species detected by different ornithologist.

Seabird are dull in color, i.e., black, white or black and white in color. They are bioindicators of land, productivity (food resources), and environment [24]. Boobies, gulls, terns, and alcids are colonial seabirds which often live in colonies and colonies may encompass of several species to million individuals, (e.g., Sooty Shearwaters, Wilson's Storm-petrel—*Oceanites oceanicus*) while others prefer to live solitary considered as the rarest, (i.e., only 10–20 pairs), e.g., Chatham Island Petrel—*Pterodroma magenta* and Chinese Crested Tern—*Sterna bernsteini* [25].

Seabirds often prefer to live marine near shore (depositional areas) foraging and upland areas (erosional environment) for loafing and breeding.

Bermuda Petrel—*Pterodroma cahow* and Black-capped Petrel—*P. hasitata* are endemic to only few marine sites of West Indies. Likewise, Fiji Petrel—*P. macgillivaryi* and Christmas Island Frigatebird—*Fregata andrewsi* are endemic to Guam South Pacific Island. In contrast, the other are migrant species which travel thousands of kilometers while migration from one area to another, i.e., pelagic seabird, e.g., sooty shearwater—*Puffinus griseus* [26].

Apparently, information on seabird community parameters (i.e. species composition, relative abundance, diversity, foraging guilds and density), habitat characteristics and closed relationship with food resources and water quality is insufficient. Marine habitat is a distinctive set of physical sea areas that seabird species use for its survival and reproduction. Notably, the marine habitat is not solely comprised vegetation, but also a combination of biotic and abiotic factors that influence the level of seabird use under certain conditions. For this reason, marine areas are ideal habitats for diverse seabird species where seabirds foraged, inhabit, and reproduced. Various globally threatened and non-threatened seabird species depend on different marine areas to fulfill their daily requirements, such as food, water and shelter for their survival and breeding purposes.

Seabird community parameters have been used to examine the status, productivity, and threats to the habitat marine ecosystem. Monitoring the various aspects of seabird community parameters provide detailed information on migration pattern, seasonal distribution, foraging ecology, breeding biology, physiology that will help in conservation activities. The population and community parameters of seabirds fluctuate from time to time and depend on productivity, prey availability, natality, mortality, immigration and emigration (**Figure 11**; [27–32]).

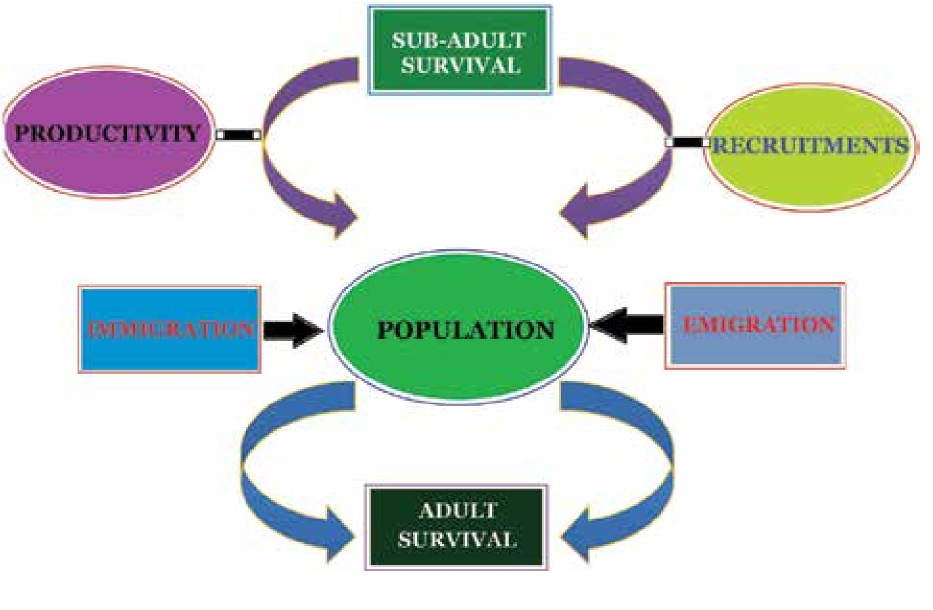

Figure 11. The major driven variable which regulates the population and community parameters of seabirds in the marine ecosystem.

Monitoring the seabird's parameters in marine habitats provides the data to evaluate the factors that cause population fluctuations among different marine habitats. In addition, monitoring, thus helps in conservation and better management of threatened and endangered seabird species.

Detailed information on the seabird's behavior and ecology in marine habitat is lacking, i.e., very little information is available on seabirds as bioindicators of marine ecosystems. Conversely, long-term population trends of seabirds, microhabitat and microclimate characteristics as well as correlationship between the seabird species with microclimate and microhabitat characteristics have not been examined. In fact, very little is known on the ecological roles of seabird species in relation to microhabitat and habitat disturbances, i.e., What would happen to the seabird species when their habitat is altered? Would the seabird population be increased or decreased? or would they move to other areas less suitable for foraging and breeding?

Seabirds have accommodated themselves in different ecosystems from North Pole to Antarctica. They directly or indirectly depend on the marine environment, such as: coastal area (i.e., mangrove, mudflats, estuaries, and islands) to perform various activities such as inhabit, foraging, perching, loafing, roosting, and breeding, etc. for their survival and existence. Seabirds are aerial birds in nature, i.e., spend hours, weeks, months, and even years at sea. Majority of seabirds observed hovering above the sea surface for searching vast areas for food that can be caught and carried from long distance to the colony. Some of seabirds, i.e., pelican, cormorant, gulls, terns, skimmers are often observed near shore and estuarine areas [33]. Likewise, albatrosses, petrels, and boobies always occur offshore. The most common characteristics of all seabirds are that they forage in salt water. Seabirds often inhabit and exploit a wide range of habitats for foraging and breeding purposes.

3. Seabirds as bioindicators of marine ecosystem

Seabirds have been used as good bioindicators of marine ecosystems. They respond more quickly to environmental changes, show their occurrence through vocalization, and are easy to detect and identify [4, 34, 35]. Previously, seabirds have been used as a bioindicators of pollution [36–39], oil spills [40, 41], contamination in the Antarctic ecosystem [42–44], evaluate wetland ecosystem health [45, 46], climate change [47], primary productivity [48], and environmental pollution in aquatic system [49–51]. This could be that, seabirds may show distinctive habitat preferences and display a variety of adaptations to exploit the marine resources and can be used to determine the marine ecosystem integrity.

Cause variable or abiotic factors may indicate the existing condition of the particular area while seabird community parameters highlight environmental condition, productivity. The cause-effect relationship is the utmost essential tool to decide what actions should be taken for conservation and protection of specific site. The information on seabird's community parameters would be more suitable to use them as bioindicators of threats and contamination due to satisfactory sample sizes and ease of sampling, i.e., colonial breeders often occur in large numbers [52]. Detailed information on seabird ecology provides the basis for interpretation to examine the toxic effect patterns and levels of contamination [53].

The choice of seabird species and study site is crucially important, i.e., some species become panic due to human presence and may cause mortality of eggs or chicks (e.g., Great Cormorant, Black-legged Kittiwakes) while other species are highly tolerant of disturbance (e.g., Northern Gannet). Seabird species should be selected as a bioindicators of marine ecosystem which has following attributes, namely accumulate high concentration of contamination, resistant to toxic effects, forage on narrow define and consistent diet feed predominantly or exclusively on prey in the food web under investigation, often occur in large number of colonies and large population size with known breeding biology, physiology, and ecology, less disturbed with human interference, easily identifiable, and easy to collect samples [52].

4. Foraging behaviour of seabirds

Fish is potential prey of seabirds, i.e., they foraged on >100 fish species (i.e., herring, sardines, anchovies, menhaden, sand eels, smelts, and flying fish, etc.) and invertebrates, e.g., squids, crustaceans, crabs, molluscs, and krills [54, 55]. The capture and handling food of depends on morphological and physiological adaptations (e.g., bill shape, feed, and body shape) and enables them to exploit a wide array of food resources in myriad ways. Furthermore, the foraging behaviour of seabird species influenced by foraging range, ability to dive, foraging efforts, energy expands on foraging, ability to catch, handle, and consume prey items [56]. Seabirds employ heterogeneous foraging techniques to catch their prey. For example: *pursuit diving*; following their prey into the water (penguins, alcids, cormorant, and diving petrels), *dipping*; picking prey, i.e., squid and krill while floating on the water surface (storm's petrels, skuas, gulls, terns, large petrels, pelicans, and albatrosses), *plunge diving* (gannets, boobies, tropicbirds, terns, and pelicans), *piracy and cannibalism* (Frigatebirds and skuas), and *aerial pursuit* [7, 57, 58]. Some species are solitary feeders while other forage in flocks [59, 60]. The occurrence of food resources and distribution may alter the demographic characteristics of seabird species [61]. Seabird can be classified according to habitat preference, e.g., albatrosses often prefer to forage over open sea and avoid utilizing the coastal area and are known as pelagic seabirds. On the contrarily, gulls and terns tend to forage in coastal areas and loaf on beaches considered as shorebirds. However, some seabird species utilized pelagic as well as coastal area during breeding and non-breeding seasons and rarely use terrestrial areas, i.e., alcids and penguins.

Seabirds detect their prey visually and tactile way and employ various foraging techniques to catch their prey. Mostly, seabirds are visual diurnal predators, i.e., mostly foraging during daylight hours, i.e., Common Murre—*Uria aalge* [62] and some are nocturnal, prey during the night, such as: Bulwer's Petrel—*Bulweria bulwerii*, Wedge-rumped Storm Petrel—*Oceanodroma tethys*, Red-footed Booby—*Sula leucogaster*, Dovekie—*Alle alle*, Red-legged Kittiwake—*Rissa brevirostris*, Swallow-tailed Gull—*Creagrus furcatus*, and White Tern—*Gygris alba*, Thick-billed

Murre—*Uria lomvia*, and Macaroni Penguin—*Eduyptes chrysolophus*, etc. [63, 64]. However, some species exhibit both diurnal and nocturnal foraging behaviour.

For example: Storm-Petrels forage on surface zooplankton, penguin consumed pelagic fish and squid, gulls and albatrosses feed on dead animals, i.e., scavengers [65, 66]. Inshore bird species such as gulls and terns often concentrate where plenty of food is available, penguins and alcids dive at greater depth to catch their prey, albatrosses, shearwaters, and petrels soar at the sea surface in search of food.

