Spheniscus penguin husbandry manual

First edition

Edited and compiled by the Penguin TAG

A publication of the EAZA

Spheniscus husbandry manual

Table of contents

Preface

Section A: Biology and field data

Biology

Taxonomy 6
Morphology and physiology 8
Longevity 13

Field data

Zoogeography and ecology 15
Behaviour 17

Section B: Management in captivity

Housing and enclosure requirements.

Introduction 34
Recommendations for exhibit and holding area size 34
Air temperature 35
Drainage 36
Substrate 36
Nest and nest substrates 36
Water quality 36
Air quality 37
Lighting 38
Special features 38
Exhibit maintenance 39

Management

Individual identification methods 41
Methods of capture, handling and restraint 45
Methods of crating and transport 47
Pest management 50
Record keeping 50
Weighing of penguins 50
Moult management 51
Ingestion of foreign objects 52
Sex determination 52

Behaviour and social organisation

Social groupings 65
Mixed species exhibits 65
Introductions and removals 66
Behavioural management 66
Behaviour, reproduction and parental care 67

Reproduction

Introduction 70
Nests and nest substrate 73
Egg production and incubation 76
Hatching (parental care, age of fledging and sexual maturity) 76
Artificial incubation 77
Reproductive management
Hand-rearing

Nutrition

Feeding ecology 102
Fish handling and preparation 103
Feeding 106
Nutrient requirements and possible toxicities 108
Formulation of appropriate diets 112
Special considerations 116
Hand-rearing 118

Health

Introduction 120
Diagnostic techniques 120
Behavioural manifestations of illness 121
Physical exam abnormalities 121
Common disease problems 122
Immobilization 130
Blood parameters 131
Post-mortem evaluation 131

Population management

Humboldt penguin 133
African penguin 144
Magellanic penguin 154

References 158

Preface

The purpose of this husbandry manual is to provide useful guidelines for maintaining and exhibiting Spheniscus penguins in captivity.
Due to the fact, however, that of this group of penguins, the Galapagos penguin (Spheniscus mendiculus) isn't kept in captivity in Europe at all, no explicit reference is made to this species.
The need for a manual like this has been felt for a long time by the Penguin TAG, though the general Penguin husbandry manual of the AZA is already available since 1994.
For this reason this manual is being used as a very important source of information for this manual. In addition, however, other contributions and other current information about Spheniscus penguins in particular have been added.
We have tried to incorporate the most current information available on the species in captivity as well as in the wild. This manual should be seen as a living document: as new information becomes available, chapters will have to be updated in the manual accordingly.

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Section A: Biology and field data

Biology

Biology [1]

Systematics and Nomenclature:

Humboldt penguin

Scientific name: Spheniscus humboldti (Meyen, 1834, Peru)
French: Manchot de Humboldt
German: Humboldtpinguin
Spanish: Pingüino de Humboldt
Native: Petranca
Other common names: Peruvian penguin

African penguin

Scientific name: Spheniscus demersus (Linnaeus, 1758, Cape of Good Hope)
French: Manchot du Cap
German: Brillenpenguin
Spanish: Pingüino del Cabo
Other common names: Jackass Penguin, Black-footed penguin [2]

Magellanic penguin

Scientific name: Spheniscus magellanicus (J.R.Forster, 1781, Strait of Magellan)
French: Manchot de Magellan
German: Magellanpinguin
Spanish: Pingüino Magellanico

The Spheniscus penguins belong to the order of the Sphenisciformes and the family of the Spheniscidae.
Sphenisciformes is the only order within the class Aves in which all the species are both flightless and aquatic. It contains only one family, Spheniscidae.
Today there is considerable disagreement about the number of species in the family, as the status of some species has been questioned. Here the most widely accepted version of 17 species has been followed. Taxonomists have divided the penguins, primarily on the basis of morphology, into at least 17 species representing six different genera.

[1] This chapter is largely based on the publications of Del Hoyo and T.D.Williams.
[2] Its common name, Jackass penguin, is also being used for Humboldt and Magellanic penguins. The species is also being referred to as the highly uninformative "Black-footed penguin"

Aptenodytes:
Emperor (Aptenodytes forsteri)
King (Aptenodytes patagonica)

Pygoscelis:
Adelie (Pygoscelis adeliae)
Chinstrap (Pygoscelis antarctica)
Gentoo (Pygoscelis papua)

Megadyptes:
Yellow eyed (Megadyptes antipodes)

Eudyptes:
Macaroni (Eudyptes chrysolophus)
Royal (Eudyptes schlegeli)
Erect Crested (Eudyptes atratus)
Snares Island (Eudyptes robustus)
Fjordland (Eudyptes pachyrhynchus)
Rockhopper (Eudyptes crestatus)

Eudyptula:
Little Blue (Fairy) (Eudyptula minor)

The family of Speniscidae contains four different species:

Humboldt penguin (Spheniscus humboldti)
African penguin (Spheniscus demersus)
Magellanic penguin (Spheniscus magellanicus)
Galapagos penguin (Spheniscus mendiculus)

The propensity of some members of the genus Spheniscus to hybridize in captivity, in addition to the observation in the wild of individual African penguins and Humboldt penguins with a double pectoral band, suggests the presence of a recessive genetic character or perhaps some breeding contact with the Magellanic Penguin.
Humboldt and Magellanic penguins hybridize in Chile, although these hybrid pairs apparently breed less successfully than monospecific pairs. [3]
Despite its double pectoral band, the Galapagos Penguin is probably descended from the single-banded Humboldt penguin.
There is at present only one study, by Grant et al. on the Humboldt, Magellanic and African taxa, using electrophoretic analysis of gene frequencies.
The three species are very closely related, suggesting that they are species, rather than subspecies, they are very recent ones. The Galapagos penguin probably evolved from a stray colonization of the islands by the Humboldt penguins , although its double-breast pattern is more similar to that of the double-banded Magellanic than of the single-banded Humboldt. Similarly, the single-banded African penguin may have evolved from the Magellanic or vice-versa. Occasional individuals of the African and, less frequently, the Humboldt, have double stripes, suggesting either occasional immigration and past interbreeding with Magellanics, or that a recessive gene for double-bandedness lurks in the best of birds.

[3] W.G.Conway. See: T.D.Williams

Morphology and physiology.

Description of the individual species.

Humboldt penguin (Spheniscus humboldti).

65-70 cm. Sexes similar, but mostly males slightly larger than female. No seasonal variation. Juveniles (one year old) separable from adults on plumage.
Adult: head mostly black with white chin and narrow white stripe extending from bill, on each side of crown, looping over eye and broadening at junction with white upper breast; body, upperparts, and tail blackish-grey, underparts mostly white, with inverted black horseshoe-shaped band extending down flank to thigh; some black spotting occurs on breast which may be specific to different individuals (Scholten); flippers blackish-grey dorsally with whitish trailing edge, mostly white ventrally; bill black with grey transverse bar and fleshy pink area at base, especially prominent in breeding season; iris reddish-brown, sometimes with pink eye ring;legs and feet black.

Immature: head brownish with greyer cheeks; lacks white head stripe and black horseshoe-shaped breast band of adults; iris grey (clour changes).

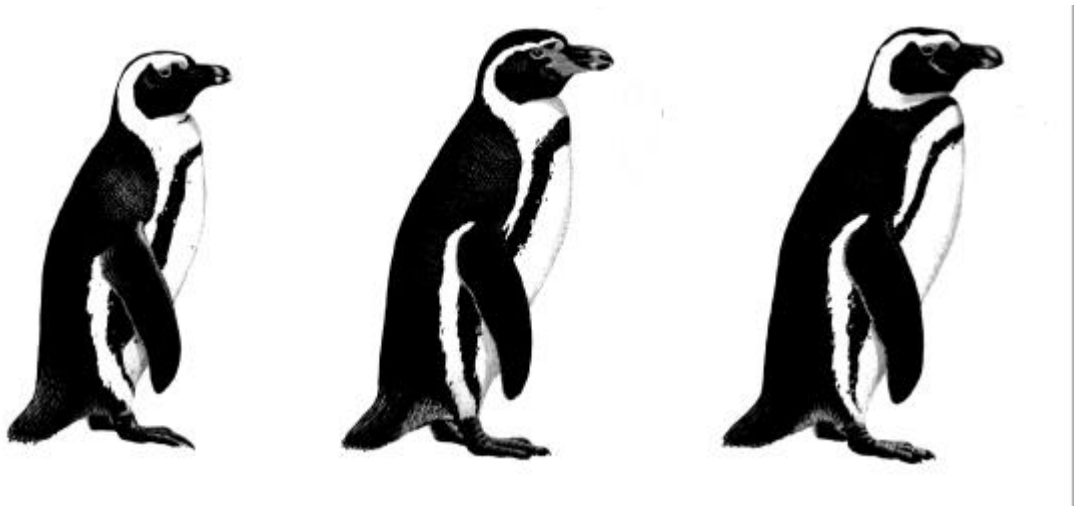
African penguin (Spheniscus demersus).

68-70 cm. Sexes similar [?]. No seasonal variation.
Adult: forehead, crown, sides of face and throat black with bare pink skin at base of bill and encircling eye; white band extends from base of upper mandible above the eyes, curving downwards behind cheeks and joining white upper breast; body, upperparts and tail, blackish-grey, underparts white with a narrow, inverted horseshoe-shaped black band crossing the breast and extending along flanks to the thighs; some birds have second black band on upper breast, as in Spheniscus magellanicus, though rarely more than incipient; flippers, blackish-grey dorsally with narrow white trailing edge, mostly white ventrally with dusky margins; bill, black with grey transverse bar; iris, dark; legs, black, mottled with grey, soles black.
Immature: head and upperparts blackish-grey merging with white underparts; lacks both the white head stripes and black breast band of adults, although some juveniles may show partial head moult to adult plumage.

Magellanic penguin (Spheniscus magellanicus)

70-76 cm. Sexes similar, but males larger than females. No seasonal variation, except that during the breeding season birds lose white facial feathers around the bill and eye (these areas are feathered between moult in february and return of the birds to land the following September). Immatures (one year of age) separable from adults on plumage.
Adult: head mostly brownish-black, with broad white band (supercilium) on each side of crown looping over eye and joining on throat; birds have bare skin between bill and around eye during the breeding season, the bare area usually pink with a black inverted “U”-shape on both sides of the face, although the pigment can vary in shape on either side of the face and between individuals; body, upperparts including tails brownish-black, underparts mostly white with inverted, black horseshoe-shaped band on breast extending down flanks to thigh, and a second wider band crossing the upper breast; the thickness and extent of these bands vary between individuals; breast also has black spots the pattern of which is characteristic of

individuals; flippers brownish-black dorsally, white with varying patterns of black feathering ventrally; bill blackish with pale whitish-grey vertical band near tip; iris brown with a small red ring in older adults; tarsus and feet mostly black with light pinkish blotches, black soles and claws.
Immature: smaller than adults, and with generally greyer plumage, lacking the bands on head, neck and breast; cheeks can be white to very dark grey but generally lighter than adult; some individuals go through a partial head moult following the main moult in February, and some juveniles therefore have a white supercilium when they first return to the colony, characteristic of adults, though they still lack the adult breast bands; iris pinkish with distinct rings in most juveniles and grey in chicks.



1 **2** **3**

1. **African penguin (Spheniscus demersus)**
2. **Humboldt penguin (Spheniscus humboldti)**
3. **Magellanic penguin (Spheniscus magellanicus)** [4]

[4] Del Hoyo

Penguins are a highly specialized group of seabirds. Their structure and physiology have been moulded both by their marine habitat and the climatological peculiarities of their environment. All penguin species are really quite similar, both in stucture and coloration.
The body is streamlined with a very short neck and long, flat wings, which are useless for flight. The tarsi are short and the legs are situated so far back on the body that the birds stand upright; the tail is short and stiff.
In general, penguins become steadily larger as one moves south into colder zones, a principle known as Bergman's Rule, whereby optimum size changes with the increased energy requirements in colder zones.

The bill is composed of horny plates and its shape is adapted to suit the typical prey. Thus, the bill tends to be long and thin in species that are essentially fish eaters, but shorter and stouter in those that take plankton.
The eyes are basically adapted for underwater vision, though birds can see perfectly adequately when they are out of the water. Experiments on Humboldt penguins indicate that this species, at any rate, may have a sense of smell. In common with the Procellariformes, penguins have highly developed supra-orbital glands, which enable them to deal with the extreme levels of salt in their diet. The excess of salt is excreted in a concentrated saline solution, which tends to dribble down the bill.
Adult plumage is very similar in all species, with upperparts black or bluish grey and underparts basically white. All of the markings that serve to distinguish the different species are on the head and the breast, which are the parts that stick out of the water, when birds are swimming on the surface.
In general, penguins are warm-blooded with average body temperatures ranging from 37,.8 – 38.9º C. Temperature regulation is accomodated by both behavioral and physiological adaptations.
Penguins have a uniform covering of feathers over their bodies unlike most other birds, which have alternating feathered and bare tracts. Only during breeding is this cover interrupted, when feathers are dropped from the ventral region to make way for the brood patch. The feathers of adult penguins are highly specialized. The bird is clothed in a thick coat of small hard, stiff coverts, which are lanceolate and slightly curved. The flippers and head of Spheniscus penguins however have less dense feathers. The rachis is long and flattened, and out of it projects a hyporachis, which provides extra thickness and makes up for the absence of down. The feathers overlap each other, in order to improve their performance in both insulating and waterproofing the body. This plumage has high wind resistance and, even in winds upwards of 60 km/h, it remains smooth and compact.
The feathers of the upperparts are slightly longer and stiffer than those of the underparts, while the covering of feathers is denser on the upperwing than on the underwing. Irrespective of the size of the bird, relative feather length is quite different in tropical and polar species. Feathers become progressively longer as one approaches the South Pole.
Chicks hatch covered in a dense coat of down. After a period, this first coat is changed for another, which is normally quite similar but thicker.

Moult.

In most of the bird world, moult involves the old feather being dropped and a new one growing in its place, but in penguins the new feather grows under the rachis of the old one and forces it out, with the result that the old feathers are not totally discarded until the new ones are in place. Moult is rather patchy, and this gives the birds a rather scruffy, moth-eaten look. This type of moult is called "catastrophic" moult.
In the premoult stage the plumage is pale in comparison with the surrounding non-moulting birds; the daily intake of food is increased. The actual moult is noticed when feathers begin to drop. This is rapidly followed by a complete cessation of feeding. In the postmoult stage the dark plumage is striking in comparison with the premoult condition. Indicative of this stage are the short tail and the feathered skin above the eye. During this last post-moult stage the bird continues to fast, while the new immature feathers grow and are preened to make them water-repellant.

Humboldt penguin chicks moult to juvenile plumage before they are 2 to 3 months old. The grey down is replaced by water-repellent plumage. Moulting usually starts with areas of friction, under the flippers and around the legs, extends to the sides of the body and then spreads to the higher parts of the body. The neck is the last region to moult and the belly is being moulted before the back.
When the moult is completed it is two to three days before the plumage again attains its typical sleek appearance, and the birds usually remain out of the water and continue to fast. [5]
However, after the first moult the chicks still differ in colour from the parents. The characteristic black and white stripe on the head and neck are absent and the colour is a uniform dark grey on the back and almost white on the front. Juveniles moult to adult plumage in the year following their year of birth. [6]

During moult both waterproofing and insulation are deficient, so penguins are forced to remain on land until their plumage returns to optimum condition. For this reason, before commencing their moult they must spend some time at sea, building up sufficient reserves of energy. The necessary period of preparation varies from one species to another, ranging from about 10 to 70 days. Birds are at their plumpest as they start their moult, but not surprisingly by the time they finish they have lost a lot of weight.
For wild African penguins, Cooper (1978) reported a 31% weight gain in pre-moult birds with a subsequent loss of 41 % of their peak body mass during molt.
Indeed, the daily expenditure of energy during moult is roughly double that used daily during incubation. Although they are largely inactive while moulting, they do not eat and have to use more energy due to their reduced insulation, as well as in the process of generating new feathers.

The whole moult-cycle takes approximately 20 days in Humboldt penguins and 18 days in African penguins, during which time the birds fast and usually do not enter the water. The actual process in which the old plumage is pushed out of the follicles by new immature feathers however takes normally from five to twelve days.
For Magellanic penguins, moult occurs during a relatively short, fixed time of year, after breeding and prior to dispersal from the colony. African penguins can be found moulting throughout the year, but this species moults annually with an interval of 321 days.

[5] Gailey Phipps.
[6] Scholten and Landowksi.

South-American penguins exhibit a strong peak in October-November and this appears to be predominantly post-breeding.

Fasting

Spheniscus penguins are capable of storing great reserves of energy in their layer of subcutaneous fat, which means that they can survive long periods without feeding at all. The length of time a bird can go without food depends basically on its weight at the beginning of the fasting period; the fatter the bird, the longer it can survive.
There are two periods when adults have to fast, which correspond to courtship and incubation, and secondly to moult. During the former, it is the males that generally have to undergo longer periods of fasting, as they tend to arrive first at the colony, and often take the first incubation stint, immediately after the females have laid. During the annual cycle a bird's weight varies enormously, with the maximum invariably occuring at the beginning of moult. Penguin chicks too have to fast, normally around the time that they become independent, shortly before going to sea.
A reduction in physical activity and perhaps an increase in the time spent sleeping are ways of diminishing unnecessary use of energy. In addition, penguins have a lower body temperature than other birds, which might also be an adaptation designed to save energy during these inactive periods of their annual cycle when feeding is impossible.
It appears that during periods of fasting only about half of what is consumed is fat, the rest consisting mostly of water.

Thermo-regulation.

One of the most remarkable characteristics of the penguins is their capacity of thermoregulation in environments with very harsh temperatures, in some cases towards both extremes. Those species of temperate or tropical zones, like the Spheniscus penguins, must be able to deal almost instanteneously with the radical contrast in temperature between the icy cold water and the shore under a hot sun. They are better adapted to regulating the temperature in the water, where conditions are more constant than on land. For this reason, when out of the water, they can have problems coping with excess heat, and the species that have to deal with high temperatures have additional methods of cooling, such as panting. These species also have relatively large feet. Areas of bare skin by the bill or the eye also help in thermoregulation.
However, this area is not bare all year round; for the Humboldt penguin it is covered right after moult by small white feathers which wear off fairly soon. After losing their chicks down, juveniles still have feathers completey covering their facial area. Bare skins start to appear somewhere between the age of about 7 months.
Between the imbricate, highly weatherproof plumage and the important layer of subcutaneous fat there is a mantle of warmed air, which also helps in insulation. The complex vascularization of the wings is another feature that plays a very important part in thermoregulation, as a bird can manage to dissipate a good deal of heat by holding its wings away from its body and bristling up its plumage, The species of colder latitudes have shorter wings, as well as longer feathers.
The dark plumage of the upperparts is well designed for absorbing heat from the sun, and increasing body temperature.

Unlike flying birds, penguins have solid, heavy bones, as they do not need to economize on weight. Normally body weight is just slightly less than the volume of water displaced, so less energy is used both in diving and in swimming on the surface.
The feet are webbed and the hind toe is vestigal. Unlike most other waterbirds, penguins do not use their feet as paddles, but instead, along with the tail, for steering, while it is the wings that provide the propulsion. These are moved as if the birds were really flying, and progress through a much denser medium than air has led to great development of the wing and breast mucles, to a degree comparable with those of flying birds. Penguins retain the same wing bones as flying birds, but these are far less flexible, because the only really mobile joint is that of the shoulder girdle with the humerus.
Another highly characteristic feature of the penguins is the form of the tarsometatarsus, which in penguins is short and thick, while in almost all other birds it is long and thin.