5. Threats to seabirds

The habitat degradation due to water pollutants has caused the great threats to marine birds and their population had declined, i.e., some of them become endangered, threatened and endangered, critically endangered and even some species become extinct out of many seabird species around the world. Seabirds are facing different challenges such as weather influence on foraging, salt load (i.e., diving Petrels—*Pelecanoides* spp.) ingestion of salt water while diving [67], anthropogenic contamination, and competition from fisheries.

The major threat to seabirds is killing by fishing gear or culling (e.g., mass mortality of diving auks, common guillemots, razorbills, and Atlantic Puffins in gill nets, drift net, and other fixed fishing gears in coastal or offshore shallow waters), alteration in food resources due to over exploitation of fishery resources, oil spills, water pollution, hunting, predation by mammals, human disturbance, climate change, introduction of invasive species in breeding area, and disturbance natural oceanographic factors that effects on prey availability [68–73]. These are major driven factors which directly or indirectly effects on seabird population community parameters, e.g., some seabird species become endangered or threatened and vulnerable to the brink of extinction.

It has been stated that human population growth in some coastal areas has been increased up to 40% in the last 10 years [55]. Rapid increase of human population in coastal areas may cause disturbances that exerts physiological stress to Adelie Penguins—*Pygoscelis adeliae*, Gentoo Penguins—*Pygoscelis papau*, Herring Gulls—*Larus argentatus,* and Redshanks—*Tringa tetanus*, egg and nestling mortality of Sooty Tern—*Sterna fuscata*, premature fledging of Rhinoceros Auklets *Cerorhinca monocerata* and Spectacled Guillemots—*Cepphus carbo*, and colony abandonment, e.g., cormorant species [74–76].

An oil spill is a serious threat to the seabird, i.e., it may cause the mass mortality among seabird species. Seabirds are the most conspicuous and prone to marine oil spills as compared to other animals [77–79]. This could be that, they spend much time of their life at sea and their populations are patchily distributed and concentrated in coastal areas and offshore habitats which often faces the oil spill problems and their survival probability is very low in case of oil spills incidence [80–83]. For example: in 2002–2003 about 60,000-ton prestige oil was spilled in the Iberian Coastal area of northern Portugal to France and caused mass mortality of auks (i.e., 9826 individuals), Common Murres—*Uria aalge* (4492 individuals), Razorbills—*Alca torda* (2861 individuals), and Atlanic Puffins—*Fratercula arctica* (2473 individuals) [84].

6. Conclusion

In conclusion, it has been clearly determined that the seabirds are closely associated with the marine environment and can be used as bioindicators to detect the changes in water quality, productivity, and other threats to the marine ecosystem. Seabirds are top predators of the marine ecosystems and easy to identify and survey. Hence, it is crucially important that the population of seabird communities must be protected to reduce the threats, to enhance the population of seabirds, and keep nature in balance for proper functions of the marine ecosystems on a sustainable basis for future generation.

7. Recommendation for future research and conservation

1. In future a detailed research on seabird ecology, interaction with food resources and marine habitats should be conducted to identify the major driven factors which effect on seabird community parameters. This will identify what are the major factors, i.e., environmental, ecological and anthropogenic, etc. variable due to which seabirds are facing severe threats for their survival and existence.
2. A mass awareness among public should be created how disturbance affects the population parameters of different seabird species and what is their ecological importance of balance and proper functions of the marine ecosystem. In addition, how to utilize marine resources without causing disturbance to the seabird while seeking for human welfare.
3. A detailed strategy should be developed to address the issues, viewing guidelines, i.e., ecological importance, threats, and disturbance to the seabirds.

Author details

Muhammad Nawaz Rajpar[1]*, Ibrahim Ozdemir[2], Mohamed Zakaria[3], Shazia Sheryar[1] and Abdu Rab[1]

*Address all correspondence to: rajparnawaz@gmail.com

1 Department of Forestry, Shaheed Benazir Bhutto University, Sheringal, KPK, Pakistan

2 Department of Wildlife Ecology and Management, Faculty of Forestry, Suleyman Demirel University, Isparta, Turkey

3 Faculty of Forestry, Universiti Putra Malaysia, Selangor, Malaysia

References

[1] Mumby PJ. Connectivity of reef fish between mangroves and coral reefs: Algorithms for the design of marine reserves at seascape scales. Biological Conservation. 2006;**128**:215-222

[2] Goulletquer P, Gros P, Boeuf G, Weber J. The importance of marine biodiversity. In: Biodiversity in the Marine Environment. Dordrecht: Springer; 2014

[3] Butchart SHM, Walpole M, Collen B, van Strien A, Scharlemann JPW, Almond REA, et al. Global biodiversity: Indicators of recent declines. Science. 2010;**328**(5982):1164-1168

[4] Croxall JP, Butchart SHM, Lascelles B, Stattersfield AJ, Sullivian B, Symes A, Taylor P. Seabird conservation status, threats and priority actions: A global assessment. Bird Conservation International. 2012;**22**:1-34

[5] Schreiber EA, Burger J. Seabirds in the marine environment. In: Schreiber EA, Burger J, editors. Biology of Marine Birds. Washington DC, USA. ISBN: 0-8493-9882-7: CRC Press; 2002. p. 1

[6] Mackey M, Gimene DP. SEA678 Data Report for Offshore Seabird Populations. Coastal and Marine Resource Centre, Environmental Research Institute, University College Cork; 2003

[7] Hulsman K. The structure of seabird communities: An example from Australian waters. In: Seabirds and Other Marine Vertebrates: Composition, Predation and Other Interactions. New York: Columbia University Press; 1988

[8] Shirihai H, Diaz HA, Huichalaf JE, Brettagnolle V. Petrels and Endemic Landbirds of the Mas Afuera (Alejandro Selkirk) and Robinson Crusoe Island, Juan Fernandez archipelago. Expedition Research Report: March 2013; 2016. www.scillypelagics.com

[9] Flood RL, Wilson AC, Zufelt K, Danzenbaker M, Ryan J and Shemilt J. Humboldt Current and the Juan Fernandez Archipelago. Expedition Research Report: November 2014; 2017. www.scillypelagics.com

[10] Brooke deL M. Seabird systematics and distribution: A review of current knowledge. In: Biology of Marine Birds, Schreiber EA and Burger J. Washington DC, USA: CRC Press; 2002. p. 1. ISBN: 0-8493-9882-7

[11] Harris MP. Breeding ecology of swallow–tailed Gull (*Creagrus furcatus*). Auk. 1970; **87**:215-243

[12] Dunnet GM, Yarrall JW, Mills DA. A 28 year study of breeding fulmars *Fulmars glacialis* in Orkney. IBIS. 1996;**121**:293-300

[13] Mills JA, Yarrall JW, Mills DA. Causes and consequences of mate fidelity in red bill gulls. In: Black JM, editor. Partnerships in Birds. The Study of Monogamy. Oxford: Oxford University Press; 1996. pp. 286-304

[14] Place AR, Stoyan NC, Ricklefs RE, Butler RG. Physiological basis of stomach oil formation in Leach's storm petrel (*Oceanodroma leucorhoa*). Auk. 1989;**106**:687-699

[15] Schreiber EA. Experimental manipulation of feeding in red-tailed tropicbird chicks. Colonial Waterbirds. 1996;**19**:45-55

[16] Enticott J, Tipling D. Photographic Handbook of the Seabirds of the World. London: New Holland; 1997

[17] Coulson JC, Thomas CS. Mate choice in the kittiwake Gull. In: Bateson P, editor. Mate Choice. Cambridge: Cambridge University Press; 1983

[18] Burger J, Gochfeld M. Black Skimmer: Social Dynamics of a Colonial Species. New York: Columbia University Press; 1991. p. 355

[19] Cohen BL, Baker AJ, Belechschmidt K, Dittmann DL, Furness RW, Gerwin JA, Helbig AJ, De Korte J, Marshall HD, Palma RL, Peter H-U, Ramli R, Siebold I, Willcox MS, Wilson RH, Zink RM. Enigmatic phylogency of skuas (Aves: Stercorariidae). Proceedings of the Royal Society of London B. 1997;**264**:181-190

[20] Cohen BL, Baker AJ, Belechschmidt K, Dittmann DL, Furness RW, Gerwin JA, Helbig AJ, De Korte J, Marshall HD, Palma RL, Peter H-U, Ramli R, Siebold I, Willcox MS, Wilson RH, Zink RM. Enigmatic phylogency of skuas (Aves: Stercorariidae). Proceedings of the Royal Society of London B. 1997;**264**:181-190

[21] Schreiber EA, Burger J. Seabirds in the marine environment. In: Schreiber EA, Burger J, editors. Biology of Marine Birds. USA. ISBN: 0-8493-9882-7: CRC Press, Washington DC; 2002. p. 1

[22] Schreiber EA. Experimental manipulation of feeding in red-tailed tropicbird chicks. Colonial Waterbirds. 1996;**19**:45-55

[23] Prince PA, Ricketts C. Relationships between food supply and growth in albatrosses: An interspecies chick fostering experiment. Ornis Scandinavica. 1981;**12**:207-210

[24] Couper–Johnston, R. The Weather Phenomenon that Changed the World: El Nino. London: Hodder and Stoughton; 2000

[25] Brooke ML. Seabird systematics and distribution: A review of current knowledge. In: Biology of Seabird; 2004. pp. 57-85

[26] Shaffer S, Tremblay Y, Weimerskirch H, Scott D, Thompson D, Sagar P, et al. Migratory shearwaters integrate oceanic resources across the Pacific Ocean in an endless summer. Proceedings of the National Academy of Sciences. 2006;**103**:12799

[27] Heubeck M, Mellor RM, Harvey PV, Mainwood AR, Riddington R. Estimating the population size and rate of decline of kittiwakers *Rissa tridactyla* breeding in Shetland, 1981-97. Bird Study. 1999;**46**:8-61

[28] Oro D, Pradel R, Lebreton J-D. The effects of nest predation and food availability on life history traits in Audouin's gull. Oecologia. 1999;**119**:438-445

[29] Oro D, Furness RW. Influence of food and predation on survival of kittiwakes. Ecology. 2002;**83**:2516-2528

[30] Shaffer S, Weimerskirch H, Scott D, Pinaud D, Thompson D, Sagar P, et al. Spatiotemporal habitat use by breeding sooty shearwaters Puffinus griseus. Marine Ecology Progress Series. 2009;**391**:209-220

[31] Raymond B, Shaffer S, Sokolov S, Woehler E, Costa D, Einoder L, et al. Shearwater foraging in the Southern Ocean: The roles of prey avaialability and winds. PLoS One. 2010;**5**:e10960

[32] Weimerskirch H, Louzao M, de Grissac S, Delork K. Changes in wind pattern alter albatross distribution and life history traits. Science. 2012;**335**:211-214

[33] Nelson B. Seabirds: Their Biology and Ecology. New York: A & W Publishers; 1979

[34] Carignan V, Villard M-A. Selecting indicator species to monitor ecological integrity: A review. Environmental Monitoring and Assessment. 2002;**78**:45-61

[35] Piatt J, Sydeman W, Wiese F. Introduction: A modern role for seabirds as indicators. Marine Ecology Progress Series. 2007;**352**:1999-1204

[36] Wayland M, Gilchrist HG, Marchant T, Keating J, Smith JE. Immune function, stress response and body condition in artic-breeding common eiders in relation to cadmium, mercury, and selenium concentrations. Environmental Research. 2002;**90**:47-60

[37] Helander B, Bigneri A, Asplund L. Using raptors as environmental sentinels: Monitoring the White-Tailed Sea eagle *Haliaeetus albicilla* in Sweden. Ambio. 2008;**37**:425-431

[38] Henny CJ, Crove RA, Kaiser JL, Johnson BL. North American osprey populations and contaminants: Historic and contemporary perspectives. Journal of Toxicology and Environmental Health-Part B-Critical Review. 2010;**13**:579-603

[39] Sonne C, Bustnes Jo, herzke D, Jaspers VLB, Covaci A, Halley DJ, Moum T, Eulares I, Eens M, Ims RA, Hanssen SA, Erikstade KE, Johsen T, Schnug I, Riget FF, Jensen AL. Relationship between organhalogen contaminants and blood plasma clinical-chemical parameters in chicks of three raptor species from northern Norway. Ecotoxicology and Environmental Safety. 2011;**73**:7-17

[40] Sanpera C, Ruiz X, Moreno R, Jover L, Waldron S. Mercury and stable isotopes in feathers of Audouin's gulls as indicators of feeding habits and migratory connectivity. Condor. 2007;**109**:268-275

[41] Moreno R, Jover I, Munilla I, Velando A, Sanpera C. Seabird's feathers as monitors of the levels and persistence of heavy metal pollution after the prestige oil spill. Environmental Pollution. 2010;**159**:2454-2460

[42] Corsolini S, Borghesi N, Ademollo N, Focardi S. Chlorinated biphenyls and pesticides in migrating and resident seabirds from east and West Antarctica. Environmental International. 2011;**37**:1329-1335

[43] Jeraz S, Motas M, Jose Palacois M, Valera F, Javier Cuervo J, Barbosa A. Concentration of traces elements in feathers of three Antarctic penguins: Geographical and interspecific differences. Environmental Pollution. 2011;**159**:2412-2419

[44] Metcheva R, Yurukova L, Teodora SE. Biogenic and toxics elements in feathers, eggs, and excreta of Genitoo penguin (*Pygoscelis papua eliswarthii*) in the Antarctic. Environmental Monitoring and Assessment. 2011;**182**:571-585

[45] Abdennadher A, Ramirez F, Romdhane MS, Ruiz X, Jover L, Sanpera C. Little egret (Egretta garzetta) as a bioindicators of trace elements pollution in Tunisian aquatic ecosystems. Environmental Monitoring and Assessment. 2011;**175**:677-684

[46] Aliakbari A, Savabieasfahani M, Ghasempouri SM. Mercury in egg and eggshell of whiskered tern (Chlidonias hybrid) from Anzali wetlands of Caspian Sea, Iran. Bulletin of Environmental Contamination and Toxicology. 2011;**86**:175-179

[47] Hoegh-Guldberg O, Bruno JF. The impact of climate change on the world's marine ecosystems. Science. 2007;**328**:1523-1528

[48] Velarde E, Ezcurra E, Anderson DW. Seabird diet provides early warning of sardine fishery decline in the Gulf of California. Scientific Reports. 2013;**3**:1332

[49] Champoux L, Rodrigue J, Trudeau S, Boily MH, Spear PA, Honetla A. Contamination and biomarkers in the great blue heron, an indicator of the state of the St. Lawrence River. Ecotoxicology. 2006;**15**:83-96

[50] Paiva VH, Tavares PC, Ramos JA, Pereira E, Antunes S, Duarte AC. The influence of diet on mercury intake by little tern chicks. Archives of Environmental Contamination and Toxicology. 2008;**55**:317-328

[51] Baker SD, Sepulveda MS. An evaluation of the effects of persistent environmental contaminants on the reproductive success of great blue herons (Ardea Herodias) in Indiana. Ecotoxicology. 2009;**18**:271-280

[52] ICES 2003. Seabirds as Monitors of the Marine Environment. Tasker ML, Furness RW. editors. ICES Cooperative Research Report, 258. 73 pp

[53] Thompson DR, Bearhop S, Speakman JR, Furness RW. Feathers as a means of monitoring mercury in seabirds: Insight from stable isotope analysis. Environmental Pollution. 1998;**101**:193-200

[54] Montevecchi WA. Birds as indicators of change in marine prey stocks. In: Furness WR, Greenwood JJD, editors. Birds as Monitors of Environmental Change. Chapman and Hall London; 1993. pp. 217-266

[55] Booth BP. Southern Vancouver Island Marine Waters and Seabird Islands Important Bird Areas Conservation Plan. Can. Nature Fed., Bird Studies Can., Fed. of BC Naturalists, Wild Bird Trust BC; 2001. p. 34

[56] Furness RW, Tasker ML. Seabird-fishery interactions: Quantifying the sensitivity of seabirds to reductions in sand eel abundance and identification of key areas of sensitive seabirds in the North Sea. Marine Ecology Progress Series. 2000;**202**:253-264

[57] Michael B, Birkhaead T, editors. Cambridge Encyclopaedia of Ornithology, a Cambridge Reference Book. Cambridge University Press; 1991 ISBN: 10:0521362059

[58] Williams TD. The Penguins: Spheniscidae. Oxford University Press. Edition: Illustrated. ISBN: 9780198546672; 1995. p. 295

[59] Hebshi AJ, Duffy DC, Hyrenbach KD. Association between seabirds and sub-surface predators around Oahu, Hawaii. Aquatic Biology. 2008;**4**:89-98

[60] Nevitt GA, Losekoot M, Weimerskirch H. Evidence for olfactory search in wandering albatross, Diomedea exulans. Proceedings of the National Academy of Sciences. 2008;**105**:4576-4581

[61] Furness RW. Impacts of fisheries on seabird communities. Scientia Marina. 2003;**67**:33-45

[62] Burger AE, Piatt JF. Flexible time budgets in breeding common Murres: Buffers against variable prey abundance. Studies in Avian Biology. 1990;**14**:71-83

[63] Brooke M de L, Prince PA. Nocturnality in seabirds. Proceedings of the International Ornithological Congress. 1991;**20**:1113-1121

[64] Croll DA, Gaston AJ, Burger AE, Konnoff D. Foraging behaviour and physiological adaptation for diving in thick-billed Murres. Ecology. 1992;**73**:344-356

[65] Hertel F, Balance LT. Wing ecomorphology of seabirds from Johnston atoll. Condor. 1999;**1010**:549-556

[66] Watanuki Y, Burger AE. Body mass and drive duration in alcids and penguins. Canadian Journal of Zoology. 1999;**77**:1838-1842

[67] Green B, Brothers N. Water and sodium turnover and estimated food consumption rates in free-living fairy prions (Pachyptila turtur) and common diving petrels (Pelecanoides urinatrix). Physilogical Zoology. 1989;**62**:702-705

[68] Garthe S. Influence of hydrography, fishing activity and colony location on summer seabird distribution in the south-eastern North Sea. ICES Journal of Marine Science. 1997;**54**:566-577

[69] Camphuysen CJ, Webb A. Multi-species feeding associations in North Sea seabirds; jointly exploiting a patchy marine environment. Ardea. 2000;**87**:177-198

[70] Huppop O, Wurm S. Effects of winter fishery activities on resting numbers, food and body conditions of large gulls *Larus argentatus* and *L. marinus* in southeastern North Sea. Marine Ecology Progress Series. 2000;**194**:241-247

[71] Tasker ML, Camphuysen CJ, Cooper J, Garthe S, Montevecchi WA, Blaber SJM. The impacts of fishing on marine birds. ICES Journal of Marine Science. 2000;**57**:531-547

[72] Baker B, Gales R, Hamilton S, Wilkinson V. Albatrosses and petrels in Australia: A review of their conservation and management. EMU. 2002;**102**:71-97

[73] Tuck GN, Polacheck T, Bulman CM. Spatio–temporal trends of longline fishing effort in the Southern Ocean and implications for seabird bycatch. Biodiversity and Conservation. 2003;**114**:1-27

[74] Skagen SK, Knight RL, Orians GH. Human disturbances on avian scavenging guil. Ecological Applications. 1991;**1**:215-225

[75] Moul IE. Population trends of double-crested and pelagic Cormorants nesting along the South-east coast of Vancouver Island. Ministry of Environment Lands and Parks, Nanaimo Report; 2000

[76] Vennesland RG. The effects of disturbance from humans and predators on breeding decisions and productivity of the Great Blue Heron in South-coastal British Columbia. MSc Thesis. Burnaby: Simons Fraser University; 2000

[77] Irons DB, Kendall SJ, Erickson WP, McDonald LL, Lance BK. Nine years after the Exxon Valdez oil spills: Effects on marine bird populations in Prince William sound, Alaska. Condor. 2000;**102**:723-737

[78] Wiese FK, Robertson GJ. Assessing seabird mortality from chronic oil discharge at sea. Journal of Wildlife Management. 2004;**68**:627-638

[79] Votier SC, Birkhead TR, Oro D, Trinder M, Grantham MJ, Clark JA, McCleery RH, Hatchwell BJ. Recruitment and survival of immature seabirds in relation to oil spills and climate variability. Journal of Animal Ecology. 2008;**77**:974-983