Longevity

There is no information available from the species in the wild. In captivity, most male Humboldt penguin birds do not live beyond 28 years and females beyond 25 years of age. [similar for African and Magellanics ?]

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Section A: Biology and field data

Field data

Field data

Zoogeography and ecology

Humboldt penguin

This species is endemic to the area influenced by the cold, nutrient-rich Humboldt current which flows northward along the coasts of Peru and Chile.
The Humboldt Current sweeps northward up the Pacific coast of South America and the cold waters of the current makes life possible for the penguins in regions where air temperature may exceed 38ºC. (100º F).
Breeding on the mainland coast and offshore islands of Chile and Peru between Isla Foca (5º 12' S)(the northern most island of Peru) and Algarobbo (33ºS); breeding also recently documented at Isla Punihuil (42ºS), 900 km south of previous range.
For Peru there are only two reported breeding sites [?], Punta San Juan 15º 22' S) and Pachacamac (ca.15ºS). The northermost known breeding site of Humboldt penguins in Chile is located at a sea cave (cueva del Caballo) a few kilometers north of Iquique (20º21'S). There is information concerning a colony that existed until 1960 on Alacran island (18º29'S), which is now connected to the mainland. There are also data suggesting five breeding sites between the Loa river (ca 21ºS) and Caldera (ca.27ºS), of which only Algodonales islet, Abtao Islet and Pan de Azcar Island are the most important. Between Grande Island and Punihuil, a total of 12 colonies has been reported. There are no data on breeding colonies between Pupuya Islet and Punihuil Islet. [7]

Marine, nests on islands or on rocky stretches of mainland coast, especially in areas with cliffs. Nests in sea caves, among boulders, in burrows and occasionally on the surface. [8]
Recent studies using satellite transmitters demonstrate that 90% of locations occurred within 35 km of their breeding islands. The area is larger than 20.000 sq km. Assuming that around every breeding location a 35 km radius may be exploited, each breeding island allows birds to exploit an area of 3800 sq.km.

Humboldt penguins live in tropical, subtropical and moderate climates (Peru, northern Chile and southern Chile). The air temperature varies between 7º and 30º C. Wind velocity is 18.5 – 24.1 km per hour (Punta San Juan, Peru). Relative humidity varies between 60 and 90%. Temperature of sea surface is 15º C average. [9]

Humboldt penguins can be found in association with Guanay cormorants (Phalcrocorax bougainvillii), Inca terns (Larosterna inca), Peruvian boobies (Sula variegata) and Peruvian pelicans (Pelecanus thagus). In caves and on beaches they are found with Patagonian sealions (Otaria flavescens) and Fur seals (Arctocephalus australis). At Pachacamax island Red-legged cormorants (Phalacrocorax gaimardi) nest on the periphery of the Humboldt penguin colony. The Peruvian or Band-tailed gull (Larus belcheri) preys on unguarded penguin eggs and possibly chicks. The Kelp or Southern black-backed gull (Larus dominicanus) probably also

[7] Penguin Camp document, 1997
[8] Hays, Araya, De Hoyo, Williams.
[9] Zavalaga and Paredes. According to Scholten, the temperature of the sea in the southern part of its habitat would vary between 13 and 18ºC, and in the northern part between 15 and 19º C.

feeds on the penguin eggs and chicks. Other avian predators are the Chilean skua (Catharacta chilensis), the Arctic skua (Stercorarius parasiticus), Turkey vultures (Catharthes aura) and Caracaras (Polyborus plancus). The Desert fox (Dusicyon sechurae) and Andean fox (Pseudalopex culpaeus) also feedson the juveniles. Sealions and Fur seals feed on other species of penguins, although there is no evidence that they kill Humboldt penguins. [10]

African penguin.

Breeds on islands off the south and southwest coast of southern Africa, from Hollams Bird Ilands (24º38'S) to Bird Is., Algoa Bay (33º50'S); non-breeding range similar as adults are sedentary; confined to southern African coastal waters, mainly in the region influenced by the cold Benguela Current. Non-breeders recorded as vagrants as far north as Setta Cama, Gabon, and Inhaca Is, Mozambique.
Main breeding populations: Dyer Is. And St.Croix Is. There are 27 extant breeding colonies – eight islands and one mainland site along the coast of southern namibia; 10 islands and two mainland sites along the coast of Western Cape Province, South Africa; six islands in Algoa Bay, Eastern Cape Province, South Africa. There is no breeding along the coast of South Africa's Northern Cape Province, which lies between Namibia and Western Cape Province. [11]
The species nests on inshore islands or less frequently on mainland coast.
African penguins nest semi-colonially at low density in burrows or on the surface. The nearest nest distances are 4.3 , 4.8 and 5.5 meter for nests in burrows / undre rocks, under bushes or abutting bushes / rocks respectively and 0.86 m in open, surface nesting colonies.

Magellanic penguin.

Breeds on Atlantic and Pacific coasts of South America, from Cape Horn to 42ºS on the Atlantic side and from Tierra del Fuego to 29ºS on the Pacific side, and on the Falkland Is. (54ºS).
Until now, the Punihuil islands (41º55'S), southern Chile, have the only known mixed breeding colony of Magellanic and Humboldt penguins. [12]
Species is pelagic in winter, ranging offshore and as far north as Peru on Pacific coast, with birds from Punta Tombo and Cabo Virgenes, Argentina, moving as far north as southern Brazil ; some immatures also winter further south. During austral winter big concentrations of birds are seen in the waters of Santa Catalina State (south of Brazil). Vagrant to Australia and New Zealand, South Georgia and Antarctic Peninsula.
Nests on beaches, hills of sand or clay, in forest or on grassy slopes. [13]

[10] Hays
[11] Penguin CAMP document, 1997
[12] Simeone and Schlatter.
[13] Williams.

The Magellanic penguin breeds on bare, grassy, bushy or forested islands and coasts, cliff faces, escarpments and flatter areas, taking advantage of local vegetation where available. Birds nest either on the surface or in burrows in areas where soil has a low sand and high clay content allowing digging; at Punta Tombo, about half of all nests are in burrows and half under bushes, typically Schinus, Chuquiraga and Lycium species. At Cabo Virgenes birds mostly nest under bushes which provide protection from wind and rain, nests that open away from prevailing winds having higher breeding success. Active nests can occur up to 1 km inland at Punta Tombo.
The nest density is highly varaible ranging from 1 nest/100 m² to 1 nest/m², largely determined by soil type and vegetation.
Within a single colony birds may nest in burrows, under bushes and in the open, birds favouring nests with greater amounts of cover which provide protection from the sun and predators; nest cover is a significant determinant of fledging successs; both sexes help in nest-building. Surface nests are often rudymentary, though feathers, leaves, sticks, and algae may be added as nesting material. Burrow nests can be more than 1 meter in length, leading to a roughly circular nesting chamber; at Punta Tombo, for 15 burrows from which chicks fledged, length averaged 590plus/minus 49 mm, width at entrance 560 plus/minus 28 mm, width at neck 370 plus/minus 13 mm and height 210 plus/minus 10 mm; for 130 nests where breeding ourcome ws not known mean burrow length was 630 plus/minus 20 mm, and mean entrance width ws 400 plus/minus 10 mm.

The main predator of Magellanic penguin chicks and eggs is the Kelp gull (Larus dominicanus). Other predators are Patagonian gray foxes (Duricyon griseus), armadillos (Chaetopharctus villosus), skunks (Conepatus humboldti), ferrets (Lyncodon magellanicus) and Southern skuas (Catharacta antarctica).

Behaviour.

Locomotion.

Penguins have three distinct modes of movement in the water: surface swimming, underwater “flying” and “porpoising”. Surface swimming is not very swift, as the birds are unable to flap fully, and turbulence causes them to lose speed. This kind of swimming is used for resting or toilet, and usually involves the head and sometimes the tail being raised up out of the water, weheras the whole body remains more or less submerged.
Underwater swimming is really a form of underwater flying. The feet serve as rudders. The torpedo-shaped body also facilitates the bird’s movement through water.
The depth at which birds swim depends basically on the location of prey, and this can vary seasonally or even daily. Of course, penguins can not stay under water indefinitely, as they

must come up to the surface to take a breath. Most species come up at intervals of a minute or less.
Porpoising is a form of surface swimming, whereby the birds make an undulating movement, flopping in and out of the water at regular intervals. The Jackass penguin spends 14 seconds under the water for every second it uses for taking a breath. Not all species use porpoising habitually, specially not the species of the genus Spheniscus. The advantages of this method of locomotion are unclear, but once a certain speed is reached, it reduces energy expenditure by cutting down the resistance of the water the bird displaces, as it is swimming near the surface. It also permits efficient breathing with a very low cost in terms of energy. Another possible benefit is that during a normal dive birds can lose part of the insulating layer of warm air between the skin and the feathers, so this has to be replaced periodically. It might also be a useful anti-predator manoeuvre, designed to confuse pursuers.

While they are expert swimmers, penguins also move about a fair bit on land, where they walk with an upright stance and short steps or hops, helping themselves at times on steep climbs with the bill or tail.
Penguins are plantigrade, walking on the sole of the foot, as opposed to other birds, which walk on their toes. The shortness of the legs and their positioning mean that the birds walk with a rather clumsy, but very characteristic gait. It also means that they can not walk very fast.

Social behaviour

Humboldt penguins are sociable and gregarious and carry out most of their life cyle in the company of conspecifics. They nest in colonies which can be more or less dense.
Social behaviour at sea has been recorded for several genera, including Spheniscus. These often form groups during the breeding season, for the purposes of movement or feeding, and they co-operate intraspecifically in the capture of prey.

Diet and feeding behaviour [1]

Introduction.

While species of the Antarctic and the subantarctic basically feed on krill and cephalopods, Spheniscus penguins predominantly feed on clupeid-type pelagic school fish such as anchovy, sardine and mullet.
Data on the foraging of Spheniscus penguins is relatively scarce. In addition to this, there are very few data on the foraging behaviour of non-breeding birds, as most of our knowledge is related to breeding birds.

[1] This chapter is mainly based on the data of del Hoyo, Williams and Wilson.

Until recent times, information was gathered from personal observations, stomach samples, fish behaviour and automatic dive recording devices, measuring depth, speed and duration of dives.
Nowadays penguins can be traced through radio-tracking systems: the birds carry a radio transmitter so that their position at sea might be determined by appropriate shore or ship-based receiving stations.
Satellite telemetry is a new technique which involves signals from the transmitter attached to the penguin's back being picked up by an orbitting satellite which determines the bird's position. This information is then relayed to lboratories on earth which, in turn, send the information to the relevant researchers.
Electronic data loggers are developed to store information on the penguins behaviour while at sea. This information is being accessed or recovered when the bird is recaptured on return to land.
All Spheniscus penguins have, at least during breeding, a marked diurnal foraging rhythm. Breeding birds leave their sites at about dawn and return in the late afternoon or early evening, but not necessarily on the same day. Foraging trips made by penguins during chick rearing are necessarily much shorter than those during incubation since adults must return frequently to the colony to ensure that the brood is adequately provisioned. In this way foraging trips can vary in length from a few hours to several days when the birds have large chicks.
The total distance travelled during foraging trips will depend on the time they spend at sea. How far birds actually travel will in turn depend on the percentage time that they spend swimming and the percentage time spent resting at the surface.
The percentage time that foraging penguins spend swimming is more variable and is dependent on the food requirements of the brood and hence the size of the chicks. This is because the amount of food that penguins are able to capture and ingest depends on the amount of prey that they have encountered. This in turn depends directly on the volume of water that they have searched, and this is a function of the total distance travelled.
In general it seems that most penguin species travel a total of less than 100 km per foraging trip and somewhere between 15 and 80 km appears to be typical. 2

Spheniscus penguins are sociable at sea as well and often form a group, that is a number of associated penguins which have interbird distances of less than two body lengths.
The diving behaviour of Spheniscus penguins can be broadly classified into four categories: porpoising, traveling, searching and feeding.
Porpoising allows penguins to breathe efficiently while travelling fast. Porpoising penguins swim at about 12.3 km/hour (maximum 14.4 km/hour) with dive durations of about 14 seconds and breathing leaps lasting less then 1 second. Porpoising occurs relatively infrequently in Spheniscus penguins and they seldom porpoise for more than a few minutes.
Travelling: Spheniscus penguins travel between their nesting grounds and foraging areas by interspacing short, shallow dives of about 15 tot 30 seconds with resting periods at the surface of about 20 seconds. When traveling underwater the birds remain within 3 m of the surface. Normal underwater speeds are between 6 and 8 km/h., surface swimming speeds are about 1.5 km/hour. Spheniscus penguins traveling to and from their foraging areas have an approximate speed of 4.5 km/h.
After executing traveling dives for some period, Spheniscus Penguins begin to dive deeper and for longer periods. The searching efficiency of a penguin will depend on dive depth and

[2] Wilson reports 72 km per day.

swimming speed since the prey encounter rate will ultimately depend on the volume of water searched rather than on the absolute distance traveled. Diving and returning angles are about 45º. Maximal dive depths recorded for three of the four Spheniscus penguins demonstrate that these birds are capable of exploiting deep water prey, but presumably, in order to optimize foraging, they rarely do so.
We do not know whether physical (e.g. depth, bottom topography, currents, wave height, temperature) or biological (turbidity, presence of fish schools) clues lead the birds to stop traveling and start searching, by diving. 3
Feeding: Spheniscus penguins searching for or catching prey remain underwater for extended periods. Birds may remain underwater for up to 240-300 seconds. The great variability in duration of dives is probably dependent on dive depth and whether the birds encounter prey. In order to optimize foraging effort, the length of time a penguin should remain underwater after encountering prey may depend on the size of the school and the relationship between dive duration and recovery duration.
Feeding dives generally go to deeper depths than traveling dives. However, energetically it is more advantegeous for penguins to forage close to the suface. As prey availability is not always highest in these surface waters, it is not surprising that the depths that penguins actually exploit while foraging vary considearbly although there remains a tendency to spend most of their time underwater relatively close to the surface.
When prey are encountered during diving the direction of swimming changes dramatically and continuously,while speeds become much more erratic.

Prey capture: when a school of fish is encountered, penguins in groups hunt co-operatively. The birds swim rapidly round the fish herding them into a dense, depolarized group. Individual penguins leave the encircling group to plunge through the fish below the school. It is thought that conspicious flank pattern may help Spheniscus penguins to capture shoaling fish, by sowing panic amongst them, with the result that they break ranks in alarm and are easier to catch. It is not known how penguins locate prey in the darkness at great depths or at night, but they are undoubtledly helped by the fact that many pelagic cephalopods,crustaceans and fish are bioluminous.
Prey handling: pelagic school fish are seized on, or just behind the opercula. The hooked beak tip is used to enclose the fish body rather than to pierce the flesh. Most prey are swallowed head first underwater while the penguin swims, but large prey may be manipulated at the surface.

African penguin. [4]

This species mostly takes small, pelagic shoaling fish (anchovy), with some cephalopods and crustaceans; catches prey by pursuit-diving to 30-90 meters; forages diurnally most trips lasting <24 hours, although some birds remain at sea overnight.

Foraging behaviour: most breeding birds leave the colony around dawn and return late afternoon or early evening [5], although in radio-telemetry study it is reported that most birds

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[3] Broni

[4] Williams.

[5] R.P.Wilson

departed for the sea in the evening and returned at night on average 45.1 plus/minus 47.9 hours later. [6]
Often feeds in association with feeding cape ganets (Sula capensis) and Cape cormorants (Phalcrocoras capensis)
Foraging range: mean distance travelled to foraging area was 110.5 plus / minus 43.1 km, direction of the outward journey being "haphazard" or zig-zag but the inward journey being direct; from line transects at sea 50% of non-breeders were <20 km from coast and 50% of breeding birds were <3 km; foraging range during an average 11 hour trip was 24.2 km. Mean group size at sea: eight [7], 2.2 [8] and 4.6 [9]

Diving behaviour: only 1% of searching dives >30 meter and 2,5% > 20 meter during foraging dives maximum depth was 130 m and mean maximum depth ranged from 46.5 plus / minus 20.3 to 62.4 plus /minus 36.2 meter in different individuals. Mean dive duration, 22.3 plus / minus 11.6 seconds inside Saldanha Bay and 146 seconds in deeper water ouside the bay; 23 plus / minus 20 seconds, dive duration positively correlated with group size.

Swimming speeds: over complete foraging trip, 3.5 – 6.3 km/hr; over 10 meter, adults 12.4 plus /minus 2.4 km/hour, juveniles 9.5 plus / minus 1.8 km/hour, fledgings 4.6 plus /minus 0.8 km/hour; underwater, 7.3 plus / minus 0.5 km/hour, males swim faster than females.

Diet:
Fish: Engraulis japonica, Trachurus trachurus, Etrumeus micropus, Etrumeus capensis, Etrumeus teres,Ssardinops ocellata
Crustaceans: Squilla armata. Cephalopods: Loligo reynaudi.
90% of prey items were beteen 50 and 115 mm. In general size ranges reported are between 20 and 310 mm.
Seasonal variation occurred in diet with Sardinops ocellata commnest in summer, and Engraulis capensis during September-November with a greater diversity of other prey species at this time suggesting reduced availability of preferred anchovy prey. Estimated total prey consumption: 76 kg anchovy per nest and 136 kg per adult per year (from metabolic rates), birds spending approximately 48% of energy budget and 19% of time budget obtaining food during chick-rearing. Chicks reared on squid diet gained weight at a slower rate, took longer to attain constant weight and had lower asymptotic weight than chicks reared on fish diet. [10]

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[6] Heath and Randall

[7] Siegfried.

[8] Broni.

[9] Ryan.

[10] Nagy, Heath and Randall.

Humboldt penguin [11]

Mainly takes small, schooling fish (anchovy, sardine), caught by pursuit-diving, mainly in shallow dives, forages diurnally.
Foraging behaviour: most birds depart colony after sunrise, foraging close to the colony at some locations but further offshore at others; at sea, most birds forage in groups, with single birds seen on only 14% of 39 observations; in 11 of 18 cases birds were associated with dense shoals of fish.
Diving behaviour: at Isla Chanaral most dives were to the seabed, birds then immediately returning to the surface, and dive duration correlated with water depth; dives to maximum 30 meter lasted 26.2 plus / minus 8.2 second; at Algarrobo most birds remained within 1 meter of the surface for full duration of dive, probably because of greater water turbidity.
Maximum dive depth recorded: 80 meter.
Swimming speeds: 0.46 – 2.40 meter/second in captivity.
0.94 meter/second during foraging in the wild. 12
Diet: Isla Chanaral, Chile: garfish (Scomberesox sp.) 94% anchovy (Engraulis ringens) 1%; Algarobbo mainly anchovy (72%), sardine (4%) and squid (14%). Also feeds on Odonthestes regis.
Size ranges of prey 36 - 270 mm long.