[80] Balseiro A, Espi A, Marquez I, Perez V, Ferreras C, Marin JFG, Prieto JM. Athological features in marine birds affected by the prestige oil spills in the north of Spain. Journal of Wildlife Diseases. 2005;**41**:371-378

[81] Perez C, Velando A, Munilla I, Lopez-Alonso M, Oro D. Monitoring PAH pollution in the marine environment after the prestige oil–spill by means of seabird blood analysis. Environmental Science and Technology. 2008;**42**:707-713

[82] Munilla I, Velando A. Oiling of live gulls as a tool to monitor acuteoil spill effects on seabirds. IBIS. 2010;**152**:405-409

[83] Velando A, Munilla I, Lopez-Alonso M, Freire J, Perez C. EROD activity and staple isotopes in seabirds to disentangle marine food web contamination after the prestige oil spill. Environmental Pollution. 2010;**158**:1275-1280

[84] Munilla I, Arcos JM, Oro D, Alvarez D, Leyenda PM, Velando A. Mass mortality of seabirds in the aftermath of the prestige oil spills. Ecosphere. 2011;**2**(7):art83

Chapter 5

Between the Land and Sea: How Yellow-Legged Gulls Have Changed Their Dependence on Marine Food in Relation to Landfill Management

Juan Arizaga, Nere Zorrozua and Alexandra Egunez

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.74821

Abstract

The Basque region (Spain) is closing all its open-air landfills, which hence provides an excellent chance to account for the effects on the trophic and spatial ecology of the local yellow-legged gulls *Larus michahellis*, which highly depend on refuse tips to forage. The closure of several landfills across the region was mainly compensated by a higher intake of terrestrial food (mainly earthworms), though only in summer. The exploitation of terrestrial prey was marginal in winter, and seasonal trophic differences emerged, unlike findings when landfills were still open. With only one landfill now open in theory, movement and territory use analyses showed that two landfills were frequently visited. Positions at two of the target foraging habitats (landfills, pastures) summed ca. 10% of all stationary positions suggesting that, at least in these habitats, gulls seemed to invest a relatively small amount of time, which might support the idea that they were able to obtain food in a fast way and, probably, from resources that they know well and have a predictable temporal distribution.

Keywords: *Larus michahellis*, refuse tips, seabirds, spatial ecology, stable isotopes, trophic ecology

1. Introduction

Many species of gulls take great profit from exploiting feeding sources of human origin all around the world, such as fish discards or refuse tips [1–3]. When such resources are abundant and predictable over time, they can have a very deep impact into population parameters like survival [4], breeding performance [5, 6], or dispersal [7, 8].

The current European policy on refuse management previews to close all open-air landfills by 2020. This entails that many gull populations with high dependence on this resource will suffer severe declines in one of their main preys, with expected impacts on several life history aspects, from diet to spatial ecology or demography. At regional levels, the implementation of such policies provides us an excellent scenario to test for the effect of this change and evaluate the capacity of such species to rapidly adapt to the new environment.

The Basque region in northern Iberia is closing all its open-air landfills [8], which hence provides a good chance to account for the effects of this process on the diet and territory use of the local yellow-legged gulls *Larus michahellis*. The population of this species within the region reached a size of up to ca. 5600 adult breeding pairs during the decade of 2000, though, today, the population has probably less than 3000 pairs (J. Arizaga, unpubl. data), with moderate-[9] to-strong [10] decreases in most colonies.

When the use of landfills was generalized within the region, an important part of the diet was based on refuse food, and the rest was mainly fish or food of marine origin, while just ca. 10% of the diet comprised food of terrestrial origin, mainly earthworms [3]. During the decade of 2010, however, the number of active landfill sites has reduced quite consistently. Thus, in a winter coinciding with local landfill sites either closed or using falconry to deter gulls access to refuse tips, gulls were found to travel longer distances [7]. This suggests that they were forced to look for food in further distant places, which might also entail trophic changes.

The aim of the chapter is to determine how diet and territory use of a resident yellow-legged gull population has changed between two periods characterized by high and virtually low availability of food of landfill origin. For the second period, we also want to test if marine food has now more importance in the diet than before [11], that is, whether the marine environment is able to absorb a trophic demand that landfills virtually are not.

2. Material and methods

2.1. Sampling area

Results provided in this chapter were collected in the Gipuzkoa province, northern Iberia. Today, this region hosts a total of 5 colonies with a population size slightly inferior to 1000 adult breeding pairs overall. Of these, the sampling was carried out in three colonies which are the most important ones (from east to west): Ulia, Santa Clara and Getaria (**Figure 1**). All the colonies are situated in marine cliffs of similar characteristics. The population at Getaria and Santa Clara has an uncertain trend (possibly stable), while the one at Ulia is estimated to be in decline [12].

As reported in **Figure 1**, the colonies are situated either close to fishing harbors or landfills. By far, the most important harbor within the region is situated in Getaria, while, in theory, all landfills have been closed and only one (Zaluaga), situated in a nearby region from France,

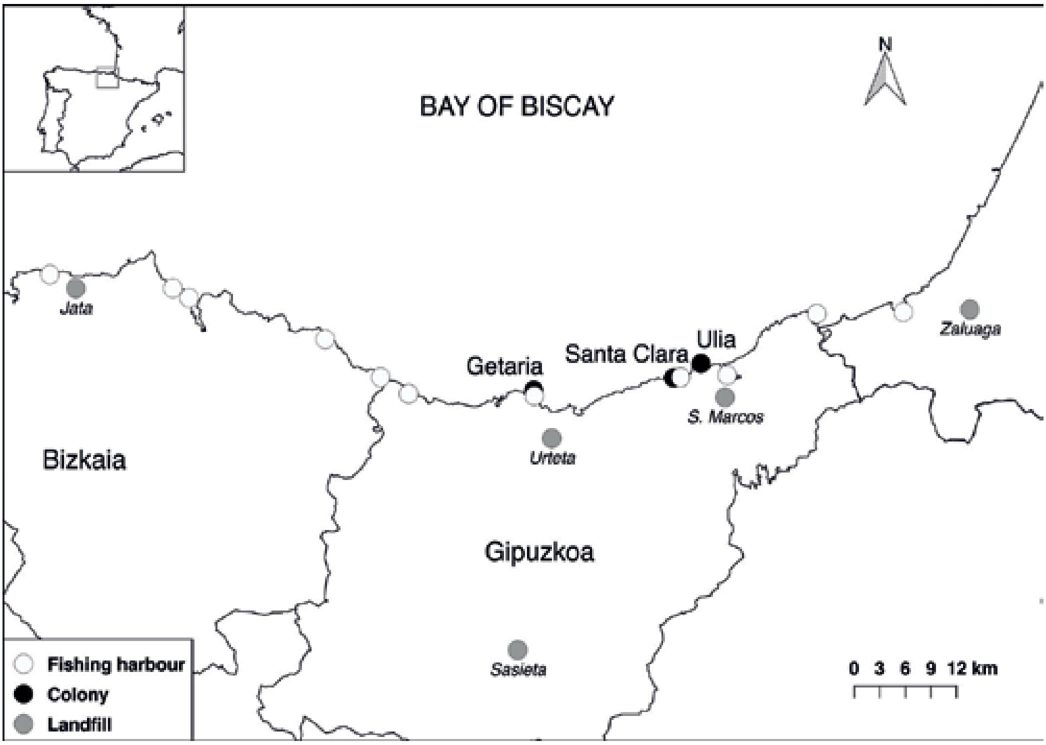

Figure 1. Geographical distribution of the colonies analyzed, and the main trophic sources (fishing harbors and landfills) existing within the region were the focus of the study and it was carried out from 2007 to 2016.

remains open (**Figure 1**). This last landfill site is known by attracting large numbers of several bird species, including gulls [13].

Regarding landfills, we considered in this study those situated within a radius of 75 km around our target colonies, since most local yellow-legged gulls do not move farther away during their whole life [7] and where marked gulls have been located. Included landfills were S. Marcos, Urteta, Zaluaga, Sasieta and Jata (**Figure 1**). Overall, these five dumps accumulated a mean annual amount of ca. 286,292 tons (**Table 1**). From a landfill management standpoint, two periods can be drawn: one with high food availability, when all these landfill sites within

Landfill	Period closed	Mean annual discharge (Tn)
S. Marcos	Since Oct. 2008	68,896
Urteta	Since Dec. 2014 (falcon: Dec. 2009–Dec. 2014)	91,079
Sasieta	Since Jan. 2015 (falcon: 2014)	71,086
Jata	Since Dec. 2013 (temporally re-open in Feb. 2016)	14,638
Zaluaga	Open (falcon: Oct. 2010–Jan. 2011) (deter works: since 2013)	40,593

Table 1. Characteristics of the five landfill sites existing within the region (around a 75 km radius from the colonies analyzed).

the region were open, and another one when most of the sites had been closed and only one/ two remained open (but used falconry or other deterring tools).

2.2. Data collection

The sampling protocol consisted of (1) collecting feathers from chicks and adults in order to estimate their diet with stable isotopic analyses and (2) attaching GPS devices in adults in order to analyze their spatial behavior and territory use.

Throughout the breeding season of 2007–2009 and 2014–2016, both chicks and adults were captured in the colonies for the collection of body (chicks) or wing (adults) feathers for the corresponding stable isotope analysis. Chicks were caught by hand at the age of ca. 20 days [14]. In total, 4–6 dorsal (mantle) feathers were taken and their body mass and tarsus length were also measured. In order to avoid possible pseudo-replications, we only considered one chick per nest. Adults were captured using spring traps while incubating. We took from them two wing feathers: the inner, first primary feather (P1) (it grows just after breeding and hence has isotopic values reflecting the diet during the preceding reproductive period) and the secondary S6 (grown in autumn-winter, thus reflecting the diet during the previous non-breeding period). In case they had already molted one of such feathers (usually P1), the next non-molted feather was taken. While chicks were sampled for the entire period (years 2007–2009 and 2014–2016), adults were only sampled in the years 2008–2010 and 2016. Feathers were stored in paper bags until they were analyzed in a laboratory (see below for details).

Regarding spatial ecology, overall, we captured using spring traps a total of 15 adult birds when they were incubating in 2017. Once captured, they were attached with a prototype GPS device provided by Wimbitek, S.L. This device was linked to the bird with a hand-made Teflon harness. The weight of the GPS was always less than 5% of the bird's body mass. GPS was programmed in order to obtain a location every 30 min from 06:30 to 22:30 (GMT + 1), with two more positions at night (01:00 and 04:00).

2.3. Stable isotope analysis and mixing models

We used $\delta^{13}C$ and $\delta^{15}N$ signatures for the stable isotopic analyses. The methodology used for that goal was described in detail in Arizaga et al. [3] and was the same for the period 2007–2009 and 2014–2016 in order to obtain comparable results. Feathers were washed in a solution of 1 M NaOH, dried (60°C) to be homogenized into fine powder with an impactor mill (freezer/mill 6750-Spex Certiprep) operating at liquid nitrogen temperature. Weighed subsamples of such powdered feathers (ca. 0.3 mg) were put in tin capsules and isotopic analysis was carried out with an elemental analysis-isotope ratio mass spectrometry (EA-IRMS) using a Thermo Finnigan Flash 1112 coupled to a delta isotope ratio mass spectrometer via ConFlo III interface. Analyses were carried out at the Serveis Científico Tècnics [Technic Scientific Service], University of Barcelona.

To assess for the relative contribution of each resource category, we conducted a Bayesian multi-source mixing model (stable isotopic analyses in R: SIAR) [15]. Overall, we considered three prey types: landfill, marine, and terrestrial. Diet reconstruction in SIAR models was

Prey category	*n*	$\delta^{13}C$	$\delta^{15}N$
Terrestrial[a]	5	−23.84 ± 2.90	+8.86 ± 2.82
Landfill[b]	3	−21.12 ± 1.17	+4.35 ± 1.88
Marine[c]	8	−18.04 ± 0.65	+11.14 ± 1.87

Table taken from Arizaga et al. [3].
[a]Includes: annelids (earthworms), mollusks (family *Arionidae*).
[b]Pork, beef, and chicken.
[c]Fish prey of both benthic and pelagic origin.

Table 2. Isotopic signatures (mean ± 95% confidence interval) of three prey types obtained from regurgitates of yellow-legged gull chicks in Gipuzkoa.

carried out considering the isotopic signatures of prey obtained from regurgitates (**Table 2**). SIAR results have been presented at 95, 75, and 50% credible intervals for the three types of feeding sources considered. Statistical analyses were done in R [16].

2.4. Movement and territory use analyses

We used for such analyses data on 8 out of the 15 gulls marked. This was due to the fact that some devices did not provide enough data for the analyses or due to the abandonment of the colony before the end of the breeding season. Selected individuals, therefore, were those shown to remain in the colony for the entire breeding season and with a high amount of data for the analyses (**Table 3**).

Our GPS devices did not provide information on whether the bird was flying or was in a stationary position (feeding, resting, …). Thus, in order to know whether the bird was in the air or whether it had landed, we considered locations in which the bird was found in less than 500 m from the previous location as stationary. The remaining locations were considered as flying.

Bird ID	Colony	Sex	Capt. date	Last date with data	No. positions	Max. distance (km)
ID 02	Ulia	M	17/05/17	15/07/17	777	41.2
ID 05	Ulia	M	23/05/17	03/06/17	204	32.5
ID 09	Ulia	F	23/05/17	15/07/17	2345	47.2
ID 11	Santa Clara	M	13/06/17	15/07/17	1059	36.0
ID 12	Getaria	F	02/06/17	22/06/17	578	35.0
ID 13	Getaria	M	03/06/17	15/07/17	1818	55.0
ID 14	Getaria	F	02/06/17	15/07/17	1511	33.3
ID 15	Getaria	M	02/06/17	15/07/17	1906	68.6

Analyses were constrained to data obtained up to 15 July (here assumed to be the end of the breeding season).

Table 3. Data provided by the selected adult yellow-legged gulls marked with GPS.

Every stationary position was attached to a single habitat using CORINE land cover. Thereafter, original habitats were lumped into 11 categories: marine (positions over the sea), landfill, pastures, colony, forest, bare soil, harbor, beach, marsh, river and urban.

Finally, we also determined the distance to all positions (either in flight or stationary) to the colony.

3. Results

3.1. Trophic ecology

Mixing models on C and N signatures of chicks revealed a slight- (marine prey, from >40 to <40%) to-moderate (landfill prey; from 40 to ca. 20%) decrease in the proportion of prey of marine or refuse origin between the periods 2007–2009 and 2014–2016 (**Figure 2**). In parallel, we also detected a remarkable increase (from <20 to ca. 40%) of prey of terrestrial origin (**Figure 2**).

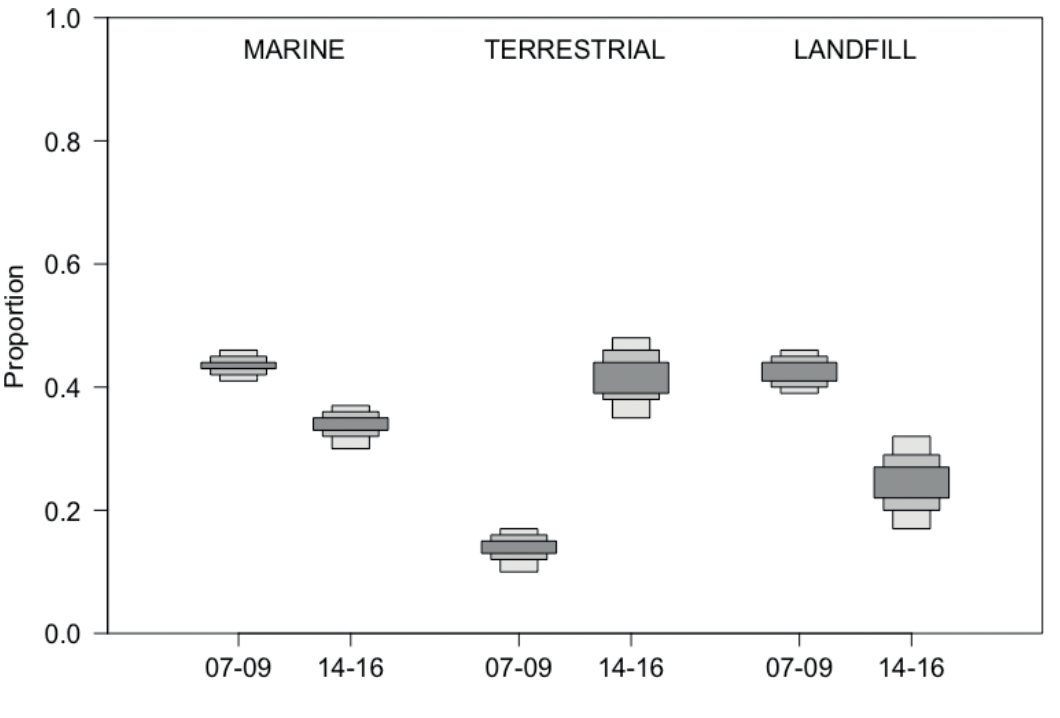

Figure 2. Mean (±95, 75, and 50% credibility intervals) proportion of prey type contribution to chicks' diet between two periods of high (2007–2009; n = 172) and low (2014–2016; n = 80) availability of prey of landfill origin.

http://dx.doi.org/10.5772/intechopen.74821

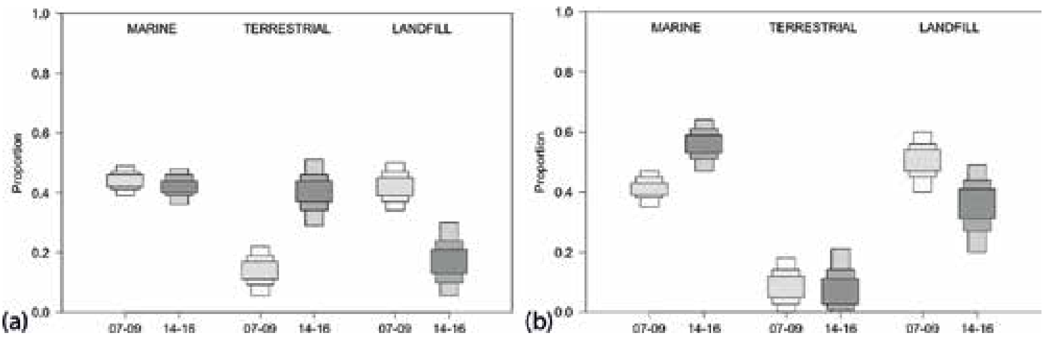

Figure 3. A. Mean (±95, 75 and 50% credibility intervals) proportion of prey type contribution to adults' diet between two periods of high (2007–2009; n = 36) and low (2014–2016; n = 33) availability of prey of landfill origin in summer time. B. Mean (±95, 75 and 50% credibility intervals) proportion of prey type contribution to adults' diet between two periods of high (2007–2009; n = 36) and low (2014–2016; n = 33) availability of prey of landfill origin in winter time.

Regarding adults, a pattern like that was found in their offsprings, which was detected for the summer period (**Figure 3**), highlighting the importance of prey of terrestrial origin during the 2014–2016 period. The estimation of the diet in winter, however, fitted to another pattern (**Figure 3**). In this period, the diet was enriched in prey of marine origin during the period 2014–2016 as compared to 2007–2009 (up to ca. 60%) and became poorer in prey of landfill origin (up to ca. 40%). The amount of prey of terrestrial origin did not vary substantially between the two periods and in both was very low (<10%).

3.2. Spatial ecology

The eight adult gulls marked in 2017 used an area comprising the coast and marine areas situated close to their breeding colonies, some inland places also situated near the colonies and some clear ways connecting the colonies with the main landfills within the region (**Figure 4**). Overall, these birds moved across a mean home range area of 711.5 (SE = 182.6) km^2 (95% kernel polygons). The 50% kernel polygons, however, revealed much smaller home ranges (51.4 ± 15.5 km^2).

Concerning the territory use, the majority (ca. 60%) of stationary positions were obtained at the colonies, followed by marine habitats (ca. 20%), urban zones (ca. 10%), and pastures and landfill sites (ca. 5% each) (**Figure 5**). Field observations show that the urban zones are used mostly for rest (e.g., roosting places at industrial buildings or pavilions, etc.), while pastures and landfill sites constitute foraging habitats. Sea areas would be used both to feed and rest (*sensu lato*, including sleeping, preening, etc.).

Distance from the colony tended to increase around midday (**Figure 6**). Positions at night or during both the first hours and the last ones of the day were detected at a mean distance of ca. 10 km. Moreover, males were found to reach shorter mean distances (8.2 km, SE = 1.0 km) than females (12.4 ± 4.3 km), but the difference was non-significant (t = 0.485, P = 0.628).