Magellanic penguin. [13]

Mainly feeds on small, schooling fish species (principally anchovy and sardine), with some cephalopods and crustaceans (the latter at the Falkland Is); forage diurnally, catching prey by pursuit-diving, with most dives to 20-50 meter (maximum 90 meter).
Foraging behaviour: at Cabo dos Bahias chick rearing adults depart for the sea at dawn with most birds returning between 17.00 and 21.00, adults having returned to 85.3% of nests by 21.00. Foraging trips duration varies between year and between breeding sites; at Punta Tombo, trips are shortest during hatching, increasing in length early in chick-rearing and then decreasing just before chick-fledging. At Cabo Virgenes foraging trips are always shorter than at Punta Tombo,averaging 1.5 days throughout chick rearing; at San Lorenzo and Punta Loberia 41%, 56% and 3% of trips were of 24, 48 and >60 hour duration. Most birds return to the colony late in the afternoon or at night when solar radiation is less intense.
Often feeds in association with predatory fish, other seabirds and Patagonian sealions (Otaria flavescens).
Diving behaviour: varies between different breeding locations; birds travelling to foraging areas make shallow dives averaging 14.1 plus / minus 3.0 seonds; at Punta Arenas, Chile, foraging dives averaged 57.8 plus/minus 7.8 meter, with maximum diving depth ranging from 6 to 90 meter (median 50 meter); at San Lorenzo, all recorded dives were >20 meter (median depth 66.5) and at Punta Loberia, 65% of dives were >20 meter with only two dives >60

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11 Williams

12 Culik.

13 Williams.

meter; at Punta Tombo, maximum dives averaged 37 meter, with the most common dive depth for 30 birds at sea for more than 1 days being 19 plus/minus 3.5 meter.
Maximum dive depth recorded: 70 meter.
Swimming speed: undewater, 7.6 plus/minus 1.3 km/hour.
Diet: highly ariable between breeding sites, including locally, and between years. Fish: Engraulis anchoita, Austroatherina spp. Merluccius hubbsi, Sprattus fueguenis, Micromesistius australis, Notothenia spp. Cephalopods: Gonatus antars=cticus, Loligo gahi. Crustaceans: Munida gregaria. Size ranges from 25 to 160 mm.

Agonistic and appeasement behaviour.

African penguin.

In agonistic behaviour of African penguins , adults are significantly more agressive, and agression is more severe towards juveniles than towards other adults; head-moulted juveniles receive significantly less agression than non-moulted bird.
Threats include

(1) “point”, bird points its beak directly towards intruder or opponent, with bill closed, flippers held at the side and, at high-intensity, with raised feathers on crest; head may be fully retracted or extended and may be rotated to one side; often aggressor gives extended 'point' and op-ponent a retracted 'point'; typically given by incubating bird to another bird passing close by nest (<0.5 m);
(2) 'gape', possibly a variant of the 'point', except that bill is held open; most often recorded in moulting groups, given by juveniles reacting to attacks from adults; accompanied by a hissing sound;
(3) 'alternate stare', head rotated from side to side, with neck extended or retracted, bird staring out of each eye alternately at opponent;
(4) 'sideways stare', with head held slightly below horizon-tal, crest erect, bird turns head to one side and stares at opponent; direct fighting, typically in-volves pecking and two birds may peck at each other simultaneously, interlocking their bills, pulling, twisting and making 'growling' vocal-ization; while their bills are interlocked birds may also attempt to beat each other with their flippers; 'beak slapping', involves two birds facing each other, typically standing and some-times stretching up, beaks placed side by side and crossed, each bird attempting to push the other's bill sideways or downwards; often in-terspersed with other aggressive behaviour.

Appeasement behaviour includes the 'look around', where the bird stands with neck re-tracted and rotates its head from side to side; may also function as low-level threat; grades into 'slender posture' or 'slender walk', where body is stretched up, neck extended, feathers sleeked and flippers held away from body; used by birds moving through colony to avoid aggression from other birds.

Humboldt penguin.

Agonistic behaviour; threats include:

1. ‘alternate stare’ where birds crouches down, arching its neck and twisting its head back and forth to show one side of its head then the other
2. ‘one-sided stare’ or ‘sideways-stare’: bird arhces its neck holding its head to one side, often exposing the white sclerae
3. ‘pointing’ where the bird leans forward, directing its closed bill towards an intruder; if the bill is held open, this has been termed “graping” ; direct fighting involves pecking, charging and two specific behaviours
4. ‘beaking’ where two birds grasp and interlock their beaks, pulling and twisting their heads

Magellanic behaviour.

Agonistic behaviour: fighting is most intense early in the breeding season from mid-Sept to early Oct and again in Jan-Feb; both males and females fight, but male-male fights are more common and more severe. While most birds retain the previous year's nest, ownership of nest-sites is sometimes con-tested, with territorial contests ranging from displays such as braying and posturing, through minor pecking with chases, to direct fighting which can injure birds; most fights are short (<1 min) and often end in one bird chasing the other away. Contests over nest-sites more often result in the intruding bird being evicted; losers then usually nest in inferior sites (with less cover) and are less likely to get a mate than those that retain their nest. The general form of displays and breeding behaviour is very similar among all Spheniscus species; magellanic penguins appear more agressive than Humboldt penguins probably because the former nest more densely.

On appeasement behaviour there is no information available.

Voice.

The constant stream of vocal exchanges mean that penguin colonies tend to be very noisy, particularly the densest ones. As Spheniscus penguins are highly social birds, they have well developed systems of communication, both visual and vocal, and there are notable differences in voice at both interspecific and intraspecific levels.
Calls are individually separable, enabling partners to recognize each other and also their chick with complete certainty in the midst of a dense colony. There are three main kinds of vocalization in the Sphenisscidae: the contact call of an individual; the display call used between partners at a colony; and the threat call. The first is usually used at sea, as an aid to visual recognition, in order to maintain the cohesion of the group. The display call is the most complex, as it has to communicate more information than the others, and must permit specific, sexual and individual recognition. The threat call is the least elaborate and is used for defending a territory, as well as for defence against predators.
Of the African penguin very little information is available. The ecstatic display (see below) is a donkey-like braying consisting of a sequence of high-pitched modulated inspirations with

larger and louder expirations. The mutual display call (see below) is similar but more complex; interindividual varition in calls is greater than intra-individual variation. [8]
From the voice of the Humboldt penguin little is known too. The contact call is a slightly prolonged hoarse note with a single pitch. The species shows some species-specific characters compared with the other Spheniscus species. The ecstatic display call consist of a uniform sequence of short phrases while the mutual display call is more complex.

The main call of the Magellanic penguin is 'donkey-bray', the function and use of which varies throughout the breeding season: used fre-quently as advertising call during pair-forma-tion (Sept-Oct and Dec-Feb) but after pairing birds are mostly silent during remainder of breeding season except for

(1) greetings at nest relief
(2) brays and calls during fights, and
(3) vocalizations of chicks; if birds fail in their breeding attempt they resume calling; when females are incubating (mid-late Oct) the colony is particularly silent. Individual variation in calls appears more marked than geographical variation: calls of birds from different colonies (Caleta Valdez and Cabo Virgenes) sound similar; intra-individual variation in calls is very small even between years, but brays differ markedly between individuals and are impor-tant for individual recognition. The contact call consists of a 'haw' sound, given occasionally on land but mainly at sea where it serves to locate other penguins and in coordination of foraging.

Sexual calls include
(1) 'donkey-like bray', which consists of several low introductory 'huffs' followed by one, or rarely two, longer higher-pitched brays that are distinctive from one individual to another; birds tend to alter-nate braying calls and even when three individ-uals are standing together their calling rarely overlaps; the 'huff' part of the call is strongest at 1 kHz but ranges up to 6 kHz and the 'bray' element can reach 8 kHz lasting 4~5 sec. Males use the 'donkey bray' to attract females to their nest-site, calls peaking during Sept-Oct, al-though braying by unmated birds occurs throughout the breeding season; females rarely bray but sometimes do so when threatened or when seeking a mate. Calling is most intense late in the evening and early in the morning, e.g. between 25 and 28 Sept at Punta Tombo, the calling rate for brays at an inland site about 1 km from the sea averaged more than 20 calls/min between 04.00 and 08.45 hrs, and was least frequent, averaging 1 call/min, around 13.00 hrs, with average rates of less than 10/min from 09.30 to 15.30;
(2) mutual braying or the 'courtship bray' occurs in pairs during nest reliefs, and the birds also give a 'purr' call while standing next to each other or during 'bowing' (with their bills pointing towards the ground or nest). The agonistic call: donkey-like brays are used before and after agonistic interactions. In intense fights 'purr' call is used particularly when in close quarter and biting each other.

Chicks begin peeping before the egg hatches and this call appears to be invariant within an individual; parents recognize chicks by their call and chicks that call but are not the adult's own chicks are often pecked and driven away, e.g. during feeding; chicks also recognize the calls of their parents and often run more than 20 meter to join the adult after it calls.

[8] Jouventin.

Life cycle and movements.

Adult African penguins are sedentary, while juveniles spend their first year at sea and return to breeding colonies at about one year of age to moult.
The Humboldt penguin is a very poorly studied species in the field. The adults are probably sedentary, though there are indications that the species might be migratory to a certain extent. Through satellite-transmitters on non-breeding bird from the Pan de Azucar Island an extended migration route of about 700 km to northern Chile has been determined. Banding studies being done at Algarobbo indicate that adult birds are dispersing to the north (50 km) and south (170 km). [9]

Pairs of Humboldt penguins raising two clutches go through the following annual cycle:

January – February: moult
March: nest occupation
April / May: incubation
May – July: chick rearing
August: nest occupation
September – October: incubation
October – December: chick rearing

In contrast, Magellanic penguins are well-studied. Adults are pelagic and migratory. Birds rarely come ashore during the non-breeding season (May-August). The migration route goes northward along the coasts of Peru and Brazil following the anchovy, one of the bird's major prey. The birds return to the colonies in September/October.

Reproductive behaviour.

Spheniscus penguins do not nest in colonies so much as they nest where suitable acces to the sea and suitable nesting sites occur.
The biggest problem for nesting Spheniscus penguins is the sun. They avoid it by nesting in sheltered sites like burrows, sea caves, crevices or under rocks, boulders or vegetation. Surface-nesting also occurs but only during winter or when there is a strong wind-chill. When penguins nest on the surface, they tend to nest densely, to protect their eggs and young against aerial predators. These surface nests are simple, open scrapes poorly dug in guanao or soil. They have a round or oval shape and have either a very low border surrounding the nest or taller sides. [10] Burrow nests appear to be more succesfull than surface nests, which may be used when covered sites are occupied or substrates are unsuitable for burrowing because of texture or susceptibility to flooding.
Field studies on Humboldt penguins and Magellanic penguins indicate that burrows have a lower thermal variation than surface nests or nests under vegetations and rocks. Though the burrow may require extra energy output of digging, their occupation rate is higher.

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9 Penguin camp document 1997,Culik.

10 Battistini & Paredes

In addition to this, chick mortality in burrows is lower; from long-term studies on Magellanic penguins it appears that the amount of nest-cover is positively correlated with fledging success, regardless of yearly differences in pair condition. The same pairs tended to be more succesful when they had more nest cover, and experimental increases and decreases in cover significantly affected survival of nest contents.
Other characteristics of nest sites, such as nest type and type of vegetation over the nest, did not affect success. Any advantage of burrows versus bush nests (if one exist at all) appear to be a function of the greater amount of cover provided by burrow nest. The positive effect of cover resulted mainly from reduced exposure of nest contents to predators during incuba-tion and to high temperatures when chicks were young.
Roof cover was positively correlated with fledging success in nests from all areas. Cover on the sides of the nest giving the most protection from the sun was positively correlated with fledging success in warmer sites and with survival of young chicks in all areas. Cover on the north and west sides was a significant determinant of chick survival. Young chicks at nests with less cover were more likely to move from their nests and to die on hot days.
Experimental results indicated that the likelihood of egg detection by predators decreased with increasing nest cover. Height of nest entrance was a significant predictor of egg loss, suggesting that accessibility of nest contents to predators was an important component of predation risk. Thermal properties of nests and risk of predation were related; predation of nest contents was more likely when adults were absent, and during hot weather adults were more often absent from nests with little cover. Although the effect of cover on success was small relative to the large yearly variation in success due to food conditions, cover is likely to influence lifetime reproductive success substantially. [11]

Nest sites must also be accessible to the sea and, for surface nesters, essentially level as penguins build only rudimentary nests. Material being used for nests varies from place to place but generally consists of pebbles, some kind of plant matter and old feathers.
These habitat requirements combine to produce complex mosaics of nesting colony distributions and nest densities.

All Spheniscus penguins are thought to be strictly monogamous that is males with only a single female in each season, and vice versa. In many species birds also retain the same mate from one year to the nest and long-lasting pair bonds can be maintained over many consecutive seasons. There appears to be little evidence for a marked improvement in breeding success with increased duration of the pair bond in penguins. Why then do most penguins show relatively high levels of pair-fidelity ? It appears to be related to the degree of association between pairs rather than simply being a conseqeuence of site-fidelity, i.e. it is a behavioural component.
The sexual behaviour of Spheniscus penguins includes three main types of display:

-The ecstatic display is most commonly performed by males at the nest site prior to the arrival of the female or during the period of the pair formation. It has a territorial function demonstrating occupation of a nest site and warning other males to keep away and also an “advertisement” function alerting lone females to potential nest-sites and mates.
In the ecstatic display standing with the feet apart and firmly planted, the bird slowly and deliberately stretches up until the head and beak point upwards. Initially the beak is closd, opening as the head is raised. Simultaneously the flippers are raised until they are nearly

[11] Stokes and Boersma.

horizontal. The breast and base of the throat heave, silently at first, grading into throbs and finally into full braying. At the climax, the beak is wide open, the head thrown back, and the flippers beat back and forth in time with deep rhythmic heaves of the breast. The ecstatic display can also be performed in a sitting or lying position.
Juveniles and females sometimes display the ecstatic song. In this case the song sounds deeper and contains an intermediate tone. [12]
These displays also facilitate the recognition of partners at a distance.
-Mutual ecstatic display: mutual displays, performed simultaneously by both members of a pair, are often very similar in form to the ecstatic display and are typically seen at the nest-site following pair-formation. The display typically involved the pair facing each other, bowing forward and then rapidly throwing their heads and bills vertically, giving a braying call similar to that of ecstatic displays. However , the beak is pointed more forward and the forward movement of the body (typical of the ecstatic display) is lacking. Mutual displays probably function primarily to strengthen and maintain the pair-bond, to coordinate the activities of the pair and to indicate ownership of a nesting territory.
Other possible functions of mutual display include stimulating and synchronizing gonadal development and copulation behaviour within the colony, thus increasing the advantages of colonial nesting, and reducing aggressive interactions between partners, while they are in close proximity at the nest-site (appeasement).
-Bowing:
Bowing may also function in strengthening and maintaining the pair bonds and in lessening the likelihood of agression between partners in the early stages of pair-formation, it is mainly seen at the nest-site when both birds are present, although single birds may also perform the display, and typicaly involves one or both birds bending forward directing the tips of their bills at the nest or at the partner's bill.
-Copulation displays: copulations are mainly seen on the nest-site and the form of the display is very similar in all penguin species. The copulation behaviour of all Spheniscus species is very similar to other species of penguins.
Copulation may be preceded by mutual displays, bowing, periods of intense nest-building activity, or circling of the nest by the pair. The male then approaches the female, often performing an appeasement display. He leans against the female's back attempting to press her down into a prone position. This action may be accompanied by the male rapidly vibrating his flippers against the female's side (the arms act) and nibbbling or preening her head and neck. Meanwhile he's pressing his breast against her back. He then gently pats her into a sitting position.
Once the female is lying prone the male stands on her back and gradually treads backwards towards her tail, positioning the cloacae for coition. The male continues to vibrate his flippers and preen the female and may rub the base of her mandible with his vibrating bill tip. The female responds by holding her tail vertically or to one side and everting her cloaca and there is a brief cloacal contact and transfer of sperm. Immediately afterwards the male jumps off and both birds may preen or perform further mutual displays. There is no formal-post-copulatory posture. The whole copulation routine may last from a few seconds to several minutes. Copulations usually take place at the chosen nest-site. They are frequent prior to egg laying and may be performed up to nine times in three hours and incomplete copulations (without cloacal contact) are also common. Mated pairs rarely copulate after egg-laying but copulations may be seen in breeding birds during the period of moult. Copulations may also,

[12] Eggleton & Siegfried, 1979

rarely, occur off the nest and outside permanent pair-bonds (the so-called “extra-pair copulations”).

The process by which birds choose mates, and the possible characteristics they may use to assess the quality of potential partners (mate-choice) has been little studied in penguins to date. This might be because penguins are typically monogamous, choosing a new partner only relatively rarely and because there appear to be few obvious differences in size or plumage characteristics within either sex that might be used to assess mate quality.
Body size: do females prefer larger males?
Females may mate non-randomly with larger males either (1) incidentally, by mating with earlier arriving males, these tending to be heavier or better quality individuals, or (2) intentionally, by selecting males based on characteristics of their ecstatic display call, which might correlate with a male’s body size or “quality”
Alternative reproductive strategies: all penguin species share incubation and chick rearing duties equally between the sexes (or at least sex plays an essential and complementary role in this process). This “requirement” for the participation of both parents in order for breeding to be successfull, will inevitably lead to the widespread occurrence of a monogamous breeding pattern, and will act against the evolution of mating systems such as polygyny (one male mating with two or more females) or polyandry (one female: two or more males). Nevertheless, there is still the potential in penguins for other alternative mating strategies such as extra pair copulation (mating outside the permanent pair bond) it is known of Adelie penguins but not of other species.

African penguin.

The sexual behaviour of the species consists of:

(1) 'vibratory head shake', apparently confined to birds on their nest-site; performed by lone birds or pairs, typically with bird sitting or crouching, less often standing; head is bowed, with bill directed downwards close to body, turned to one flank and vibrated from side to side; at high-intensity, head may be swung through 180° from one flank to the other; functions to advertise nest-site and terri-tory occupation, may also appease aggression between mates;
(2) 'ecstatic display',
(3) 'mutual ecstatic display',
(4) 'bowing', a complex and extensive set of behaviours, ma inly seen between pairs and functioning in maintenance of pair-bond; 'extreme bow', only given between mates, with one bird extending and arching its neck towards its partner, crest held erect and flippers held away from sides; 'oblique stare bow', very intense behaviour, where bill is dropped on to breast with neck re-tracted and arched over and head tilted to one side; performed with vertical head swinging and during nest-building;
(5) ‘allopreening’ recorded between mates, between parents and chicks and between chicks;
(6) 'beak slapping', as de-scribed above, but also performed by pairs and associated with allopreening and mutual ecstatic displays.

African penguins nest semi-colonially at low densitie in burrows or on the surface. The nearest nest distances are 4.3, 4.8 and 5.5 meter for nests in burrows/under rocks, under bushes or abutting bushes/rocks respectively and 0.86 m in open, surface nesting colonies.

Pair fidelity and site-fidelity average around 60% for birds breeding in the wild. [13]

Humboldt penguin.

Of this species there are few detailed studies of birds in the wild; most information is from birds in captivity.
Agonistic behaviour: threats include (1) 'al-ternate stare', where bird crouches down, arching its neck and twisting its head back and forth to show one side of its head then the other; (2) 'one-sided stare' or 'sideways stare', bird arches its neck holding its head to one side, ofien expos-ing the white sclerae; (3) 'pointing', where the bird leans forward, directing its closed bill towards an intruder; if the bill is held open, this has been termed 'gaping'; direct fighting involves pecking, charg-ing and two specific behaviours: (4) 'beaking', where two birds grasp and intelock their beaks, pulling and twisting their heads; and (5) 'beak vibrating', similar to bill-slapping in African Penguins; no sex differences occurred in the frequency of agonistic behaviours in birds in captivity.
On appeasement behaviour there is no information available.
Sexual behaviour:

1 Ecstatic display, performed mainly by males at, or close to, the nest site (74% at nest site in wild birds, Scholten 1992); in captivity 91.3% *(n* = 2392) of displays by males, with males having more calls per display bout (1.9-3.0, mean 2.4) than females (1.3-2.0, mean 1.5, Scholten 1987); in wild birds, 100% of ecstatic displays by males (Scholten 1991), with 1-4 calls per bout (median 2 calls). When a change of nest-site occurs, the male sometimes starts giving ecstatics at the new nest-site a year or more before actual nesting ocurs.
2 Mutual ecstatic display.
3 'arms act', performed mainly by males (95% of cases, *n* = 259); one bird ap-proaches a second and, while pressing its body against that of the other bird, beats or vibrates its flippers against that bird’s body.
4 'bowing', usually seen in pairs, one bird pointing its beak to the ground and vibrating its head from side to side; most often per-formed by females.
5 Allopreening, usually performed with the mate.

The nest is a by the birds excavated burow, typically with along, narrow entrances, or a cave or a natural crevice amongst fallen boulders. Occasionally birds nest on the surface in areas protected against ground predators; nest often lined with feathers. Most nest-building and furnishing is carried out by male, e.g. in captivity 81.5% of nest material was by male and in the wild females were never seen carrying nest material.
The species is monogamous. Facts about pair and site-fidelity are mostly based on captive birds. However, recent studies at Algarobbo show that 67% of the breeding pairs remain together for the next reproductive period. In case one of the partners had died, 25% chose for a new partner. Only 8% chose for a new partner while the old one was still alive. [14]

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[13] La Cock

[14] Diebold.

In captivity females broke up existing pair-bonds significantly more often than males: 10 of 11 mate changes in males were due to partner death or desertion compared to only 3 of 8 mate changes in females. Thus, mate choice may be mainly determined by the female. This phenomenon fits in with with the general theory of mate choice. Females invest more in their offspring than males. Females can produce only a very limited number of gametes each breeding period, while males can produce millions and fertilize several females. Therefore, errors in mate selection are more serious for females than for males. The possible functions of mate choice are to find a partner of the right species and to assess the value of the partners potential investment in parental care.
Mate choice by the female seems to be highly influenced , apart from the quality of his territory, by the physical characteristics of the male, his weight in particular. In fact an optimal weight of the male and the female will allow them to fast longer during breeding, will give them a better protection against the loss of body-temperature and will allow longer foraging trips. In addition, heavier males are able to show longer ecstatics. An optimal weight will also allow the birds to invest much time for courtship and therefore a better pair-bond.
In captivity, during the breeding season, established, but unsuccessful pairs spend much more time with each other than established, successful pairs, due to the need to invest more time and energy in the quality of the pair bond. This is expressed for instance in a higher number of mutual calls.
However, newly formed pairs usually do not invest too much time with each other in order to have a short try out and to be able to find possible “better” partners later on, without losing too much energy.
Established and succesfull pairs show a high level of behavioural synchronisation, which is expressed in time spent together, partner-specific interactions and mutual calls.
During pre-breeding (3-4 weeks prior to egg-laying) partners of all three pair categories spend more tme than usual together. This is probably the result of mate guarding, which is pronounced in unsuccesful pairs.
Polygynous / lesbian and polyandrous / homosexual bonds have been recorded in captivity, in populations with surplus females or males respectively. However, these trios will be almost impossible to recognize if birds are not marked properly. [15]

In captivity 91% of males (n=134) and 89% of females (n=136) used the same nest-site for successive breeding attempts; most changes of nest-site were made by both birds of a pair, not following mate change; males retained nest-sites following mate change.
At Alagarobbo Humboldt penguins show a high degree of nest fidelity, with more than 60% returning to the exact same nest site in subsequent reproductive periods. Major changes in the nest location occurred in less than 10% of the recorded events. Major changes in nest location were more to occur in females than in males. Nest site fidelity may be stronger in males; this is in agreement with findings from studies of captive birds, where nest site selection appears to be initiated by males, and that nest site fidelity in female Humboldt penguins is at least in part a reflection of a strong pair bond.

[15] Linzmeier

Magellanic penguin.

Sexual behaviour includes:

(1) 'bill-duelling' or bill-slapping, where two penguins hit their bill tips against each other; between male and female this may represent part of courtship be-haviour, although it also occurs between males when it may lead to fighting;
(2) 'circle dance', a courtship behaviour where the male walks in circles around female with neck contracted before leading her to the nest or beginning flipper patting;
(3) “flipper patting” when the flippers are vibrated vigorously against the other penguin, occurs only between mated pairs and between males attempting to court females;
(4) ‘mutual preening’, mainly occurs between mated pairs although parents also preen chicks and sibling chicks occasionally preen each other. Copulation behaviour is similar to the other Spheniscus species. Copulation occurs mainly on land as birds tend to remain at the nest-site for a few days or even several weeks before egg-laying; cloacae of both male and female swell before egg-laying; females probably control copulation, although males will sometimes attack females that are not receptive; birds copulate mostly in front of the nest-site, copulation starting as much as two weeks before first eggs appear; females can store sperm for at least four days as males excluded from the female between the laying of the first and second egg still had fertile eggs.

In general birds that retain the same partner have a higher reproductive success than newly mated pairs; divorce rates varied between years from 3.3% to 18.4% with a mean of 9.6%. Successful pairs were less likely to divorce the following year than pairs that failed.
At Punta Tombo, among experienced breeders, nearly 80% of males and 70% of females retained the same nest-site between years; few adults banded at Punta Tombo are sighted at other colonies indicating that natal fidelity is strong; when pairs divorced, males were more likely than females to retain the same nest the following season; birds were more likely to return to the same nest if they were successful the previous season. At Punta Tombo, birds that do change nests usually move very short distances (<50 m) with <1% moving >200 m. Males that moved to poorer quality nest-sites (those with less cover) atracted fewer females on average than in the previous season, while those moving to higher-quality sites attracted more females.

Spheniscus penguin husbandry manual

First edition

Edited and compiled by the Penguin TAG

A publication of the EAZA

Section B: Management in captivity

Housing and enclosure requirements

Housing and enclosure requirements.

Introduction.

A well designed penguin exhibit should include the following components:

1.Land space. Enough land mass to accomodate the number of birds housed in the exhibit which allows for territorial disputes and provides areas for nesting during the breeding season.

2.A pool. The water area should be large enough to accomodate all the aquatic behaviour of the birds and its size and shape should be such as not inhibit normal swimming. Birds should be able to swim at maximum speed without encountering any obstruction. A minimum depth of 80 cm is required. The pool should be designed in such a way that there is no stagnant water.
In case water-passages are being designed, a minimum width for two penguins passing at the same time is needed, i.e. at least 100 cm.

3.Isolation area. A separate area to house birds that need to be isolated for whatever reason (e.g. non-contagious health problems, behavourial problems etc.). This area can temporarily be established in the main exhibit. Birds should be able to have visual contact with conspecifics in the main exhibit.

4.Quarantine area. A separate facility to accomodate newly-acquired birds or birds that must be separated from the group for health-related reasons. This area should provide separate air and water systems from the main exhibit.

A quarantine area can serve as an isolation area if not in use for its intended purpose, or if one commits and treats the isolated birds as quarantine birds whenever quarantine is active. An isolation area without separate air and water systems should not be considered as an appropriate quarantine area.

Recommendations for exhibit and holding area size.

Attempts at defining a standardized formula to calculate optimal housing dimensions for penguins, taking into account all parameters, has been difficult at best.
The following guideline is recommended as minimum and only minimum criterium for exhibit and holding standards. It is recommended to consider providing additional land area and pool depth.

	Land surface area	Pool surface area	Pool depth
Per bird for first six birds	2,5 m²	2,5 m²	70 cm
Each additional bird	1,25 m²	1,25 m²	70 cm

The total land mass should be larger than that of the pool. A recommended land – water ratio is 2 : 1

In addition, facilities should be strongly encouraged to build or renovate exhibits that will allow offspring to be held for up to two years.

Air temperature.

The optimum air temperature range for indoor exhbits for Spheniscus species is 3º C to 22º C (37º F to 72º F). The same parameter can be used seasonally by northern facilities to exhibit these species outside.

Spheniscus penguins can be successfully housed indoors or outdoors, or in exhibits using a combination of both. The success of an outside exhibit depends chiefly on the ambient temperature and the relative humidity of the area.
Spheniscus penguins have been housed successfully in warmer climates where the exhibit is directly on the coast and the air is breezy.
As a rule, penguins do not thrive in humid climates. They are highly susceptible to malarial infection; outside exhibits in areas with heavy mosquito populations should not be considered. Additionally, warm, humid climates may be conducive to Aspergillus infection in birds.
In general, draft should be avoided at all costs.

When housing Spheniscus penguins outside in areas where the temperature rises above 29.4º Cº (85.0ºF), provisions should be made to allow the birds a means of heat relief. Sprinklers, misters, shaded areas, and forced-air movement are methods to be considered. Outside exhibits should be constructed so that the birds have shelter from freezing winds in the winter months.
Though being penguins, it is a misunderstanding to accept that Spheniscus penguins could bear extremely low temperatures. When the temperature falls below freezing and particularly in combination with a strong wind from the east, all birds should have access to shelter as they may develop frost-bite in feet and flippers. These shelters can be of a very straightforward design, with an open front, but not orientated to the wind.

Open water must be available all winter and pools should not be not allowed to freeze. Some institutions have reported mortalities among penguins that became entrapped under a pool's frozen surface. Larger colonies may benefit from a "beach” area to facilitate individual feeding of supplemented fish.

Drainage.

Drainage is a vital component for a good penguin enclosure as the birds are susceptible to high levels of humidity.
Drainage systems for land areas and pool areas should be separate, to avoid pool contamination from run-off of exhibit maintenance. Drains, intake valves, and skimmers should be covered so that direct contact by birds is not possible. In filtered systems, care should be taken to provide a large enough bottom drain cover to prevent the possibility of a bird being sucked onto the drain.

Surface drainage should be adequate to allow for quick drying and **all floors should slope to the drain**. Low spots that puddle should be avoided because a constantly wet substrate will eventually cause foot problems in penguins, not to mention the added staff hours needed for servicing the facility.

Substrate.

Adequate substrate has been the topic of concern since zoos and aquariums first began exhibiting penguins.
Historically, concrete has been used as a substrate; it is easy to clean and readily available. Over a period of time, however, the abrasive nature of concrete takes its toll on a penguin's foot and the result can be pododermatitis (bumble foot).
For this reason concrete, or any substrate, **that remains wet for long periods of time** should be avoided altogether. Many zoos have found it advantageous to use matting over concrete in selected areas of the exhibit. Some facilities place a protective coating of lacquer over concrete surfaces to reduce abrasiveness and to fill in the small pores where bacterial colonies can become established.
In designing or renovating an exhibit, a variety of materials and textures should be provided for the birds to stand and move on. These can be natural rocks, sand, grass, pebbles and matting. An uneven surface causes a different distribution of the bird's weight on the feet during standing and walking, which is of vital importance in avoiding bumblefoot.
It should not be forgotten that Spheniscus penguins are good climbers and therefore additional rocky slopes are recommended for reasons of exercise. This behaviour also has an attractive and educational value to the public.

Nests and nest substrate.

For this section see the chapter on reproduction.

Water quality.

Captive penguins historically have been exposed to a variety of water sources; both fresh water and salt water are used in exhibits. Though, freshwater exhibits by far exceed the numbers of salt water exhibits. Water quality ranges anywhere from chlorinated tap water to sophisticated, state-of-the-art filtration systems.
Areas with hard water may experience mineral deposits on exhibit viewing glass; use of a water softener may alleviate this problem.

The water in a penguin pool should be clear and of good colour with low bacterial count. There are several ways of controlling coliform levels. Water treatment filtration systems include sand/gravel, diatomaceous earth, ozone, biological and ultraviolet light (UV). The addition of a chlorine or Bromine system in conjunction with the filtering system aids in controlling coliform levels. Older exhibits without filtration should maintain a clean supply of constantly running water, with adequate surface water skimming. Skimming capacity is essential for birds' health. Oils that build up on the water need to be removed in order to maintain healthy feather condition. The number of skimmers should correspond to pool size and configuration.

Turbidity can be reduced by proper placement of water jets directed toward the pool bottom. A rotating fish-eye adaptor at the end of the jet provides the flexibility of directing the water current so that debris is moved towards the bottom drains. Underwater vacuum systems are also effective in keeping the pool bottom clean. Exhibit pool floors should be smooth to facilitate the movement of feces and bottom debris to drains and filters.
Water chemistry and temperature should be checked on a regular base. In the use of chlorine, Spheniscus penguins can be kept at a pH of 7.5 – 7.65
The acceptable water temperature range for Spheniscus penguins is 0º – 29º C (32º – 85º F)
As some outside exhibits may have an ambient temperature that could rise above 29º C during the summer months without causing adverse effects on the birds. Care must be taken to assist birds in thermoregulation during the hot summer months. Methods to consider in accomplishing this include cool-down of pool water through the addition of fresh water, a cool misting system or a water chiller.

Grime in the water gets in the bird's feathers and may cause over-preening. The bird can't get it off, but keeps trying thus wearing out the feathers. It doesn't take much exposure for the bird to develop this problem and can therefore be prevented by a thorough skimming of the pool, expecially during feeding in the water. Water jets at the suface or air bubbles for maximum skimming are also a big help.

Air quality.

Penguins as a group are highly susceptible to air-borne fungal infections. For this reason the air quality in an indoor penguin exhibit must be optimal. Air flow, fresh air exchange, and filter capacity should be researched to provide the cleanest air possible.
Aspergillus fumigatus spores range in size from 2.5 - 3 microns with other Aspergillus species spores as large as 10 microns; therefore in order to remove them from the air, a filter must remove particles in that size range or smaller. If possible sources of Aspergillus are external to the exhibit, then consideration should be given to reducing fresh air intake and providing a high-quality filter on the incoming air line as well as in the recirculation line. If the possible source of Aspergillus are internal to the exhibit, then a high-quality filter in the recirculating system, a high volume air change per hour, and perhaps increased fresh air exchange (as well as identifying and removing the Aspergillus source within the exhibit) should be considered.

Air turnovers in the range of 15 air changes per hour have been recommended for laboratory animals. These parameters may be acceptable for penguins, however, the specific design of an air system needs to balance the trade-offs between:

a) filter efficiency and air flow or ventilation.
b) fresh air exchange and temperature regulation capacity. Doors should be well-sealed to prevent air exchanges with outside areas.

Collection of regular air cultures in the exhibit as well as the air-handling system is a good practice in preventative maintenance. To aid in control of malaria in outdoor exhibits, consideration should be given to installing fans, since mosquitoes avoid persistent air movement.
Another possibility is the use of mosquito magnets. In using this device, attention should be paid to the exact location where it is being used; this makes much of a difference in the capture rate. Of course, regular inspections in the zoo for identifying areas which may be actual or potential breeding sites is crucial.

Lighting.

Spheniscus penguins are maintained successfully in both northern and austral lighting cycles. Birds that are transferred from one cycle to another will usually adapt biologically within three years. Types of lighting that have been used are: sky-lights, mercury vapor, metal halide, quartz halogen, fluorescent (normal and full-spectrum) and incandescent.
Although penguins have reproduced on a simple turn on/off lighting system, some zoos report enhanced reproductive success by varying the day length and light intensity. Several zoos and aquariums use lighting schedules that approximate that of the latitudes in which the species exhibited are found.
Variations in moult patterns have been correlated with lighting schedules. Artificial lighting in relation to captive penguins is an area that bears further research (might cause rachitis).

Special considerations and features.

Environmental actions aiming at avoiding mosquitoes,due to the fact that these may transmit malaria, (see health) are worth considering. These can be:

-the use of fans to circulate the air
-water sprays
-selection of exhibit (cool area, no stagnant water)
-plantation of walnut
-removal of overhanging branches as they seem to encourage and attract mosquitoes

Pests can cause severe and often unnecessary problems in outdoor exhibits. For this reason enclosures should be well protected. This can include trapping or making the enclosure predator-proof through the use of predator-proof barriers such as fences or electrical barriers (see pest-management).

Several types of features should be considered for penguin exhibits. These can include:

- Video cameras can be an excellent to assist in recording the bird's behaviour.
- High velocity fans, though relatively new, appropriately placed to create an environment undesirable to mosquitos, warrants consideration and testing.

- A built-in scale with a remote control for regular weighing of birds, in combination with the possibility of reading the appropriate transponder (see next chapter).

Exhibit maintenance.

A broad spectrum disinfectant and fungicide should be used to clean penguin exhibits. A heavy-duty garden or fire hose is the best tool for removing penguin guano from exhibit surfaces. Nylon scrub brushes that easily lose their bristles should be avoided as penguins have been known to ingest fallen bristles.
It is recommended that disinfectant foot-baths be used on entering and exiting the exhibit. Regular rotation of disinfectant is recommended.

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Section B: Management in captivity

Management

Management

Individual identification methods.

A basic requirement for succesful research and captive management of animals is unambigious individual identification.
The type of individual identification that is used whether it is an auxiliary mark or an alternation on the animal itself, should be easily and humanely applied, permanent (in most cases), unambigious, unobtrusive yet visible at a distance and should not affect the animal's behaviour.
In most cases a combination of methods is used. The types of identifiation methods available are discussed here:

Natural markings.

Apart from specific natural markings such as natural minor variancies in plumage and possible mutilations (damaged flipper etc.), Spheniscus penguins can be individually recognized by the pattern of dark spots on the breast. This phenomenon is totally unique for an individual and doesn't change during moult. The spot pattern of juveniles is also permanent and clear enough to be used for identification, although it becomes clearer after moulting into the first plumage.
In addition, the black and white pattern of the underside of the flipper is unique too, though less visible.
Though this technique is non-invasive, good observation of keepers is required, as well as accurate drawings and/or photos. Further it is time consuming to establish and for people to get familiarised with.
Like for transponders (see below) this technique is strongly recommended as a back-up too for the use of flipper bands (see below).

Leg bands.

These are normally not used for Spheniscus penguins. They can cause injury and are difficult to read.

Transponders.

Implantable microchips or transponders are a type of permanent animal identification consisting of microchips sealed in bio-compatible glass. Each microchip is encoded with a unique ten-digit alpha-numeric. The transponders is about the size of a grain of rice and, using a modified hypodermic, is easily implanted under the bird's skin, in the coelmoic cavity or into the muscle. A scanning device is passed over the animal at the implantation site to activiate the microchip and read its signal.
The implantation site needs to be standardized to decrease the amount of time spent in scanning. The advantages of using transponders for individual identification are:
-they contain unique codes
-they do not affect the animal's health or behaviour
-they should stay in place and continue to function as long as the bird lives
-they are easy to apply
-they are easy and fast to read accurately
-can be used as a back-up for a visual system

Disadvantages are:
-transponders as well as reading devices are rather expensive
-detection range is still very small (<10 cm)
-the bird has to be disturbed in order to read the transponder
-transponders might fail or migrate. It seems that migration is not related to a specific site where the transponder has been inserted. Though further investigation is needed in this respect, the experiences of insertion in the breast and shoulder and neck area seem to be satisfactory.
-rejection: this can be minimized by insuring that the opening created by the needle is above rather than below the transponder

In general, the Penguin TAG highly recommends the use of transponders as a back-up for some kind of visual system, as the reading of the transponders might cancel out the benefits derived from this application.

Tattoo.

Tattoos are not considered as a satisfactory identification technique, as the only possible place to use it is the foot. Problems in reading and fading of the tattoo make this technique unapplicable to identify penguins.

Wings staples / ear tags.

These have been used in the past, but should no longer be used as they result in a permanent damage to the flipper with possible resulting infection and the tags falling out.

Flipper bands.