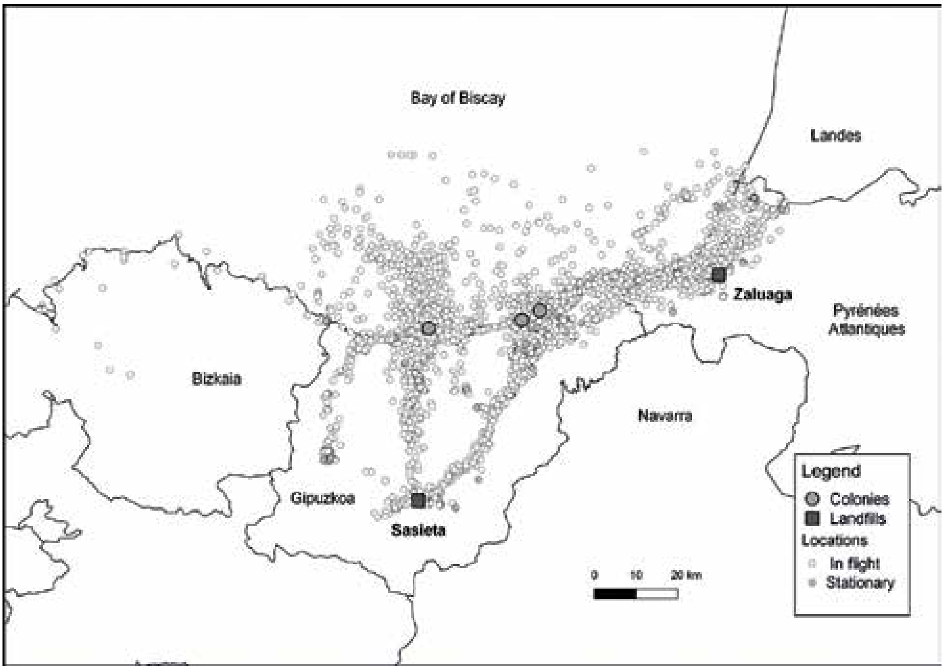

Figure 4. Geographic distribution (as provided by GPS devices) of adult yellow-legged gulls (n = 8) during breeding season of 2017. Adults were caught and marked at three colony sites in Gipuzkoa. The main still existing landfill sites within the region are Zaluaga and Sasieta (the last is theoretically closed).

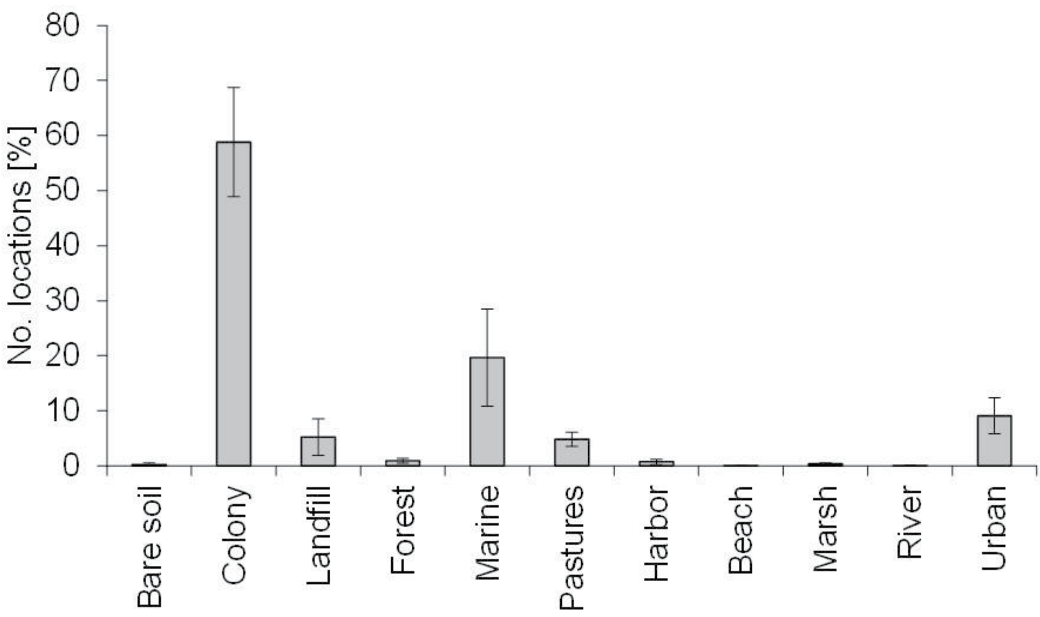

Figure 5. Mean (±SE) number of stationary positions of adult yellow-legged gulls during breeding period within each habitat type.

http://dx.doi.org/10.5772/intechopen.74821

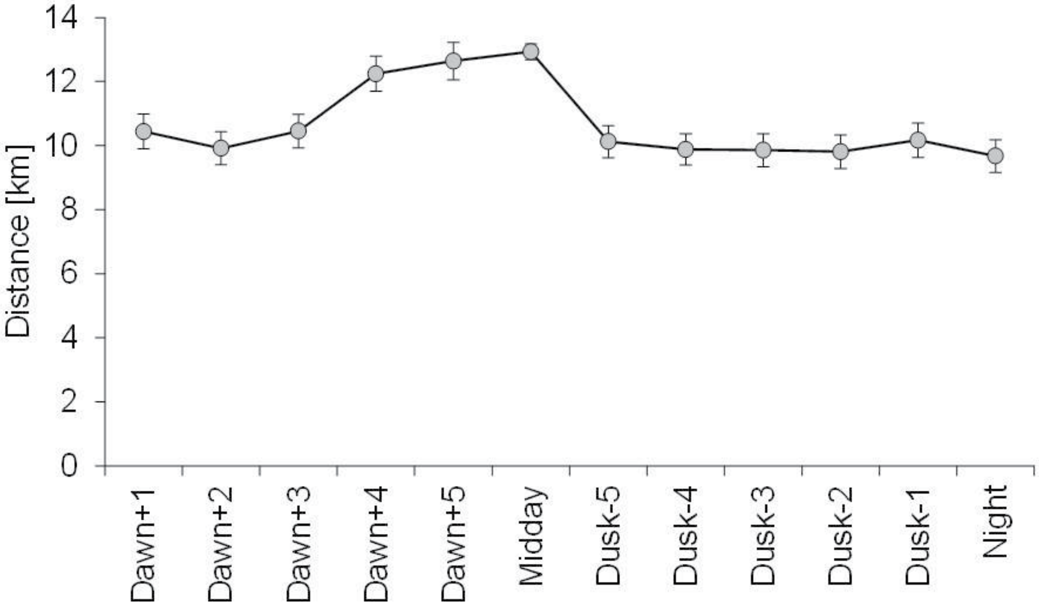

Figure 6. Mean (±SE) distance to the origin colony of adult yellow-legged gulls during breeding period and in relation to the hour of the day (dawn+1 stands for the first hour after dawn; data around midday and at night are shown pooled).

4. Discussion

The closure of open-air landfill sites in Europe is expected to have a deep impact on opportunistic species exploiting this resource, and our experience from a resident yellow-legged gull population within a region in northern Iberia reflects relevant changes in trophic ecology. When the use of open-air landfills was a widespread phenomenon within the region (period 2007–2009), ca. 40–60% of the diet was based on food of landfill origin. However, during the period 2014–2016, mixing models revealed that the proportion of this resource in the diet fell up to 20–40%, both in summer and in winter, in chicks and adults. This decrease in the importance of refuse food on the diet was compensated by a higher consumption of prey of marine origin in winter (from ca. 40 to 60%), but not in summer time, when both chicks and adults tended to forage on prey of terrestrial origin (ca. 40%, as compared to ca. 10% during the period 2007–2009). Thus, the response provided by local gulls to an apparently relevant shortage in what was one of their main preys (refuse food) varied seasonally and revealed high plasticity in the use and exploitation of alternative feeding sources.

Diet reconstruction suggests that adults forage on a higher proportion of terrestrial prey during summer but, interestingly, not in winter. In this last season, gulls were found to still forage on a higher proportion of landfill (as far as they can) as well as marine prey, probably by reaching foraging places situated at longer distances and/or that cannot be used in summer, when adults must feed their chicks; hence, they cannot look for food if this is situated too far [17]. In addition, in winter, earthworms become less accessible, hence forcing gulls to exploit a smaller range of feeding sources. Results from spatial analyses confirm the presence of local breeding gulls on pastures in summer, where field observations indicate intense foraging at this habitat type.

Movement and territory use analyses also showed that two of the landfill sites existing within the region were visited very frequently. Even though one of these is still open and in use (Zaluaga), the other one (Sasieta) is closed, in theory. The high number of data (positions) from this last landfill site suggests that some food must be available in the zone [18], which might be because in practice the landfill was active [19] or because food from past times was still available.

Habitat partitioning analysis revealed that positions at two of the target foraging habitats (landfills, pastures) summed ca. 10% of all the detected stationary positions. This suggests that, at least in these habitats, gulls seemed to invest a relatively small amount of time, which might support the idea that they were able to obtain food in a fast way and, probably, from resources that they know well and have a predictable spatial distribution. By contrast, the number of positions in the sea was much higher (20%). Even though a fraction of such positions may not correspond with foraging activity (but resting, sleeping and preening), others would reveal active foraging [20].

Daily patterns of distance from the colony had an expected unimodal curve, since positions around midday were situated at a mean longer distance than positions during other parts of the day. However, early and late positions during the day, as well as positions at night, were found at a mean distance of 10 km, which is an unexpected result, since birds at that time should be expected to be at the colony (incubation, chicks' attendance, etc.). Causes explaining such results are unknown to us; hence, we can no more than attempt some possible hypotheses. Thus, foraging outside daylight periods cannot be rejected, since gulls have been reported to feed very actively at night [21], for example, when they follow fishing vessels or use the high amount of light around the cities. Due to data selection carried out before the spatial analyses, it is less likely that some birds might abandon the nest and, therefore, would start to exploit areas further away from the colonies and even sleep in other places.