In general, flipper bands, either plastic or metal, are put on the penguin's flipper right next to the body. Care must be taken that the bands are not too tight since restricting circulation can cause serious injury. During moult, when flippers swell somewhat, bands need to be checked too in order to avoid any circulation problems.
When using this method, the band should be tightened to the point where a finger can be slipped between the band and the bird's flipper. Also, because the bands can continue to tighten after being applied, they should be either glued when in place or monitored to ensure that they do not tighten further and impede circulation to the flipper. The band must be placed in such a manner that the fastener does not rub against the penguin's flipper and so it won't get hooked on protruding objects.
Flipper-bands can occasionally fall off. Several institutions, particularly those with large collections, use bands on both flippers. Therefore, if one band is lost, the bird can be identified by the remaining band. Another advantage of using two bands is that identification is possible from different angles of view. Flipper-bands can also be glued at the end to prevent falling off and accidental ingestion by penguins.
If one band is in use, male birds can consistently be marked on the right flipper and females on the left flipper; unsexed birds can be identified by applying a colour (see below).
Eventually, traditional flipper bands cause a large hydrodynamic drag during swimming and "porpoising". Currently, research and tests are carried out in order to develop a flipper band which would reduce the power increase in swimming and porpoising by 90%

Plastic.

Plastic flipper bands are widely used in captivity, though they can degenerate with time and are not aesthetic. There are two types in use, the Darvic flipper band and plastic cable ties. Of these, the Darvic type is to be rejected as being too rigid.
Self fastening plastic cable ties, normally used for the binding together bundles of electrical wires, are commonly used in captive situations because of their ease of use and durability. They are available in various widths and lengths. The size normally in use is 187 x 5 mm. They are made of an extremely tough plastic which is virtually immune to wear and breaking. Each tie has a small plastic, or plastic and metal, fastener at one end; the other end of the strip is ribbed in such a way that it will only go through the fastener in one direction; once it has been pushed through the fastener, it cannot be loosened. The easiest way to apply a cable-tie wing-band is by first starting the free end through the fastener to produce a loop large enough to pass easily over the bird's flipper; then, after placing it on the bird's flipper, it can be tightened as desired and the excess (free end) cut off, as close to the fastener as possible to avoid having a sharp end sticking out. Due to the design of the fastener, if a band is accidentally tightened too much, it must be cut off and discarded, but experience soon makes this a rare occurrence.
These ties are favoured due to their great durability and ease of use. They do not cause wear on the feathers beneath the flipper.
Two methods of colour-coding these bands can be used. In one, coloured plastic mending tape is tightly folded around the section of the tie nearest the fastener. The tape will not pass through the fastener, so the coloured portion must be made just a little less than the circumference of the loop around the flipper; a used band can be measured for length, and coloured tape applied to that length of tie. Plastic tape lasts longer than fabric-based tape such as library mending tape. Solid colours are the most durable, but stripes can be used also, when the number of birds exceeds the number of colours available. When the tape is carefully put on, it will last from a few months to a couple of years; eventually, wear and abrasion will cause it to chip or peel off.
A more sophisticated way of colour-coding uses additional coloured plastic ties, in a very narrow size. These ties are looped tightly around the band itself and the excess is cut off, leaving the fastener and cut end facing outward so that they are visible and do not rub against the bird when the band is applied. The coloured ties are like coloured beads on a string conveying a coded message. Ten colours of narrow ties are available, so that each colour can stand for a numeral; red/red/yellow can stand for 116, bird #116, for example.
Each of these colouring methods has its advantages and disadvantages. The coloured tape is highly visible even at a distance and less prone to confusion than the coded series of coloured cable ties; however, the cable tie "beads" are more durable than the plastic tape. [14]
Institutions having very large colonies of birds (>100 up to 999) could identify their birds with colour-codes, i.e. two colour bands on each flipper. Each colour means a number, for instance Red is 1, Blue is 2, Yellow is 3, Green is 4, White is 5 and Black is 0. The bands on the right flipper show the hundred and ten numerical positions, while those on the left the one numerical position. For instance 114 then is Red-Red (right), Black-Green (left); 222 is Blue-Blue (right) Black-Blue (left); 81 is White/yellow (right) and Red (left), 35 is Yellow (right0, White (left) etc. [15]

[14] Cheney
[15] See: Tokyo Sea Life Park, Japan

Attention should be paid in case a band turns for whatever reason, that the colour marking is still visible; this can be solved by adding up the whole with the specific code (with separations in case the code doesn't fill up the whole band).

Metal.

Though metal bands have some drawbacks, they are also extensively being used in zoos and in most cases are considered to be functional. The drawbacks are:
-they can become too tight during moult
-they can cause damage to flippers. The band join must always be on the outside (i.e. on the top of the flipper) otherwise the ends may damage the bird.
-the number engraved can be difficult to read from a distance
-they are not aesthetic
On the other hand, they are durable and the loss rate is low. As there is no specific information available on the suppliers being used, further investigation of the systems in use is required. Currently, most of the metal bands are supplied by:

Lambournes Ltd.
Shallowford Court
Off High Street
Henley-in-Arden
Solihul
West Midlands B95 5BY
England
Tel. 44.1564.794971
Fax. 44.1564.793075

Leather.

Some collections seem to use leather bands succesfully, but further details are missing.

Marking nestlings.

In zoos with large colonies, which are producing many young each year, to avoid losing the identity of the nestlings they must be marked soon after hatching and well before they fledge. If the chick is large enough it can be fitted with a transponder. In other cases, the chick must be marked temporarily until a more permanent method can be applied. White paint (or liquid paper) is being used; drops of acetone-base lacquer paint in various colours have been applied in a pattern to specific feathers. Also, harmless dye (such as food colouring) on one flipper can be used. When young penguins are close to fledging and leaving the nest, regular bands can be applied. By the time the juvenile moults the following year, the first band may well become too tight and need to be replaced.

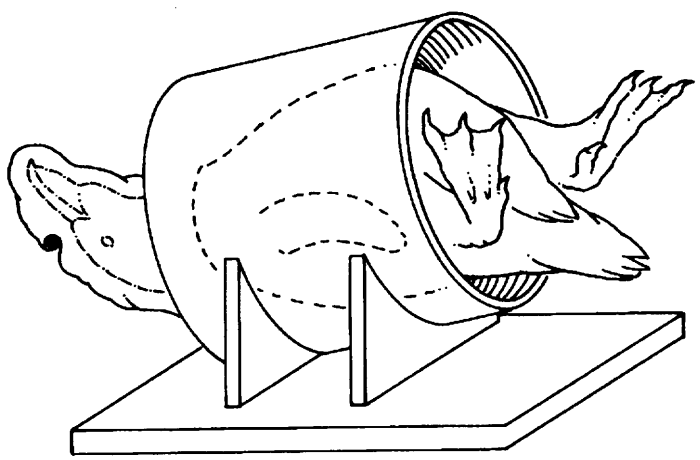
In general, the Penguin TAG recommends a double system. For instance a metal or plastic flipper band, backed up by a transponder (or a photo for the breast pattern).

Methods of capture, handling and restraint.

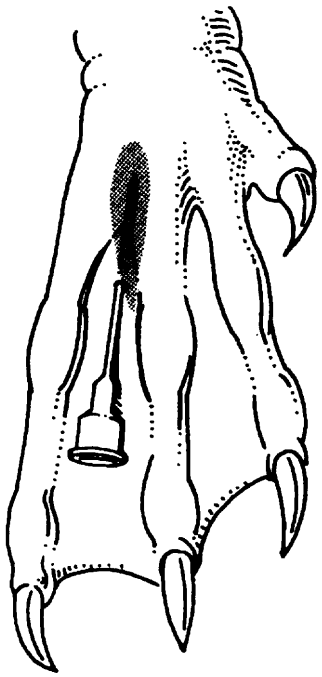
Penguins are hardy animals and can normally tolerate routine handling for nail-trimming and beak-trimming, banding or weighing. The individual to be captured should be separated from the colony and lifted from behind. There are several different methods for capturing the animal with initial restraint often done by grabbing the neck. Caution must be used when grabbing a bird by the flippers. Flippers can be broken during handling.

For penguins, being very strong, heavy muscled birds, there are a variety of restraint techniques. Non-invasive procedures may necessitate only minimal restraint. However, medical procedures, such as drawing blood, which require the bird to be immobile, dictate stronger restraint.
One method used successfully involves placing the penguin between the handler's legs such that the flippers are held secure. The handler is in a sitting position. In this way the handler's hands are free to restrain and positon the head and neck to facilitate blood removal, rebanding, or the dictated procedure.
Five to ten minutes of restraint is usually adequate for a complete clinical examination if the bird is firmly held.
Another technique for restraint , for instance in order to draw blood is by using a device consisting of a section of sturdy plastic drainpipe, 33 cm long and 21.5 cm in diameter, with one end covered with leather or heavy rubber secured with a worm clamp or similar fastener. In the centre of this leather or rubber cover a hole is cut. For juvenile penguins a plastic pipe of a diameter of 17 cm can be used. The penguin is placed head first into this pipe, so that its head protrudes through the hole cut in the leather or rubber. The pipe is carefully placed into the plywood stand, with the bird's ventral side up. If necessary the pipe is secured to the stand with straps. Since the penguin's flippers are pressed down against its body, struggling is minimized. One person tends the bird's head, holding it still and monitoring breathing. A second person holds the feet while blood is drawn from one foot. This person also has to keep a hand on the penguin's body to prevent it from rotating. Prior to placing the penguin into the restraint device a black cloth hood is put over the bird's head to calm it and keep it from biting. This hood of triangular shape should allow the bird to open its beak and should permit ample air circulation.
Once in the restraint device,the penguin is now in position for blood to be drawn.
As the metatarsal vein is sometimes difficult to locate, and the toe nail clipping often results in too little blood, or bleeding that is hard to stop, the intradigital vein can be used.
A length of surgical tubing, secured with a hemostat, is used around the leg as a tourniquet if needed to make the vein easier to locate.
The skin is cleaned with Betadine. A 20- or 22-gauge needle is used; bending the needle slightly makes it easier to attain the correct angle of approach. Once the needle has been introduced into the vein, which is raised from the effect of the tourniquet, and blood begins to flow into the syringe, the tourniquet can be released to allow the blood to flow more freely, and from 1 to 3 cc of blood can be collected. If the needle is introduced into the correct area, and the tourniquet removed, quite often the syringe fils by itself. Upon removal of the needle, a gauze pad is pressed against the site, and then a drop or two of superglue is applied to stop bleeding. Because the penguin is susceptible to overheating while in the restraint device, birds can sometimes be removed from it before bleeding has completely stopped.
After being removed from the pipe and un-hooded, each penguin is put into a pan of (ice and) water about 8 cm deep for several minutes to reverse any overheating, stop bleeding and to permit observation.

During restraint and handling, the birds must be carefully monitored for overheating and gaping, and it is very important to minimize the length of time that each bird is subjected to handling. Therefore a good team of at least 6 persons is necessary. [16]



Penguin with hood on, in position in restraint device.



Insertion of needle into intradigital vein of right foot.

If a penguin needs to be moved a short distance, it is recommended that the handler carry the bird close to his/her body with the head at their side facing their back. If the bird need to be

[16] C.Cheney.

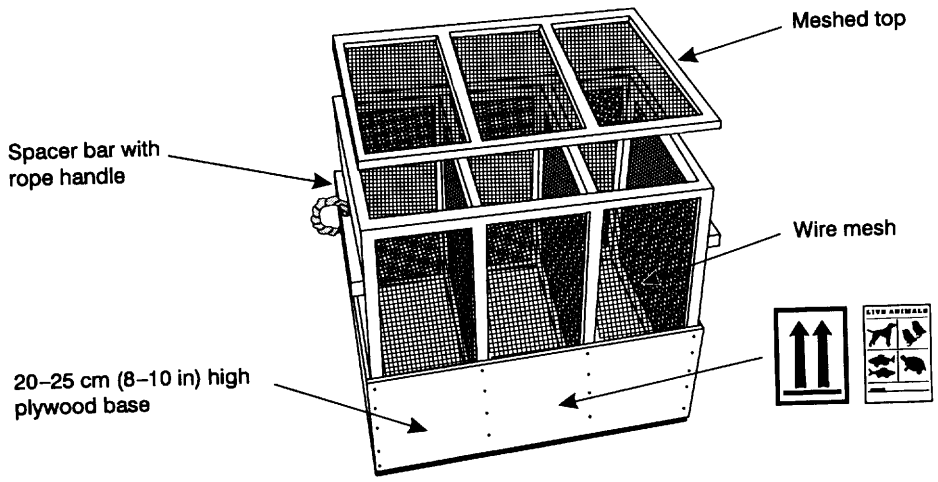
moved to a different location, such as the hospital or a different holding area, it can be placed in an appropriate container such as an air kennel or large tub.

Methods of crating and transport.

Because of physiological stress associated with moulting, it is necessary to avoid transporting penguins during this time. The Penguin Tag recommends that birds should not be transported within one month before and within two months after moult.
In addition to this, shipping should also be avoided during the breeding season unless the birds to be shipped out have been separated well before this period has started.
For Spheniscus penguins it is recommended that shipping occur during cooler weather (0-21º C) and/or during the cooler parts of the day.
Consideration should be given to treating transported birds prior to and after shipping with a prophylactic treatment for Aspergillosis.
It is even more crucial to be certain the environmental conditions in quarantine be similar between the sending and receiving institutions. Post-transport stress is still an underestimated phenomenon which deserves much attention. It is therefore strongly recommended that staff at the sending and receiving institutions consult with each other regarding light cycles, temperatures, management. housing and diet. It is also important, if possible, to have two or more birds quarantined together because of the social needs of the animals. If this is not possible, efforts should be made for quarantined birds to have visual or auditory contact with other penguins.
Adult penguins which have already established pair-bonds should be transferred as pairs, since established successful pair-bonds have a higher rearing rate than newly formed pairs.
Wild living penguins leave their colonies as soon as they have fledged and do not return until they start breeding for the first time. A transfer of penguins between zoos should comply with their natural behaviour. Therefore it is recommended to transfer penguins as juveniles. [17]
Both these recommendations, however, have also to be considered within the framework of possible respective captive breeding programmes for the species. This could mean that established pairs can be split up intentionally or that adults are transferred.

[17] Linzmeier.

Container construction for Spheniscus penguins. [18]



Size.
The normal habits and necessary freedom of movement of the bird species involved will determine the size of the crate.
Each container or compartment must allow the bird to stand in an upright position with a head clearance of 5 cm after the possible bedding has been put in.
The Spheniscus penguin species require a compartment with minimum dimensions of 45 x 20 x 80 cm (length x width x height).

Frame.
A solid frame of 3 x 3 cm in smoothed wood, either screwed or nailed and glued with a non-toxic glue.

Sides.
A 3 or 6 mm plywood base with a height of 20-25 cm with wire mesh to the top of the container frame. The mesh must either be such that the Spheniscus species can pass their beaks through easily or not at all, i.e. a mesh with diameter of 3/4 x 3/4 cm. If a larger mesh is used a warning notice "**THESE BIRDS BITE"** must be clearly displayed.
Any internal partitions must be made of wire mesh of a size that prevents any protrusion of any part of the bird from one compartment to the next. The interior of the container must have no sharp protuberances on which the bird can injure itself.

Handling spacer bars and handles.
Must be provided as shown on all four sides of the container. Ropes handles must be attached to the spacer bars on two sides of the container.

Floor.

[18] Live Animal Regulations nr.22 LAR edition nr.26

Solid plywood of 6 mm. It must be covered with a suitable soft bedding, such as wood shavings, to a depth of at least 10 cm [?]

Stocking density.
One bird per compartment which must not be able to contact another bird in any way. In case more than one bird is transported in the same container, visual contact is recommended.

Roof.
Wire mesh within the solid wooden frame as for the sides. The top can be hinged or slotted into the frame of the four sides to form the means of loading and unloading the container from above. It must have a secure means of fastening.

Feed and water containers.
Are not required during transport, pieces of fresh fish, placed on the floor, are used for moisture and food in emergencies.

Feeding and watering guide (for emergencies only)

Feeding during the journey must not be necessary except in cases of delay. Small fish or pieces of raw fish must be provided which will also provide all the moisture requirements in case of emergency.

General care and loading.

Birds are very nervous by nature and therefore containers must be handled carefully. The container must not be jolted or tipped unneccessarily. It must be stowed in a dim light in order that the birds can see their food if feeding is needed during transport.
Direct contact with sunlight should at all times be avoided. Where the ambient temperature is above 24º C penguins must be regularly inspected for signs of exhaustion. This is indicated by the gaping of the beak, swelling of the feet; dropping of the head may occur at the same time. In the case of exhaustion being suspected, the container must be moved to a shaded location. The bedding must be thoroughly wetted with cold water as excess body heat is mainly lost via the feet.

Transport of eggs.

If prior arrangements have been made, it may be possible to ship fertile eggs from one location to another. If traveling time exceeds five hours, it is necessary to have a portable incubator that maintains a constant temperature. However, for shorter connections, a well insulated cooler with a mounted temperature probe can carry the eggs. A hot water bottle can be used as a heat source.
Timing of transport is important. Eggs should be transported either during the last-third of their incubation period or before incubation begins. The temperature in the cooler or incubator should be maintained at approximately 35,6º C (96º F). When the temperature drops below

this, additional water should be added to the hot water bottle from a thermos carried for this purpose. Upon arrival at the destination, eggs are placed in an incubator.

Pest management.

Pests can cause problems in outdoor exhibits. Rats can destroy eggs, foxes and other predators can prey on eggs and/or adults. Fish should not be left outside overnight to avoid attracting rats; also, if there are other exhibits nearby which attract rats, efforts should be made to keep these areas rodent-free. It is critical not to place any poison or traps in areas to which the birds have access.
If predators are a problem at an institution, then efforts should be made to protect the colony. These efforts can include trapping or making the exhibit area predator-proof through the use of predator-proof barriers such as fences or electrical barriers. Trapping should be used to remove potential predators from the area. Local laws concerning trapping or depredation of native wildlife should be checked prior to predator removal in this manner.

Native gulls or herons often will raid penguin exhibits for fish, sometimes even taking fish from the beaks of the penguins. Several methods can be employed to discourage gulls and herons including placement of fake predator in the area, playing recorded gull and heron distress calls, placement of “dead”-gull/heron taxidermy specimens, and placing monofilament line over the exhibit. It is important to vary these methods to be varied because gulls are likely to habituate quickly. Modifying the penguins’ feeding times as well as the method of feeding may reduce the competition from the gulls.
As with any animal facility, food preparation and storage areas should be kept clean to avoid attracting mice, cockroaches and other insects.

Record keeping.

Accurate records are essential for long-term management of penguin populations. It is very strongly recommended to participate in the International Species Information System (ISIS) and use ARKS (in house record keeping system) and SPARKS (studbook software), also in order to be able to comply with data requests by species coordinators and/or studbook keepers.
Minimum records should include the ISIS accession number, whether the bird is wild caught or captive-hatched, parentage, date of birth or capture, capture location if known, individual identification method, breeding history, weights and lengths, incubation and brooding information, behavorial observations, environmental parameters, moulting data and food consumption.
Types of information on reproduction include for instance identity of pair members, location of nest-sites, dates and times of copulation, dates of laying, hatching and fledging of offspring.
Also thorough medical and nutritional records should be maintained.

Weighing of penguins.

Weights are important for monitoring the health of individual animals; weights may also be helpful in sex-determination (see below).
Weighing of individuals should be carried out whenever possible. This can be done on a routine basis if exhibit design and bird behaviour allows it. The birds should always be

weighed when they are handled for other reasons. Individual weight records should be maintained over time and utilized for comparison when a bird appears sick.
Methods which can be used are putting the bird in a container on a (digital) scale or a balance scale, or by using a walk-on scale. This last method is of course the least stressful for the bird, but requires a sophistically built in scale in the exhibit, which can be read through a remote control. A 20 kg capacity scale can be used from which the platform can be enlarged (for instance 80 x 50 cm), and the exit can be enlongated up to 10 meters. In order to let the birds pass over individually and in a proper pace, it is advisable to have some kind of barrier to be built in the enclosure, but this depends on its design.

Moult management.

Moulting is physiologically a stressful time for penguins. A great deal of energy is expended for the regeneration of new feathers. Also the moult from juvenile plumage into adult plumage is particularly demanding and needs attention of keepers and managers.
The peak season for moulting of Humboldt penguins in captivity is August, for African penguins in [] and for Magellanic penguins in [].
Prior to moult there is a significant increase in appetite that corresponds with a visible gain in weight. Therefore, every attempt should be made to feed the pre-moult bird as much as it will take in order to prepare it for moult and post-moult. If food is limted at that stage the proper weight and conditon for a successful moult may not be obtained and the bird's health will be jeopardised.
At the start of the moult a bird can weigh up to twice its normal weight. Once the birds begin moult, their appetite decreases dramatically. Some birds refuse food altogether; others may only eat one or two fish a day.
In cases where birds do not achieve top condition prior to moult, birds will either not go into or not complete their moult or will have an extended pre-moult
In a partial moult the bird will end pre-moult and enter the next stage, moult, but will only replace the feathers over a portion of the body, leaving the rest of the body with old worn and damaged feathers. An extended pre-moult is when a bird in sub-optimal condition fails to enter moult at all and maintains its old worn and broken plumage. This reduces the bird's thermal protection and increases its drag coefficient in the water significantly.
In cases where Humboldt penguins skip one moult their blackish parts will turn more brown. [19]

Moult also seems to be affected by the breeding condition of the birds: pairs which fail either to hatch or care for their broods begin to moult on average on day 76 after hatching (or due hatching date) whereas pairs which are in the process of rearing young start on day 94. [20]
Usually male Humboldt penguin moult earlier than females. [21]
Problems with moult are discussed further the chapter dealing with health.

During moult the birds lose all their feathers in a short period of time. In captive environments, this large loss of feathers can cause problems for some filtration systems and it may be necessary to remove birds from the exhibit during this time. If birds are to be moved off-exhibit it is recommended that they are moved before they drop their feathers. Shed tail

[19] Scholten
[20] Kojima
[21] Scholten.

shafts have been reported ingested by some penguins (see section on ingestion of foreign objects below).

After completion of the post-moult the bird will weigh less than its normal weight which may affect its ability to dive and catch prey. Birds may compensate for this by swallowing stones to neutralize their abnormal buoyancy. Should post-moult extend too long, the penguin is in considerable danger. After ten days of post-moult fasting force feeding should be employed in an attempt to stimualte appetite. Small amounts of fish should be given several times a day until the bird begins to feed on its own. [22]

As mentioned earlier, another consideration during moult is the potential need to change flipper-bands. The swelling that occurs during moult can cause the bands to constrict around the flippers. Bands may need to be removed and replaced with looser bands during moult; birds can then be re-banded after moult is completed. If the band is not removed it is important that the birds are closely observed to ensure that the bands do not impede circulation.

Ingestion of foreign objects.

Some institutions reported penguins eating foreign objects that can cause medical problems and even death. Some of the items that have been reported being ingested include nesting material (sticks, feathers and stones), bristles from brushes used for cleaning, coins, and even molted tail feather shafts. Care should be taken to keep exhibits clean of such material. If it is suspected that a bird has swallowed a foreign object, consult the chapter on health for diagnosis and treatment.

Sex determination.

Determination of the sex of individual Spheniscus penguins is vital for proper long-term population management. It is important not only to maintain equal sex ratios within colonies, but the sex of all individuals must be determined for genetic management.
Because penguins are monomorphic, methods have been developed and efforts have been made to determine the sex of individuals. A variety of different techniques will be discussed here.

Cloacoscopy. [23]

Spheniscus penguins may be sexed by cloacal examination.
The bird is held gently, facing the operator, its head gripped between his knees and feet dangling. The feet are then grasped and the entire body lifted through 180º so that the head, still held fast by the operator's knees, is pointing down and the tail up. The bird's dorsal surface is now nearest the operator. The weight of the abdominal contents is thus below the

[22] Stoskopf
[23] Sladen.

cloaca, allowing for an easy insertion of the cloacascope into the vent. This position allows excess urine or faeces to fall back into the proctodaeum.
The bird can also be restrained in a device as described before.
The cloacascope consists of a anascopic speculum with obturator and which is connected to a opthalmacope as a source of light.
The cloacoscope is then very gently pushed well into the coprodaeum. The obturator is then removed. Slight pressure is then exerted on the posterior wall as the speculum is withdrawn across the ridge between the coprodaeum and the urodaeum. In this way the urogenital characteristics can be seen.
The avian cloaca is divided into three chambers . The first part is the coprodaeum, which is a continuation of the colorectum. The ureters and genital ducts and appendages are located in the middle chamber, called the urodaeum. The proctodaeum opens into the exterior as the vent. In the young bird the bursa fabricius opens into this third chamber.
In the male penguin, the posterior wall of the urodaeum contains four easily recognised papillae. These papillae range in length from 2-9 mm and
are arranged in two pairs close to the midline (Fig. 1a). The vas deferens opens at the tip of the two outer papillae; the ureters at the tip of the two inner ones. The four papillae are usually of equal length, although sometimes the urethral pair may be as much as 3 mm longer than the genital pair.
The urethral papillae are similar in both sexes, but in the female penguin the lateral genital papillae are residual and much smaller, even during the breeding season (Fig. 1b). On the left side, and close to one of the residual genital papillae, the opening of the oviduct can be seen. This is conspicuous and diagnostic, especially during the breeding season when the oval opening is usually surrounded by a lip of raised tissue.

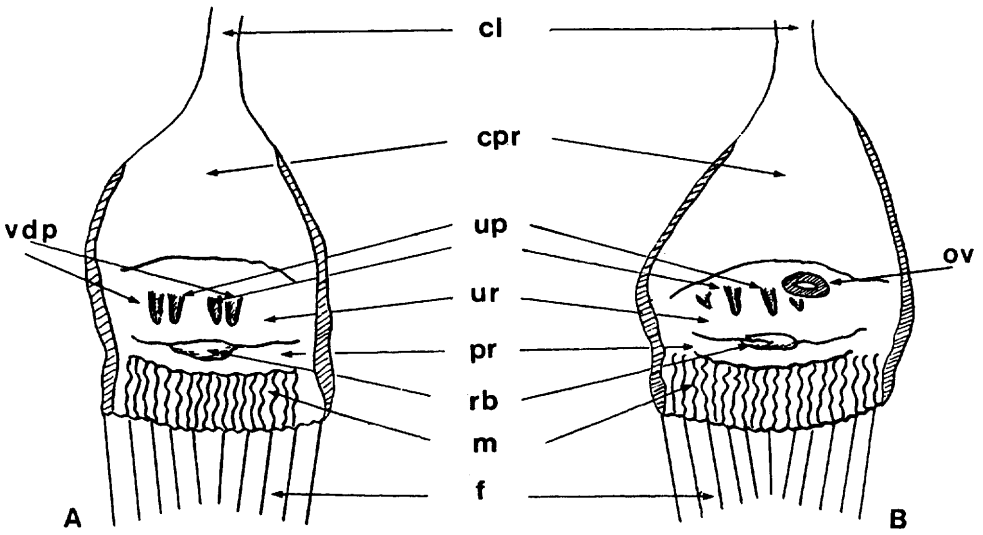


Fig. 1. Dissected cloaca of (A) ♂ and (B) ♀ Adelie penguin *Pygoscelis adeliae* showing urogenital characteristics in the urodaeum as seen through the cloacascope. (The oviduct on the right in Fig. B. is situated on the left side when the bird is upright.) cl. colorectum; cpr. coprodaeum; vdp. papillae for vas deferens; up. papillae for ureters; ov. oviduct; ur. urodaeum; pr. proctodaeum; rb. opening of residual bursa; m. muscle of vent; f. feathers around vent.

A diameter of 11 mm for the insertion end of the cloacascope is recommended for Spheniscus species.

The most reliable use of this technique however is constrained to a one-week period following egg-laying, which is right in the breeding season and particularly at this stage handling of the birds should be avoided at all costs.
In addition, the differences between male and female physical characteristics are slight and extensive experience in handling the cloacascope and the penguins is needed for this method to be used. For these reasons it is felt that this technique is not developed to the point where it can be reliably and practically used for captive birds.

Laparoscopy

With this method the bird is restrained, usually with anaesthesia. A small incision is made in the vicinity of the sex organs. A laparoscope is inserted into the body cavity, and the sex organs examined. Suturing of the incision is sometimes required.
This technique is highly invasive, requiring catching the bird, immobilization (usually with anaesthesia) and minor surgery. Death of the bird or infection is more probable than with other methods. This procedure is best carried out by a veterinarian.
The reliability is dependant on the age and sexual condition of the bird and experience of the veterinarian; comparisons with another method has indicated that laparoscopy is 80-90% reliable.
Although this technique is applicable to most bird groups, it can be very stressful.
The results are more reliable if the procedure is undertaken on sexually mature birds.
Many zoos have a veterinarian that is qualified to carry out laparoscopy and several European veterinarians specialized in this procedure travel to different facilities in order to sex birds.

Behavorial observations. [24]

Behavioral observations of individuals is a non-invasive way of sex determination of Spheniscus penguins. However, most of these observations in order to sex the birds can only be carried out during the breeding season and therefore with sexually active birds only. Further, atypical behaviors such as homosexual pairing and male on bottom / female on top copulation can make this method unreliable.
However, there are some indications which may help in sexing adult birds, particularly in combination with morphometrics.

These are:
-males usually instigate to build the nest, which is eventually finished by the female.
-as a result it's the males which usually steal nest-materials from other nests
-males usually perform the ecstactic displays
-males usually instigate agression caused by competition for nesting material or territory protection
-males are more domimant during display
-mutual preening is mostly instigated by the male
-during copulation male is on top / tread marks on the back of the female
-it's usually the male which performs the arms act and the neck rubbing

Morphometrics. [25]

[24] Scholten, Edgington.
[25] Humboldt penguins. See: Scholten, Linzmeier, Edgington.

In morphometrical differences between males and females there is some overlap in the characteristics and sex determination using this technique is therefore not widely considered reliable at this time. Moreover, this technique can only be used for fully-grown birds. Lastly, measurements have to be taken very closely and consistently.
However, in combination with behavioural observations, the results might help determining the sex of the birds.

In general, at least for Magellanic and Humboldt penguins, males are larger in overall size than females.
Males usually also have a higher forehead and a broader head than females. They are often more muscular in appearance, particularly the top of the legs. Other apparent features of males are a longer, higher and wider bill and wider and longer flippers (see tables). Please note that all measurements are taken from birds in the wild, except for those given by Scholten. [26]

African penguin measurements in mm.

Unsexed adults	**Reference**	**Mean**	**Range**	***n***
Flipper length	Rand	-	194-202	247
	Williams	186	173-206	72
Bill length	Rand	-	54-59	247
	Williams	57.1	51-56	78
Bill depth	Williams	22.6	21-25	28
Foot length	Williams	116	102-128	76

Immatures	**Reference**	**Mean**	**Range**	***n***
Flipper length	Williams	186	177-196	15
Bill length	Rand	-	-	-
	Williams	50.3	45-60	15
Bill depth	Williams	15.9	15-19	15
Foot length	Williams	116	106-122	15

Humboldt penguin measurements in mm.

Males	**Reference**	**Mean**	**Range**	***n***
Flipper length	Murphy	173.5	163-182	5
	Battistini & Paredes	156.3		98

[26] Williams.

Flipper width	Scholten	69	65-73	15
Bill length	Murphy	65	61-68	5
	Scholten	64.7	61.2 - 68.4	15
	Battistini & Paredes	65.4		112

Females	**Reference**	**Mean**	**Range**	***N***
Flipper length	Murphy	164.5	158-172	4
	Battistini & Paredes	149.3		103
Flipper width	Scholten	66	62-70	25
Bill length	Murphy	60	58-62	4
	Scholten	57.8	49.6 – 62.6	25
	Battistini & Paredes	60.8		111

While Murphy and Battistini & Paredes worked on wild birds, Scholten did so on captive ones.

Magellanic penguin measurements in mm.

Adult males	**Reference**	**Mean**	**s.d.**	**Range**	***n***
Flipper length	Boswall	195	-	182-221	18
	Scolaro	195	0.5	-	49
Bill length	Boswall	53.7	-	45.1 – 57.3	18
	Scolaro	58.8	2.6	-	49
	Thompson	56.6	2.3	-	9
Bill depth	Boswall	23.7	-	21.2 – 25.2	18
	Scolaro	25.0	1.1	-	49
	Thompson	22.2	1.8	-	9
Foot length	Boswall	120	-	112-132	18

Adult females	**Reference**	**Mean**	**s.d.**	**Range**	***n***
Flipper length	Boswall	186	-	178-197	18
	Scolaro	186	0.5	-	49
Bill length	Boswall	48.9	-	46..5 – 54.7	18
	Scolaro	54.5	2.0	-	49
	Thompson	52.2	2.3	-	3
Bill depth	Boswall	20.6	-	19.0 – 22.4	18
	Scolaro	21.6	1.3	-	49
	Thompson	19.3	2.2	-	3
Foot length	Boswall	114	-	106 – 123	18

Unsexed adults	Reference	Mean	s.d.	*n*
Flipper length	Boersma	152.5	0.09	5746
Bill length	Boersma	56.0	0.04	5746
Bill depth	Boersma	23.2	0.03	5746
Foot length	Boersma	118.3	0.08	5746

Unsexed immatures	Reference	Mean	s.d.	*n*
Flipper length	Boersma	149.5	0.12	3789
Bill length	Boersma	56.1	0.05	3789
Bill depth	Boersma	21.0	0.03	3789
Foot length	Boersma	119.6	0.10	3789

Weight.

Weight can also help in sexing adult birds, but one should bear in mind that the weight varies according to the time of the year, as we can see from this table on African penguins living in the wild. [27] Males are usually heavier than females.

African penguin weights (g)

Stage	Reference	Mean	s.d.	Range	*n*
At sea	Rand	2547	450	-	247
Breeding adult	Cooper	3099	-	2325-4050	124
	Williams	2994	-	2125-3675	72
Pre-moult adult male	Rand	4044	-	-	-
Pre-moult adult female	Rand	3527	-	-	-
Pre-moult adult	Cooper	4067	-	3200-4975	65
Pre-moult juvenile	Cooper	4185	-	3600-4950	31
Post-moult adult	Cooper	2419	-	2000-2925	32
Immatures	Williams	2697	-	2125-3225	2697

One should bear in mind, in reading the data of the next table, that all these data come from birds which are held in captivity, except for those of Battistini & Paredes.

[27] Williams.

Humboldt penguin weights (g) [28]

Sex	Reference	Mean	s.d.	Range	*n*
Adult male	Scholten	4900		4100-5700	15
	Whipsnade Wild Animal Park [29]	5050		4600-5500	13
	Zurich Zoo	3252		3025-3430	?
	Linzmeier	5432		-	14
	Battistini & Paredes	4931.08			112
Adult female	Scholten	4500		3600-5800	15
	Whipsnade Wild Animal Parl	4250		3800-4700	13
	Zurich Zoo	3177		2570-3900	?
	Linzmeier	4745		-	14
	Battistini & Paredes	4317.85			111

Magellanic penguin weights (g)

Though it can be supposed too for the African and Humboldt penguin (as sufficient data are lacking), of the Magellanic penguin it is known that the weight of birds living in the wild varies markedly within a breeding season and between years, due to annual variation in food availability.
Adults arriving for breeding at Punta Tombo (recorded over 10-day period ending 14 days before median first egg date) had a mean weight between 4580 and 4980 gram with a 5-year mean of 4820 gram. Maximum weight occurs pre-moult, for males 7790 gram and females 6550 gram and minimum weight occurs at the end of incubation, males weighing 3060 gram and females 2300 gram. [30]
Weights of captive birds are lacking. [Karlsruhe]

Chromosome analysis [31]

Chromosomal blood kareotyping

A sterile blood sample of 0.5 to 2.0 ml is taken, usually from the foot. The blood is placed in Lithium-Heparin or Na-Heparin tubes and sent to the facility where it will be cultured and the sex chromosomes examined with a microscope. It requires catching the bird and physical immobilization while the foot is outstretched and the blood sample taken. The blood sampling

[28] All weights are of captive birds, except for those of Murphy.
[29] Weights taken in january 1997.
[30] Boersma, unpublished data.
[31] C.King. Methods for sexng birds available to zoos. Rotterdam Zoo.1994

must be done very hygienically or culturing of the blood will fail; this is best done by an experienced technician or a veterinarian.
The Lithium-Heparin or Na-Heparin tubes needed for blood storage are usually available from a veterinarian. Samples must be at the culturing facility within three days; cooling of samples during transport is only necessary in very hot weather. Arrangements for receipt and processing must be made prior to delivery.

Chromosomal DNA probe.

This method is based on DNA analysis using specific gene markers. A toenail is clipped a bit short, and blood droplets are collected in a 20µl capillary tube from a kit and then placed in a vial of DNA preservative. The samples are sent to the appropriate laboratory where a DNA probe is used to identify sex-specific DNA sequences.
It requires catching the bird and physical immobilization while the toenail is clipped and the blood sample taken.
The blood sampling and storage preparation is quite simple, but requires a storage test kit distributed by the company undertaking the sexing.
The blood sample is stable in the DNA preservative for months, thus immediate shipping and stringent planning for delivery arrangements are not required. The blood does not have to be kept cooled during storage or transport. Reliability is not considered to be 100% at this time as so far no success has been achieved with Spheniscus penguins.
There are no age limitations: it just requires that the bird be large enough to obtain the blood sample.
This method is currently available commercially from Vetgen in England. The address is:

Vetgen Europe
P.O.Box 60
Winchester SO23 9XN England
Tel.00.44.1.962.880376
Fax.00.44.1962.881790

Chromosomal feather pulp kareotyping.