In conclusion, the closure of several landfill sites across the region where the study was carried out was mainly compensated by a significantly higher intake of food of terrestrial origin (mainly earthworms), and not of marine origin, though only in summer. The exploitation of terrestrial prey tended to be very marginal in winter and seasonal trophic differences emerged, unlike the lack of seasonal dietary variations found in the previous period when landfills were open. The fact that earthworms in winter become less accessible and that gulls would be able to exploit resources farther from the colony may explain such seasonal variations observed after landfill closure.

Acknowledgements

This research was partly funded by the Gipuzkoa Administration and the Basque Government. The Gipuzkoa Administration provided us the permits to take the feather samples and

http://dx.doi.org/10.5772/intechopen.74821

capture and attach the GPS devices. N. Zorrozua benefited from a fellowship of the Basque Government and A. Egunez from a fellowship of the Gipuzkoa Administration. We are grateful for the help provided by the members of the Txingudi Ringing Station, Aranzadi Sciences Society, especially to A. Aldalur and A. Herrero.

Author details

Juan Arizaga*, Nere Zorrozua and Alexandra Egunez

*Address all correspondence to: jarizaga@aranzadi.eus

Department of Ornithology, Aranzadi Sciences Society, Zorroagagaina, Donostia, Spain

References

[1] Bertellotti M, Yorio P, Blanco G, Giaccardi M. Use of tips by nesting Kelp Gulls at a growing colony in Patagonia. Journal of Field Ornithology. 2001;**72**:338-348

[2] Ramos R, Ramirez F, Sanpera C, Jover L, Ruiz X. Diet of yellow-legged gull (*Larus michahellis*) chicks along the Spanish Western Mediterranean coast: The relevance of refuse dumps. Journal of Ornithology. 2009;**150**:265-272

[3] Arizaga J, Jover L, Aldalur A, Cuadrado JF, Herrero A, Sanpera C. Trophic ecology of a resident yellow-legged gull (*Larus michahellis*) population in the Bay of Biscay. Marine Environmental Research. 2013;**87-88**:19-25

[4] Newton I. Population Limitation in Birds. London: Academic Press; 1998

[5] Duhem C, Bourgeois K, Vidal E, Legrand J. Food resources accessibility and reproductive parameters of Yellow-legged Gull Larus michahellis colonies. Revue D Ecologie-La Terre Et La Vie. 2002;**57**:343-353

[6] Belant JL, Ickes SK, Seamans TW. Importance of landfills to urban-nesting herring and ring-billed gulls. Landscape and Urban Planning. 1998;**43**:11-19

[7] Arizaga J, Aldalur A, Herrero A, Cuadrado J, Díez E, Crespo A. Foraging distances of a resident yellow-legged gull (*Larus michahellis*) population in relation to refuse management on a local scale. European Journal of Wildlife Research. 2014;**60**:171-175

[8] Egunez A, Zorrozua N, Aldalur A, Herrero A, Arizaga J. Local use of landfills by a yellow-legged gull population suggests distance-dependent resource exploitation. Journal of Avian Biology. 2018 (in press)

[9] Arizaga J, Aldalur A, Herrero A. Tendencia poblacional en tres colonias de gaviota patiamarilla *Larus michahellis* Naumann, 1840 en Gipuzkoa: 2000-2013. Munibe. Sociedad de Ciencias Naturales Aranzadi (San Sebastian). 2014;**62**:61-69

[10] Galarza A. ¿Está disminuyendo la población de gaviota patiamarilla cantábrica *Larus michahellis lusitanius* Naumann, 1840? Censo 2013/2014 de Bizkaia (País Vasco) Munibe. 2015;**63**:135-143

[11] Payo-Payo A, Oro D, Igual JM, Jover L, Sanpera C, Tavecchia G. Population control of an overabundant species achieved through consecutive anthropogenic perturbations. Ecological Applications. 2015;**25**:2228-2239

[12] Juez L, Aldalur A, Herrero A, Galarza A, Arizaga J. Effect of age, colony of origin and year on survival of yellow-legged gulls *Larus michahellis* in the Bay of Biscay. Ardeola. 2015;**62**:139-150

[13] Arizaga J, Resano-Mayor J, Villanúa D, Alonso D, Barbarin JM, Herrero A, Lekuona JM, Rodríguez R. Importance of artificial stopover sites through avian migration flyways: A landfill-based assessment with the White Stork *Ciconia*. Ibis. n/a-n/a. (in press)

[14] Cantos FJ. El anillamiento científico en colonias de láridos. Revista de Anillamiento. 2000; **6**:12-23

[15] Parnell A, Inger R, Bearhop S, Jackson AL. SIAR: Stable Isotope Analysis in R. 2008. http://cran.r-project.org/web/packages/siar/index.html

[16] R Core Team. R: A Language and Environment for Statistical Computing. 2014. Available from: http://www.R-project.org

[17] Gaston A. Seabirds. A Natural History. London: T & AD Poyser; 2004

[18] Gyimesi A, Boudewijn TJ, Buijs R-J, Shamoun-Baranes JZ, de Jong JW, Fijn RC, van Horssen PW, Poot MJM. Lesser black-backed gulls *Larus fuscus* thriving on a non-marine diet. Bird Study. 2016;**63**:241-249

[19] Navarro J, Grémillet D, Afán I, Ramírez F, Bouten W, Forero MG. Feathered detectives: Real-time GPS tracking of scavenging gulls pinpoints illegal waste dumping. PLoS One. 2016;**11**:e0159974

[20] Tyson C, Shamoun-Baranes J, Van Loon EE, Camphuysen K, Hintzen NT. Individual specialization on fishery discards by lesser black-backed gulls (*Larus fuscus*). ICES Journal of Marine Science. 2015;**72**:1882-1891

[21] Burger J, Staine KJ. Nocturnal behavior of gulls in coastal New Jersey. Estuaries. 1993;**16**: 809-814

Chapter 6

Guano: The White Gold of the Seabirds

Ewald Schnug, Frank Jacobs and Kirsten Stöven

Additional information is available at the end of the chapter

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

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

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

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

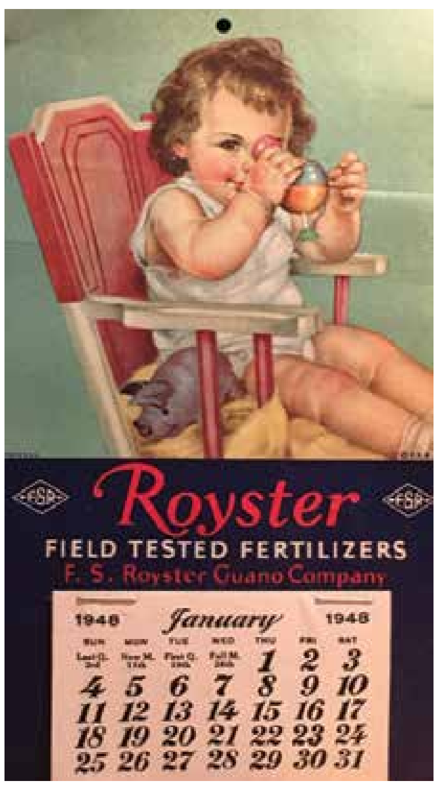

Figure 4. Fertilizer manufacturers rendered the apatitic phosphates in Guano soluble by treating with sulfuric acid. 1948 calendar sheet from the Royster fertilizer company.

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

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.

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

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

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

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].

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

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.

Acknowledgements

The 2010 Henri Nannen Award-winning photos in **Figures 6**, **9–12** were provided free of charge by Chilean photographer Tomás Munita for this publication. For that, our thanks.

Author details

Ewald Schnug, Frank Jacobs and Kirsten Stöven*

*Address all correspondence to: kirsten.stoeven@julius-kuehn.de

Institute of Crop and Soil Science, Julius Kuehn-Institut, Federal Research Centre for Cultivated Plants, Braunschweig, Germany

References

[1] CGP Grey. 2007. www.CGP.Grey.com - https://www.flickr.com/photos/cgpgrey/4889912886/in/album-72157624597004409/

[2] Soniak M. Why is Bird Poop White? 2012. http://mentalfloss.com/article/31262/why-bird--poop-white

[3] Purcell SL, Goldsborough GL. The significance of waterfowl feces as a source of nutrients to algae in a prairie wetland. UFS (Delta Marsh) Annual Report. 1995;**30**:43-51

[4] Kandil MAM. The effect of fertilizers for conventional and organic farming on yield and oil quality of fennel (*Foeniculum vulgare* Mill.) in Egypt. Diss: Technical University of Braunschweig; 2002. https://publikationsserver.tu-braunschweig.de/receive/dbbs_mods_00001313

[5] Fleming I. Dr. No. 1962. https://en.wikipedia.org/wiki/Dr._No_(film)

[6] Riechmann D. Guano – Das weiße Gold Perus. 2003. http://www.scinexx.de/dossier-detail-153-11.html

[7] von Scheffel JV. Gaudeamus. Guano: Lieder aus dem Engeren und Weiteren; 1854. http://www.zeno.org/Literatur/M/Scheffel,+Joseph+Viktor+von/Gedichte/Gaudeamus.+Lieder+aus+dem+Engeren+und+Weiteren/Naturwissenschaftlich

[8] Velty S. Sedimente – Kapitel Geologie im Modul Einführung in die Bodenkunde – Vorlesung J. Zeitz im SS 2003 a.d. Humboldt-Universität Berlin; 2003. https://www.bodenkunde-projekte.hu-berlin.de/boku_online/pcboku10.agrar.hu-berlin.de/cocoon/boku/sco_2_substrate_44f6db.html?section=N10053

[9] Tietze W. Westermann Lexikon der Geographie; 2. Auflage 1973. Braunschweig: Georg Westermann Verlag; 1973. p. 1969

[10] Hudson Institute of Mineralogy. 2016: Rock Guano. http://www.mindat.org/min-35977.html

[11] Meyers Großes Konversations-Lexikon, Bd. 8. Leipzig; 1907. S. 479-481. http://www.zeno.org/Meyers-1905/A/Gu%C4%81no

[12] Weischedel K, Kaiser S. Prüfung eines Guano-Düngers - Projektarbeiten am Institut Dr. Flad unter Betreuung von Prof. TU Clausthal: Dr. Georg Schwedt; 2003. http://www.chf.de/eduthek/projektarbeit-weischedelkaiser.html

[13] Anonymus. Corporate profile: Royster Guano. ACS. 1959;**7**:291

[14] Mayer A. Die Düngerlehre. Heidelberg: Carl Winter Verlag; 1928. S. 122-127

[15] Wichern G, Wöhlbier W. Die organischen Dünger natürlich Ursprungs. In: Honcamp F, editor. Handbuch der Pflanzenernährung und Düngung, Bd. II. 1931. pp. 606-661

[16] Wimmer D, Holzwarth F. Guano als Stickstoffquelle.- Hausarbeit i. Seminar Stoffgeschichte Stickstoff a. Lehrstuhl f. Ressourcenstrategie a. d. Univ. Augsburg i. WS 2012/2013. 2013. 18. S.

http://www.stickstoffausstellung.de/fileadmin/redakteure/materialien/hausarbeiten/Guano.pdf

[17] Kretzschmar E. Guano. Unterricht Biologie, Heft 14. Soest: erfasst vom Landesinstitut für Schule; 1990

[18] Römpp. Guano. 2002. https://roempp.thieme.de/roempp4.0/do/data/RD-07-02111

[19] Remington JS, Francis W. The Manure and Fertilizer Note Book. 4. ed. London: Leonard Hill; 1953. S. 27-28

[20] Körber H, Körber H, Will A, Hilverkus G. Bestandsaufnahme der Fledermäuse im Raum Wermelskirchen (Bergisches Land); 1995. http://fledermaus.wtal.de/biodat1.htm

[21] Bayerisches Landesamt für Umwelt. UmweltWissen – Natur - Fledermäuse und ihre Quartiere schützen. 2015 12. S. http://www.lfu.bayern.de/umweltwissen/doc/uw_104_fledermaus_quartiere_schuetzen.pdf

[22] Nöggerath J. Guano von Fledermäusen. In: Westermann's Jahrbuch der illustrierten deutschen Monatshefte, Band 20. Braunschweig; 1866. S. 665-666. https://books.google.de/books?id=DBnnAAAAMAAJ&pg=PA666&dq=Flederm%C3%A4use-Guano+ist+auch+bisher+als+nutzbares+D%C3%BCngemittel&hl=de&sa=X&ved=0ahUKEwi9wszo8O3LAhXFiCwKHWmcD7wQ6AEINDAA#v=onepage&q=Flederm%C3%A4use-Guano%20ist%20auch%20bisher%20als%20nutzbares%20D%C3%BCngemittel&f=false

[23] Knickmann E. Organische Abfälle als Düngemittel. In: Linser S, editor. Handbuch der Pflanzenernährung und Düngung, Bd. 112. Wien: Springer; 1968. S. 1428-1435

[24] Hirth G. Der Guano und seine Fundorte. In: Die Gartenlaube. Leipzig: Ernst Keil, Verlag Ernst Keil; 1863. https://de.wikisource.org/wiki/Der_Guano_und_seine_Fundorte

[25] Kanter O. Kleckern und klotzen. In: mare – Die Zeitschrift der Meere, No. 53. 2005. http://www.olafkanter.de/pdf/geschichte/ok_kleckernklotzen.pdf

[26] Kurtze A. Die Gegenwart. Eine encyclopädische Darstellung der neuesten Zeitgeschichte für alle Stände. 1856. https://books.google.de/books?id=qJ5NAAAAcAAJ&pg=PA330&dq=Feuillee+huano&hl=de&sa=X&ved=0ahUKEwi015qeuvLKAhVFnw4KHdWpBkIQ6AEIIzAB#v=-onepage&q=Feuillee%20huano&f=false

[27] Vogel C. Der Guano: Seine Entstehung, Fundorte, Geschichte; seine chemischen Bestandtheile und Sorten; seine Prüfung und Werthbestimmung; seine Bedeutung, Anwendung und Wirkung; seine Ersatzmittel etc., auf Grund der bewährtesten Erfahrungen u. nach den besten Quellen dargestellt. Mit einer Abbildung.- Verl. Schotte & Cp. 1860. http://reader.digitale-sammlungen.de/de/fs1/object/display/bsb10299504_00018.html

[28] Stiftung Preußischer Kulturbesitz – Staatsbibliothek zu Berlin. Alexander von Humboldt – Amerikanische Reisetagebücher. BMBF-Verbundprojekt d. Univ. Potsdam u. d. Staatsbibliothek zu Berlin – Preußischer Kulturbesitz; 2015. http://humboldt.staatsbibliothek-berlin.de/leben/

[29] Cushman GT. Guano and the Opening of the Pacific World: A Global Ecological History. Cambridge University Press; 2013. p. 30, 31, 349. https://books.google.de/books?id=LbIEXKafflMC&printsec=frontcover&dq=Guano+and+the+Opening+of+the+Pacific+World:+A+Global+Ecological+History&hl=de&sa=X&ved=0ahUKEwjTnKug4J7bAhWB6qQKHfsjAeQQ6AEIJzAA#v=onepage&q=Guano%20and%20the%20Opening%20of%20the%20Pacific%20World%3A%20A%20Global%20Ecological%20History&f=false

[30] Beatson A. Tracts relative to the island of St. Helena: Written during a residence of 5 years. 1816. https://books.google.de/books?id=hmhTAAAAcAAJ&pg=PA10&lpg=PA10&dq=Alexander+Beaston+Guano&source=bl&ots=nzQR-M5ScT&sig=2fT221Y-5TpjMF5hloqvjK9r6ls&hl=de&sa=X&ved=0ahUKEwjyuNuV2_LKAhWCfA8KHQm9D6gQ6AEINTAD#v=onepage&q=Alexander%20Beaston%20Guano&f=false

[31] Gibbs W. Guano—Report from 18.07.2015. 2015. webblog thegardenstrust.org. https://thegardenstrustblog.wordpress.com/2015/07/18/Guano/

[32] The House of Representatives. Reports of Committees of the House of Representatives—Order of the House of Representatives. In three Volumes.1854, Washington; 1854. https://books.google.de/books?id=zqoFAAAAQAAJ&pg=RA2-PA23&dq=first+huano&hl=de&sa=X&ved=0ahUKEwjN1rmi1vLKAhVDow4KHc-mATYQ6AEIHDAA#v=onepage&q=first%20huano&f=false

[33] Jenkins H. Guano trade by W. Myers—Article in Webblog Intheboatshed.Net. 2011. http://intheboatshed.net/wp-content/uploads/2011/04/Myers-Co.pdf

[34] Snyders H. Stinky and Smelly—But Profitable: The Cape Guano Trade, c.1843–1910. University of Stellenboch; 2011 http://www.academia.edu/1409527/_Stinky_and_smelly-but_profitable_the_Cape_Guano_trade_c._1843-1910

[35] Miller S-W. An Environmental History of Latin America. Cambridge: Cambridge University Press; 2007

[36] Trade and Environment Database. TED Case Studies. Guano Trade; 1997

[37] Eckert R. Tierphysiologie. 2. ed. Stuttgart: Thieme; 1993

[38] IUCN. A bird droppings biodiversity paradise—The Guano Islands and Capes National Reserve System; Peru. 2013. 13 September 2013 – Fact sheet. http://www.iucn.org/about/work/programmes/gpap_home/pas_gpap/paoftheweek/gpap_paamerica/?13669/A-bird-droppings-biodiversity-paradise–the-Guano-Islands-and-Capes-National-Reserve-System-Peru

[39] King RJ. The Devil's Cormorant: A Natural History. Lebanon, NH: University Press of New England; 2013. https://books.google.de/books?id=rcOyAAAAQBAJ&pg=PA312&lpg=PA312&dq=proabonos+agrorural+2008&source=bl&ots=6i6eAm7B98&sig=0p-3okNsFdZKh7gPhI9mD1rjDeY&hl=de&sa=X&ved=0ahUKEwjqoLm7wfzKAhUCM5oKHWDRAX4Q6AEITTAH#v=onepage&q=proabonos%20agrorural%202008&f=false)

[40] BBC. How a Peruvian island is making money from bird poo. 2010. http://www.bbc.com/news/av/business-11156842/how-a-peruvian-island-is-making-money-from-bird-poo

[41] Richts S. 360° - GEO reportage. Guano, Schatzinseln und Vogeldreck. Berlin: Medienkontor; 2011. http://www.geo.de/GEO/geo-tv/Guano-schatzinseln-und-vogeldreck-70229.html

[42] Neesen W. Plastik in Komposterde nachgewiesen. N3 television format "Markt", 28.05.2018. https://www.ndr.de/ratgeber/verbraucher/Plastik-in-Komposterde-nachgewiesen,kompost206.html

[43] Anonymus. 2011. http://www.gartengnom.net/Guano-torf-bio-kann-die-umwelt-gefaehrden/

[44] Lawrence J. A History of the Peruvian Guano Industry. 2014. https://yaffle53.wordpress.com/2014/05/22/a-history-of-the-peruvian-Guano-industry/

[45] Schulz R. 2009: Guano-Gewinnung in Peru. GEO Magazin Nr. 09/09. http://www.geo.de/GEO/natur/fotogalerien/fotoshow-Guano-gewinnung-in-peru-61545.html?image=2

[46] Rovira RG. The Hard Workers of the Peruvian Guano (the Chincha Islands); 2014. https://www.agencevu.com/stories/index.php?id=1564&p=89

[47] AFP. Peru mines new gold in Guano. Friday 8 October 2010. https://www.independent.co.uk/environment/peru-mines-new-gold-in-Guano-2102574.html

[48] Anonymus. Guano-Dünger - Zusammensetzung & Tipps zur Anwendung – report in hausgarten net. n.d. http://www.hausgarten.net/gartenpflege/duenger/Guano-duenger.html

[49] Kratz S, Schnug E. Rock phosphates and P fertilizers as sources of U contamination in agricultural soils. In: Merkel B, Hasche-Berger A, editors. Uranium in the Environment. Berlin: Springer; 2006. pp. 57-67

Edited by Heimo Mikkola

Changes in seabird populations are good indicators of large-scale and long-term change in marine ecosystems, and are important because of their global impacts on the marine environment. This book has six chapters that present a wide variety of global seabird-related issues, from India to Svalbard, Norway. It also gives a comprehensive history of the use and chemical content of guano and certification schemes in fisheries for seabird conservation in Argentina. With the knowledge available in this book we should know how best to protect seabirds, which need all our support to survive in changing environments and climates. We can all do our best to recycle plastic waste to reduce global plastic pollution, which has affected seabirds' physical state, food sources, and nesting areas.

Published in London, UK

IntechOpen

ISBN 978-1-83881-614-8