The pulp is cultured, and the sex chromosomes examined with a microscope.
This method requires catching the bird and physical immobilization while suitable feathers are removed. Feathers should be complete, i.e. with the complete quill and fresh.
The results are 100% reliable, but achieving results is dependant on culturing success.
In the meantime there are several laboratories which are able to sex Spheniscus penguins through blood and / or feather kareotyping. Some of them are:

UK

University Diagnostics Ltd.
LGC Building
Queen's Road, Teddington
Middlesex TW11 0NJ
United Kingdom
Tel. 00.44.20.89438400
Fax.00.44.20.89438401
e-mail: udl@lgc.co.uk

Pentlands Science Park
Bush loan
Penicuik
Midlothian, EH 260PZ
Scotland

Avian Biotech International
'P.O.Bix 107
Truro, Cornwall, TR1 2YR
UK
Tel. 44.1872262737
Fax. 44.1872262737
e-mail: abiuk@globalnet.co.uk

Germany

Pluma Molekularbiologische Analytik
Postfach 700359
70573 Stuttgart
Germany
Tel. 00.49.711.9905923
Fax.00.49.711.9905924

Genekam
Dammstrasse 31-33
47199 Duisburg
tel. 00.49.203.358272
fax. 00.49.203.358299
www.genekam.de
Genedia
Burgstrasse 12
D-80331 M
Tel. 49.8964289624
Fax. 49.896249666

Laboklin
Prinzregentenstrasse 3

D-97688 Bad Kissingen
Tel. 49.971.72020
Fax. 49.97168546
e-mail: laboklin@t-online.de

Tieraerztliches Institut
Georg-August-Universit Göttingen
Abr.Molekularbiologie
Groner Landstrasse 2
D-37073 Göttingen
Tel. And Fax. 49.531.393399
e-mail: ipfeiff@gwdg.de

Austria

Pluma
Lochauenstrasse 2
6912 Höbranz
Tel. 00.43.557385403
Fax. 00.43.557385403

Czech Republic

Genservice
Laborator molekularni genetiky
Palacheko 1-3
612-42 Brno
tel. 420.541.562646, 648
fax. 420.541.562648
e-mail: genservice@volny.cz

Statni veterinarni ustav Brno
Palacheko 174
612 38 Brno
tel. 420.541.321229
fax. 420.541.211509, 41212383
e-mail: svubrno@login.cz

The Netherlands

Gendika
Industrieweg 1
9641 HM Veendam
the Netherlands
tel.00.31.598.619343
fax.00.31.598.612194

Dr.van Haeringen Laboratorium BV
Agro Businesspark 100
Postbus 408
6700 AK Wageningen
tel. 31.317.416402
fax. 31.317.426117
e-mail: vhl@bedrijf.diva.nl

France

Labofarm
4 rue T.Botrel
BP 351
22603 Loudrac
tel. 33.296286343
fax. 33.296660888
e-mail: labofarm@wanadoo.fr

Genindexe
6 rue des Sports
17000 La Rochelle
tel. 33.46306966
fax. 33.46306968
e-mail: contact@genindexe.com

Spain

R.Capdevilla
Aparado de Correos, 6
43330 Ruidoms
tel / fax. 34.97.7269096

Ultrasonography. [32]

Transcloacal ultrasonography has been used to sex captive Humboldt penguins. The technique was used during the non-breeding season in order to visualize the left oviduct. In order to be able to do so, birds have to be anesthesized.
The technique involves placing the ultrasound scanning probe into the cranial part of the (clean) cloaca and gently moving it laterally across the craniocaudal axis. The vaginal part of the functional oviduct is located in the left abdominal region and is visualized by rotating the probe about the vertebral column. The diameter of the oviduct can be measured with an electronic caliper system within the ultrasound computer. The diameter of the caudal part of the oviduct of Humboldt penguins measures from 2.0 to 3.5 mm. Adult females can unambiguously be distinguished from adult males by sonographic visualization of the left oviduct along the dorsolateral cloacal wall.

[32] Hildebrandt et al.

The presence or absence of the buresa fabricii in the dorsal wall of the caudal part of the cloaca can be established to estimate the stage of sexual maturity of each bird. The whole examinations normally takes around 15 minutes per bird.
For reasons of completeness this technique is mentioned here, but the need for specialized equipment and knowledge, linked to the fact that birds have to be anesthesized, make this technique a complicated and laborious one. [33]

Steroid analysis.

In recent years plasma steroid ratios have been analysed by radio-immuno-assay to predict the gender of captive Humboldt penguins.
Concentrations of testosterone were divided by concentrations of estradiol to predict the gender of the individuals. A ratio of 10 was used as a cut-off point; samples with ratios above 10 were scored as males, and samples with ratios below 10 were scored as females. All, except one, matched the already known sex of the birds involved.
The cut-off point was determined using the values observed in various endocrinological studies on penguins. All, except one, matched the already known sex of the birds involved. However, the technique involves the taking of blood. In addition, at least Humboldt penguins have very low steroid concentrations which are not detectable by commercially available steroid asssay kits. Therefore, the test can only be carried out in specialized laboratories and is therefore not widespread. Lastly, the cut-off value of 10 may not be suitable for all Spheniscus species.

Concluding, the more reliable techniques for sex determination like the chromosomal analysis are more expensive than the other techniques. If zoos do not have financial resources to carry out any chromosomal analysis at all, a combination of behavioural observations and the assessment of morphometrics / weight is strongly recommended.

[33] The technique has been used by Hildebrandt et al. from the Institute for Zoo Biology and Wildlife Research in Berlin.

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Edited and compiled by the Penguin TAG

A publication of the EAZA

Section B: Management in captivity

Behaviour and social organisation

Behaviour and social organisation.

Though most types of behaviour of Spheniscus penguins in the wild have been dealt with in a previous chapter, in this chapter specific behavioural aspects of these penguins in captivity in particular will be discussed.

Social groupings.

Spheniscus penguins are social, colonially-nesting birds. There is good evidence that reproduction in penguins, as in other colonial waterbirds, is socially facilitated and that adequate stimulation by conspecifics is essential to successful reproduction under captive conditions. For Humboldt penguins it is suggested that egg productivity is increased significantly with the number of breeding pairs and with the total population, but not so much with the number of males / females, the population age or density. [34] The Penguin Tag recommends three pairs of a single species as the absolute minimum social grouping in order to have a socially interacting group in combination with the successful rearing of young. [35] Considerations in development of social groupings include:

- the number of birds able to be accommodated by the exhibit
- the availability of sufficient numbers of birds to encourage assortative mating and facilitation of successful reproduction
- a balanced sex ratio within the group
- a balanced demographic structure within the group
- intra-specific aggression and compatibility of individual birds
- a consistent way of keeping the group in captivity

Mixed species exhibits.

Many facilities successfully house and breed several species of penguins in one enclosure, and in some cases mix penguins with other species such as Inca terns (Larosterna inca) or cormorants (Phalacrocorax spp). In addition to the considerations mentioned in the previous section, concerns for mixed species exhibits include: inter-specific compatibility and aggression, differential life support requirements, differential habitat use and habitat requirements, and avoidance of hybridization.

Hybridization among several penguin genera, Spheniscus in particular, has been documented. The Penguin TAG strongly recommends that managers should avoid hybridization at all costs. Avoidance of hybridization is a key factor in the conceptual development and subsequent management of mixed-species exhibits. Aside from a few cases where multi-species exhibition may be problematic, housing several species together can work well if seasonality is maintained.

[34] Boersma, CBSG annual meeting 1998, Blay and Côté.
[35] Gailey-Phipps

Introductions and removals.

In general, introduction of novel stimuli, including new birds, to a social group of penguins is met with curiosity and investigation. As with all animal introductions, staff should closely monitor both the introduced bird as well as the social group for signs of stress and aggression. The introduction of a new bird or introduction of a group of birds to an exhibit has been approached in several ways:

1) Gradual introduction. Use of this technique will depend on exhibit design as well as temperament of the birds. In gradual introduction, birds are introduced to an exhibit for a few hours at a time, with close monitoring, over a several-day period. The time the birds are left in the exhibit is gradually increased until the birds appear to be acclimated. This technique is the most conservative and most likely to result in successful integration of new birds into an existing social group.

2) Group introduction. Most penguin managers feel that it is inadvisable to introduce a single bird into a colony. New birds can be isolated with one or more conspecifics removed from the social group for a period of time. Birds can then be introduced into an exhibit together and monitored by staff.

3) "Howdy" cage introduction. Birds are placed in a small enclosure within the exhibit for several hours daily and slowly acclimated to the exhibit and other penguins. Generally, a Gradual Introduction procedure, as described above, follows.

4) Immersion introduction. Birds are placed in the exhibit and regularly monitored by staff. Introduction of hand-reared chicks into exhibits requires close monitoring and is likely to be most successful if a gradual introduction procedure is followed.

In large colonies, removal of individual birds does not seem to have a well-defined effect on social dynamics, except for individuals whose mates have been removed. In these cases, birds may show some signs of lethargy or may repeatedly visit the nest site, if it is the breeding season, as if searching for the bird that has been removed.
In smaller colonies, removal of a dominant individual may cause a shift in the dominance hierarchy and may lead to a short term increase in aggressive behavior as equilibrium in the social group is re-established.

Behavioural management.

Behavioural enrichment.

Behavioral enrichment programs for penguins are a relatively new concept and merit consideration. Beyond normal stimuli in a captive environment, such as water and conspecifics, penguins generally tend to respond with curiosity to novel objects.
Enrichment does not require elaborate or costly apparatus. Items that penguins appear to find stimulating include varying water currents / waves, sprinklers and sawhorses with securely-

affixed strips of fabric under which the birds can run. Underwater visual barriers may also provide enrichment. Some facilities report good success with the use of different feeding strategies, e.g. live fish feeding, multiple feedings, extended feedings and scatter feedings. Success has been achieved with alcids in using durable plastic and rubber sea creatures including squid, jelly fish, octopus, anemones and artificial kelp plants. Of course these should be strong and large enough so that the birds will not be able to swallow them or parts of it.
Large feathers can also be a good source for enrichment during the nesting season.
In using a wave-machine, one should pay attention that penguins cannot be trapped in rear; this can be prevented by shielding the device by a frame or a net.

Behavioural management of imprinted birds.

Occasionally, when birds are hand-reared, they develop preference for human companionship over that of conspecifics. Depending on the species, highly imprinted birds may or may not eventually reproduce. Highly imprinted Spheniscus penguins, however, have been reported to breed and may make very good parents.
Imprinted birds can be disruptive in penguin colonies, wandering over other birds' nesting territories. Social disfunction sometimes can be overcome in imprinted birds, especially if they pair with a non-imprinted bird. In general, it is advisable to discourage staff from reinforcing attention from imprinted birds. As with most species, the best strategy is the avoidance of imprinting during rearing.

Management of aggressive behaviour.

Aggressive behaviour in penguins is most pronounced during courtship and pairing and again once chicks are hatched. Although it is a natural part of the reproductive cycle, aggression should be monitored closely by staff during the breeding season to ensure that reproduction is not deterred because of excess aggression or competition. Some institutions report mate "stealing" in exhibits with skewed sex ratios. There is also need to closely monitor birds that have been isolated and subsequently returned to the group. Harassment by groups is not common in penguins. Most aggressive exchanges take place between individual birds or pairs.

Behaviour, reproduction and parental care.

Throughout most of the year, the behaviour of a captive penguins is fairly predictable, primarily consisting of eating, swimming, and generalized social interaction. The onset of the breeding season, which varies between species, may create a flurry of activity much like that which is reported for wild penguins. In the wild, the onset of the breeding season of Spheniscus penguins takes place when the birds return to the nesting territory.

The breeding season can be defined in terms of four major phases: courtship; incubation; chick-rearing; and fledging. Under captive conditions, some behaviours, such as mutual displays, observed during the early phases of the breeding season may be seen year-round, albeit less intensely.

In general, behaviours associated with pairing are observed more intensively three to four weeks prior to egg-laying. Depending on the species and exhibit, initiation of courtship can be enhanced by manipulation of artificial lighting or introduction of nesting materials.

Spheniscus penguins usually are housed in colonies large enough that birds can select their own mates. Occasionally, it may be necessary to selectively pair adults when undesirable pair bonding takes place (e.g., sibling, polygynous, polyandrous, or same-sex bonds). In Spheniscus a pair bond may be encouraged by isolating the desired pair through egg-laying and incubation. It is desirable to use the male's territory for this isolation.
In general, in captivity (like in the wild), pairs of Spheniscus penguins usually breed in the same nest-box each season.

Agonistic displays increase during the breeding season as birds begin to reclaim and defend nest territory or compete for prime nest locations. Overall rates of vocalization and display may increase throughout the exhibit. It is important to note that injuries from disputes may occur more frequently, particularly in multi-species exhibits with high density.

Approximately three to four weeks from onset, courtship and nest building are complete. Copulations, which usually occur at the nest site, may be observed within one week of the onset of the breeding cycle. In Spheniscus, copulations may be noted frequently during courtship and nest building.

Atypical pairing behaviours have been noted in captivity. For example, same-sex pairing has been reported for Humboldt and African penguins. Other unusual behaviors include: copulations in which the traditionally effective male on top/female on the bottom position is switched; extra-pair copulations; or polyandrous or polygynous trios.

For many species housed in captivity, copulations are frequent and egg laying occurs rather predictably after the onset of breeding behaviors. Extra-pair copulations after pairing are commonly observed in captive Spheniscus penguins. Paternity should not be assumed based on pair bonds.

It has never been recorded that Spheniscus penguins laid a second clutch of eggs while the first clutch that failed to hatch was still present. There are no indications to assume that the breeding birds dispose of their clutch as soon as they realize that the eggs will not hatch anymore. Therefore, eggs which are obviously overdue have to be removed by the keeper.

As with most species, whenever feasable, the Penguin TAG recommends that parental rearing is always preferred to hand-rearing.

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Section B: Management in captivity

Reproduction

Reproduction.

Introduction.

The development of successful reproductive programs in captive populations of penguins is of increasing importance for several reasons. Most notably, two of the 11 penguin taxa now present in captivity are considered threatened in the wild. Environmental parameters, primarily temperature, humidity, photoperiod, substrate; and diet, along with group dynamics interrelate to make an impact on eventual reproductive success. The following chapter is intended to provide information on the captive breeding biology of Spheniscus penguins and help penguin managers develop protocols which are conducive to successful breeding programs. Please refer to the other appropriate chapters in this manual for specific information concerning these topics.

Humboldt penguin. [36]

There are no records available from the wild on sexual maturity and age at first breeding: in captivity breeding is possible between 2-25 years for females and 2-30 years for males. Peak production between 8–18 years.
Seasonality: in the wild the species breeds all year round, but strong seasonal peaks have been linked to differences in food availability and nesting-success. In captivity peak laying is between February and June, with a very strong peak of egg-laying in March.
Eggs / laying: laying interval 3.3 days Egg size: single egg average 74.3 x 56.7 mm, two eggs in single clutch: 69 x 51 mm and 69 x 52 mm. Wild: average weight 125.5 gram. Clutch size: two eggs.
Incubation period: 40.7 days. (varies between 39 and 42 days) Both sexes sharing incubation duties, probably with frequent change-overs.
Birth / hatching: Chicks are semi-altricial and nidicolous; egg hatch asynchronously with mean hatching interval of 2.6 days.
Development: Chicks are covered with a velvety grey coat of down and have the eyes closed for the first week; appear then to be more vocal. Between the second and third week the chick darkens considerably as the second grey coat of denser down commences to grow in. This down stays until around 42 days when the chick starts moulting into the bleak waterproof plumage which is reached at two to two and a half months. Fledging at 90 days.

African penguin. [37]

Sexual maturity: at 4 years old. Age at first breeding: In captivity, usually, after two years of age the birds are ready to begin breeding and to select a partner.

[36] Williams
[37] Williams

Seasonality: Breeding occurs all year round, with local variations. Peak laying in November / January in NW, May/July in SW and April/June in E. Breeding interval for succesful birds is 10.5 months and relaying occurs at 4.0 months after unsuccesful breeding.
In captivity in Europe, the breeding season runs from August to May. The production of eggs reaches a peak in August and September and there is a second peak in December.
Eggs / laying: 107 and 105 gram, first eggs significantly larger than second eggs within clutches.
Average sizes and weights: first egg 69.6 x 52.1 mm, 106 gram; second egg 67.6 x 52.0 mm, 104.8 gram.
Runt eggs have been reported with smallest 33.6 x 30.2 mm and 17 g, sometimes laid with normal-sized eggs in two-egg clutvh; no runt eggs hatch and are probably infertile as yolk content is very small.
Clutch size: 2 eggs. Less than 1% of clutches having one egg. Laying of second clutch recorded.
Laying interval: 3 days
Mean incubation period: for first egg 38.0 days, second eggs 37.2 days. Incubation shared equally by both parents with shifts of average 1.1 days in succesful nests and 3.1 days in nests that were eventually deserted, the last shift before desertion averaging 6.6 days.
Birthrate: Success to fledging 15-50 %
Hatching: typically asynchronous, average interval between eggs 2.1 days.
Development: Chicks attain thermal independence at 25 days of age but may be guarded by parents for up to 40 days afte hatch; crèches form at surface-nesting colonies but more often only amongst poorer-condition chicks, otherwise chicks remain at or near the nest or in burrows until independence.
Chick growth: asynchronous hatching gives rise to a size and feeding hierarchy amongst siblings so that, within broods, the later-hatched B-chick has an initially slower rate of increase in body mass; initial size hierarchy is only maintained beyond 25 days of age if the initial difference in hatching weights is >45 gram. Lack of significant difference in survival of chicks from synchronously and asynchronously hatching broods or in survival or fledging weight of A- and B-chicks from asynchronously hatching broods suggest that asynchronous hatching is not adaptive in facilitating brood reduction. Rates of chick growth vary seasonally, being slower in summer (December-March). [1]
Single chicks grow faster than chicks in broods of two. Chick weight at hatching average 71.7 gram; at fledging, in synchronous-hatching broods 2201 grams and in asynchronous-hatching broods, A-chicks 2289 gram and B-chicks 2198 gram. Maximum weight is attained at about 70 days then decrease slightly before fledging. After that the weight is usually very slowly increasing to reach the normal adult weight.
Fledging period: single chicks average 73.4 days, twin chicks average 80.5 days. Synchronous hatching broods, average 96 days and asynchronous hatching broods, A-chick average 85 days and B-chick average 90 days.

Development: Chicks have a dense brown down, dark brown above and lighter below. 2nd down bluish grey above, turning brown, white below. In captivity, the juveniles moult into adult plumage from 13 – 18 months, with a mean of 15.2 months of age.
Chicks are semi-altricial and nidicolous, and may be guarded for up to 40 days following hatching. Both parents share guarding and chick-feeding duties.

Magellanic penguin. [38]

Sexual maturity. The age at first breeding differs between sexes with females first breeding at 4-5 years and males at 6-7 years.
Seasonality: arrival at colony in August / September; laying in September / October. Species is therefore strongly seasonal.
Eggs / laying: laying highly synchronous.
Size varies significantly between years and locations, from 73.1 mm to 77.7 mm in length and 54.2 mm to 55.6 mm in width. Usually first egg is larger than the second one. Weight varies from 115 to 145 grams; average around 125 gram.
Clutch size: two. Rarely one; replacement clutches are very rare; birds usually develop yolky follicles for three eggs. Mean interval 2 days.
Eggs: creamy white, with surface chalky but smooth; often have red or green stains from bile and blood, first egg in particular often marked with small dots of blood from the brood patchs.
Incubation period: 38-42 days (del Hoyo), 39-42 days (Williams), both parents sharing incubation duties in alternating shifts with two prolongated shifts, first by female (15 days), second by male (17 days), and series of shorter shift towards hatching (<4 days).
Incubation period differs between first and second egg with first eggs having a longer period between laying and hatching because they are not fully incubated until the second egg is laid.
Birthrate: Breeding success 0.02 – 1.36 chicks / pair
Birth / hatching: Chicks semi-altricial and nidicolous, typically hatching asynchronously within clutches.
Chick-rearing: guard period lasts 29 (plus minus 4 days) at Punta Tombo, followed by a period of 40-70 days during which the chicks are unattended except during feeding visits; both parent alternate guard duties and chick feeding; at Punta Tombo, chicks are fed on average every 1.4-
1.9 days during first 15 days after hatch, and every 2.0-2.6 days between 15 and 75 days post-hatch, with some chicks fasting for up to 11 days prior to fledging.

Chicks fledge late January to early March, at 60-70 days of age (though up to 120 days)
In captivity, adults spent 40% of their time during chick-rearing attending their young, 5% in maintenance and 33% resting. During the brood period a feeding took on average 4.4 plus minus 0.4 in with adults feeding chicks in both the morning and afternoon.In the wild feeding of large chicks is often completed within 20 minutes.
Chick growth varies significantly between years and between sites reflecting annual variation in food availability; at 30 days of age mean weight in good years can be twice that in poor years (1560 vs.717 gram); mean weight of unknown age chicks (prior to fledging) likely to fledge in early February varied between 2620 and 2919 gram, and at this time size (but not weight) was greatest in good food years and lowest in poor years; single chick grow faster than chicks in broods of two.
Development: 1st down grey, 2nd down brownish grey above, whitish below. Creche at 20-23 days.
Fledging period: Fledging success: first hatched chicks are nearly twice as likely to fledge as second chicks; second-hatched chicks are significantly more likely to die in the first 10 days and after 40 days than first-hatched chicks but the timing of the seond peak of chick mortality

[38] Williams

varies between years depending on food availability. Differential survival and brood reduction do not appear to be related to the degree of hatching asynchrony, rather brood reduction appears to be based on size asymmetrics which arise independently of asynchrony; the chick that is largest at the time of hatching of the second chick is the most likely to fledge. Egg-size differences do not contribute to overall fledging succes but chicks from larger eggs may have increased probability of survival for the first 10 days after hatching.

Nest and nest substrate. [39]

In designing nest sites for Spheniscus penguins the following criteria should be considered: location of nests in the exhibit, number of nests, type of nest, substrate, size, entrance orientation, ventilation, reduction of humidity.
In general it is advisable to create nest-sites which can be removed, rather than creating built-in nest-sites. This will facilitate the possibility to make changes in case some nest-sites need to be re-arranged or re-designed.

Though Spheniscus penguins in the wild breed in covered nests (burrows, crevices etc.) as well as surface nests, they prefer covered nests.
Most zoos offer covered nests in the form of nest-boxes (produced of natural rock, concrete, wood, plastic). In case they are built of wood, this should be painted in order to seal out moisture. Some zoos use plastic air kennels succesfully, others have good experiences with cement pipes, open at both ends.

In most cases surface nests in captivity are created by the birds themselves, but this may have to do with the lack of sufficient suitable covered nests than with the intentional purpose of having surface-nesting.
Very few zoos have experience in offering actual pre-fabricated burrows or a substrate suitable for digging them. In designing naturalistic exhibits it is crucial to provide soil with at least 20% clay to prevent nest cave-in. In case however where water may collect at the bottom of the nest, the burrow should be drained and removed from access by birds.

In the wild Spheniscus penguins cover large distances before they reach the nesting-sites. After coming ashore, the birds rest and preen for some time on the shore; in the meantime their feathers dry up. Then they start to move towards the breeding-grounds in smaller groups. By the time they reach the nest the birds are fully dry and therefore do not contribute to a higher relative humidity.
In captivity these conditions should be met in the maximum extent as possible, i.e. the nests should be as far away from the pool as possible. These distances will also help the birds getting a lot of exercise and therefore a better physical condition.
There are some indications too that breeding success may be positively influenced by a larger distance of the nests in relation to the area where the visitors are, at least so that the entrances do not face the visitors directly.

[39] Battistini & Paredes, Sasaki, Linzmeier, Boersma

In the wild, Spheniscus penguins only occur at the breeding grounds during the breeding season. Ideally, therefore only a part of the total land mass should be available as breeding sire.

The number of nests should exceed the number of possible breeding pairs in the group so that the birds have the opportunity to choose the best nest site they can have. A too low number of nest sites compared to the actual number of pairs will contribute to a lower breeding success as birds will show more agressive behaviour in obtaining a good nest-site and some birds will choose for a nest-site which may be less suitable for breeding.
The number of nest-sites should exceed the number of potential pairs by 50% So, in general the number of nest-boxes needs to be adjusted every season according to the number of adults.

Sizes of nests in the wild, as well as in captivity, are extremely variable. Though there doesn't seem to be a very direct relation between size and reproductive success, there are some aspects which might contribute to this success.
First of all, an entrance which is not as wide as the nesting chamber itself creates more privacy for the birds and will give better opportunities for defending the nest towards conspecifics as well as predators. Further, it will help keeping out the sun. Entrance width should vary between 15 and 25 cm, whereas the nest-chamber itself can be much wider (40 to 70 cm). Height of the nest chamber can be set between 35 and 75 cm whereas the length can vary between 50 and 80 cm.
Ideally a small tunnel, either straight or curved, (25 to 35 cm long) between the entrance and the nest-chamber will create a real "burrow".
Smaller nesting-chambers give a better air circulation than larger ones and in larger ones the penguins tend to defecate in the nest. Normally, all age classes of the Spheniscus penguins defecate outside of the nest, except of course for small chicks.

Moderate slopes also appear to be preferred nesting terrains. First of all as it is easier for the birds in the wild to build burrows, but also as the higher level gives a better view over the environment.

The density of nest-sites in the exhibit is another important factor in designing breeding-sites. The immediate surroundings of the nest itself are of great importance for the reproductive success well. That is, birds need a proper space in front of and around the nest to stand and to show their reproductive behaviour (courtship etc.). The absolute minimum inter-nest distance should be 50 cm. [40]Birds should be able to establish and maintain a proper territory. This can be stimulated by directing the entrances of the nests in slightly different directions and creating optical barriers between the nests, such as rocks, vegetation or small knolls.
As far as the orientation of the nest entrances is concerned, it is of great importance not to have one nest entrance face another.

As Spheniscus penguins, in particular small chicks, are highly susceptible to higher levels of humidity, the nests should be kept dry as much as possible.

[40] An average distance found for Humboldt penguins is 76.0 cm (Battistini & Paredes

In the wild, at least Humboldt penguins have nests which face the prevailing wind, not so much to counteract the effects of the heat as well as to maintain an optimal level of ventilation inside the nest.
As the European wind, as a rule, is not so strong and continuously blowing as in South America and South Africa, very special care should be taken care of ventilation in the form of holes or slots to increase air flow and water evaporation.
Especially in nests which contain organic nesting material, Aspergillus may develop. As a rule here too, all floors of nests should be sloping or the substrate should be absorbant to keep the nest dry. It can consist of either sand, pebbles or natural rock as long as there is a kind of drainage. Some zoos have good experience in using kitty-litter or even aspen–chips as a substrate.
Further, to prevent flooding, a threshold is another preventive measure which can be taken. In addition, a proper threshold is also useful in preventing very young chicks to wander out of the nest into other nests. This usually ends up in death due to trauma or drowning.

As a rule, in the wild most nests face to the south.

A key element in the location and design of nests is flexibility, so as to be able to experiment if necessary.

Apropriate nesting-material is another criticial factor for nesting. While nest materials are not necessary for the comfort of the chicks, the collection of nesting material seems to be a strong component in pair bonding.
Good experiences have been achieved in using pebbles (too large to swallow), small twigs (willow, birch, Potentilla aborescens), dry grasses, alfalva-hay, heather, dried leaves and even rock-wool. Some institutions however have bad experiences with sticks: young chicks may be impaled or become trapped under them, or birds ingest them.
Other zoos also have good experience using latex tubing (1/4 inch and 3/16 inch) cut into pieces 8 to 12 inch long; these can be disinfected easily.
In the wild, usually bird bones, dried seaweed, pebbles and feathers are being used.
Straw is not recommended as it will, more than the other organic materials, deteriorate easier and therefore might cause Aspergillosis. It is also suggested, at least for Humboldt penguins, that the use of vegetation as nesting material reduces the chick-productivity compared to the use of sand / gravel. [41]

As stated before, natural or semi-natural burrows are practically not used in zoos as fas as we know (apart from Sea World, USA), so there is very few experience in birds digging burrows themselves. This process may however help in strengthening the pair bond, with a possible higher chance of reproductive success.
As we have seen before (see field data) burrows in the wild also suffer less from climatic variations in the ambient temperature and relative humidity, than covered nests above the ground, not to speak about surface nests.

From the management point of view it is useful to have some kind of access to the nest-site, particularly from the back for inspection, cleaning and disinfection . The degree of daily maintenance of nest boxes or burrows varies amnong facilities. While some zoos clean nests daily, others do not clean them at all until the breeding season has ended. Other institutions

[41] Cf.Blay and Côté.

remove nest boxes from the exhibit completely until the next breeding cycle. Daily cleaning of nest boxes does not appear to be necessary and may be disruptive. It is recommended that nest boxes are disinfected and maintained annually.

Some institutions take away nest boxes from the enclosure for some time of the year for repair, cleaning etc. One should bear in mind however that they need to be present well in advance of the breeding periods. Additionally, they can be used by the birds as shelters during extreme cold winters in case there are no other shelters available.

Egg production and incubation.

In general, Spheniscus penguins lay smaller eggs relative to their body weight than almost any other bird species.
The normal clutch size for this genus is two eggs. Reports of single and triple-egg clutches have been reported but are unusual. Onset of incubation varies among species. In African penguins, females incubate the first egg immediately. Humboldt partially incubate the first egg, but are still willing to come off the nest until the second is laid. Magellanic penguins do not incubate until completion of the clutch.
Depending on the egg management practices for a given group, Humboldt and African penguins may produce to three clutches on an annual cycle with peak laying periods as described before.

Egg size.

Sample egg measurements from captive-laid* or wild collected eggs:

Species	**Mean length x width (mm)**	**Range length (mm)**	**Range width (mm)**	**Range weight (g)**
Humboldt *	73 x 52	62 – 85	46 - 56	95 - 134
Magellanic	73 x 55	68 - 82	50 - 60	94 – 134
African	65 x 49	62 – 72	44 – 60	72 - 98

Hatching.

Hatching success can be affected by parental behaviour during incubation. First-time parents do not always adequately cover the eggs. They also tend to exhibit a higher degree of aggresion which may adversely affect fertility or lead to egg breakage. There is an apparent correlation between young, inexperienced parents and infertile or inadequately incubated

eggs. [42]

Comparison of average weight ranges for developing Spheniscus demersus chicks:

Age in days	**Parent-reared**	**Hand-reared**
5	130-170 gram	90-120 grams
15	500-800 grams	300-400 grams
25	1000 – 1200 gram	700-900 grams
30	1600 – 1800 gram	1000 – 1400 gram
40	2000 – 2300 gram	1500 – 2300 gram
60	2800 – 3300 gram	2800 – 3300 gram

The food regurgitated to newly hatched chicks is very watery. As the chicks age, the regurgitated food becomes less moist. Older chicks are better able to digest solid food.
As the chicks grow, the demand fr food from the parents should increase. Therefore, the needs of parents be met through increased frequency of feeding or by increasing the volume fed per feeding. Adults may increase their food consumption by three or four times their normal amount during this time.

By three weeks of age, chicks of smaller species are able to swallow whole fish of moderate size.
At this time, some institutions begin feeding their Spheniscus on the nest to encourage acclimation to hand-feeding.

Age of fledging and sexual maturity.

At the onset of fledging, chicks often go through a timid stage and may even act aggressively towards keepers. This change in behaviour may be accompanied by an apparent disinterest in food. A weight loss of as much as 1 kg is not unusual at this time; appetite improves over time. Some facilities report higher mortality among birds molting into their adult plumage; thus staff should continue to monitor fledglings closely.

Artificial incubation.

Preparation of the incubator.

The incubator can be disinfected by fumigation with formalin/potassium permanganate.

Fumigation or disinfection of the eggs.

Because many penguin eggs can become quite soiled in the nest before being removed to the

[42] Cheney

incubator, there may be concern regarding cleaning and/or disinfecting eggs in an antibiotic solution.

Types of Incubators.

There are a variety of incubators available that are suitable for incubating penguin eggs.

Considerations in choosing an incubator to hold penguin eggs include:

* incubator room/ambient conditions
* size of eggs to be incubated
* number of eggs to be incubated at one time
* turning requirements

Temperature and Humidity.

Artificial incubation temperatures reported vary from 35.2 º C (95.5 º F) to 37.5 º C(99.5 º F) on the dry bulb and 26.6 º C (80 º F) to 30 º C (86 º F) on the wet bulb. The most commonly used dry bulb temperature is 35.8 º C (96.5 º F). [check, for instance farnham: 36.5° C)
Eggs of Magellanic penguins seem to have a better hatchability at a dry bulb temperature of 36.6 º C (98 º F).

The values needed will need to be adjusted, depending on the type of incubator, local humidity, altitude, number of eggs in the incubator etc.
Monitoring eggs through egg weight loss measurements is well described in the literature, and can assist managers in establishing humidity requirements for their care. A weight loss of 15% for Spheniscus penguins is normal.

Egg setting, egg turning technique and frequency.

Eggs should be set flat, not on end, in the incubator. The majority of institutions that have attempted artificial incubation report automatical mechanical turning of the eggs every one to two hours. In addition to mechanical turning, some institutions also perform a 180° manual turn of the egg, carried out seven times a (working) day. This practice facilitates a more even development of vascularization in the egg.
For incubators without automatic turning capability, manual turning can be done five or seven times (an uneven number of turns) in a 12 hour day. Eggs should be turned slowly to avoid rupture of developing blood vessels in the egg. During the last three days before hatching eggs should not be turned anymore.

Managing the pip-to-hatch interval

Eggs may need to be candled more frequently in the week prior to expected hatch, though handling should be avoided as much as possible . Some institutions report daily candling of eggs in the incubator at this time. Candling should be carried out vertically at the bottom side of the egg (air-chamber). A penguin egg is ready to move to the hatcher following external pip. Turning of the egg is no longer necessary at this time.

At the time of pip, humidity should be increased by 1–2° C (2-3° F) on the wet bulb. This can best be accomplished in a hatcher separate from the incubator. This is important for several reasons, including the ability to increase humidity without adversely affecting other earlier stage eggs and preventing contamination of the incubator by hatching eggs. However, this may not be feasible for those with one incubator. Hatching eggs should be checked four to five times per day, and the area surrounding the pip misted with distilled water. Water for misting should be kept in the hatcher so that the temperature is the same as the hatcher. The pip-to-hatch interval for Spheniscus penguins is 24-48 hours.

Hatching Problems.

Generally, penguin chicks experience relatively few problems in hatching. However, when a questionable situation arises it is helpful for managers to be familiar with the normal hatch sequence (pip-to-hatch interval, appearance of a newly hatched chick, etc.) which will help in determining when a problem arises.

Some general indicators of improper hatching (whether in the incubator or observed under the parent) are:

- if a chick has rotated inside the egg without further chipping such that the bill is no longer visible at the pip hole.
- if the membranes of the egg are too dry
- if a chick has made internal pip but has failed to progress for over 12-15 hours or is well beyond expected incubation period.
- if a chick has chipped through shell, but has failed to progress after 12-15 hours.

The most common hatching difficulty for penguin chicks is malpositioning of the chick inside the egg. This may or may not be accompanied by unabsorbed yolk and/or residual albumen. Once a chick is determined to be having hatching difficulty, the egg should be removed for assistance (from the hatcher or from under the parent). When performing an assisted hatch, care should be taken not to introduce bacteria to the chick. Hands should be washed and gloved and all instruments clean. The pip should be examined and an evaluation of the problem should be made before beginning to assist the chick to hatch. The egg should be candled to assess vascularization (is the chick ready to hatch) and pip location (above or below the air cell) and a small flashlight can be used to look inside the pip hole to look for unabsorbed yolk, residual albumen or other problems. Once these steps are completed, carefully peel away small portions of the shell from the pip site with forceps.

After the pip area has been further exposed, the membrane should be moistened with warm water on a swab to check for active vessels. If no vessels are present, the membrane can be peeled back to expose the chick. Be sure the membrane does not stick to the nares and occlude breathing. Efforts should be made to expose the head first. In extreme cases, it may be necessary to manipulate the head out from under the wing.

If the chick is to be parent-reared, it should be returned to the nest as soon as possible, following a careful examination for other problems. Sticky chicks (those with residual albumen) or chicks with protruding yolk sacs should be considered for hand-rearing.

Reproductive management.

General Record Keeping.

The necessity of maintaining good records cannot be over-emphasized. Staff can learn from previous attempts at chick rearing if complete records are available to them. By reviewing past records, changes can be made to improve protocols for the future.

Egg production and reproductive history records.

Individual identification is essential if accurate records are to be kept. It is imperative that pedigree information from birds that were transferred from other institutions be obtained if available. This information can easily be acquired for studbook species and is important in maintaining the genetic history of each individual.

Record keeping relating to reproductive management should begin at the time of egg-laying. Marking the first egg laid is important if the expected incubation dates are to be calculated. Egg logs should be used to record data such as lay date, number of days incubated, sire and dam, sibling identification, and method of rearing. Further, the fertility results should be noted for each egg as well as survivability of chicks. By tracking a pairs' reproductive history, trends in success and/or failure can be identified.

Chick records.

Hatch weights and subsequent daily or weekly weights are important in determining the overall growth rate. Many institutions develop records which include first morning weight, weight before and after each feeding, amount of food offered and consumed at each feeding, types of food consumed, comment on behaviour, and vitamins and medication. It is useful to record ambient temperature and brooder temperature (if applicable). Chick records should be maintained through fledging.

Egg Management.

Managers and staff should be familiar with how husbandry, nutrition, genetics, disease, and incubation impact on egg fertility and chick production.

Candling.

This can be a useful tool in determining the fertility and development of an egg. Candling techniques require practice and a person with experience should be consulted prior to handling the eggs. Some managers are of the opinion that the eggs should not be handled before the tenth day following onset of incubation due to the potential damage to the embryo. If staff are experienced at candling, this should not be a concern. Care should always be taken to avoid jarring the egg during handling or burning the embryo with the light source. Cooling should be kept to a minimum; slight cooling of the egg during candling does not appear to have deleterious effects.

Penguin eggs with their white shells are relatively easy to candle. Major changes in the structure of the developing egg can be seen in the size of the yolk and the coverage of the inner surface of the shell by the vascular extra-embryonic membranes. Fresh eggs have yolks 3-4 cm across, which appear to be deep within the egg and move easily when the egg is rotated. As incubation proceeds the yolk increases in diameter, such that at day 4 it is 4.5 to 5 cm and appears to be closer to the eggshell. By day 7 the yolk occupies 40%, and by day 10 50% of the eggshell surface and no longer moves freely when the egg is rotated.
By day 7 of incubation the growth of the area vasculosa is apparent as a red ring in the centre of the yolk. Absence of any increase in yolk size or growth of the area vasculosa is considered to indicate infertility or early embryonic death and the egg is removed from the incubator. The area vasculosa incerases from 25% of the eggshell surface on day 7 to 50% on day 11. At this time it reaches the equator of the yolk sac and between days 12 and 16 of incubation there is only a slight increase in the area occupied by the vascular membranes. Although the area vasculosa does continue to grow around the yolk, it moves away from the shell surface and the growth is not apparent when the egg is candled. Growth of the chorio-allantois starts around day 9 of incubation and only when it reaches the edge of the yolk sac close to the shell, ca.55-60% of the shell surface, does the area occupied by blood vessels increase further. Growth of the chorio-allantois around the rest of the shell is rapid and complete coverage of the inner surface of the eggshell is achieved by day 22 (55%) of incubation. As incubation proceeds the eggs becomes darker and less detail of the developing embryo can be seen but embryonic viability is easy to check by looking for movement. Near the time of hatching, light can be seen only near the air space. Internal pipping occurs on days 35-40. [43]

During the majority of incubation, the air cell will be clearly visible. The shape of the air cell will usually change during the 24-48 hours prior to external pip or chipping of the shell by the chick. This is described as drawdown and is immediately followed by internal pip (where the chick penetrates through the membrane into the air cell).

Removing eggs.

Age of the pair, reproductive experience, environmental and social conditions, as well as the goals of the reproductive program, factor into any decision to remove eggs from the nest. Other considerations that might necessitate the removal of an egg include:

* overdue hatching
* improper incubation
* replacement with dummy egg to avoid recycling
* fostering to another pair
* transportation to another facility
* contraception
* egg damage

If eggs are to be removed for the purpose of contraception, it is advisable that it be done soon after the eggs are laid to avoid any development. A dummy egg can be placed with the parents to prevent double-clutching. Eggs removed for fostering to another pair can be taken at any

[43] Deeming

point during incubation. Options at this time include placing the egg in an incubator until the target (foster) pair is ready to receive the egg or transferring the egg immediately to the target pair. If this is the case, the target pair should be incubating a dummy egg prior to replacement with the fostered egg.

Institutions should be familiar with expected incubation behaviour for a given species in order to properly manage eggs on the nest. Many times eggs are removed from a pair based on an assumption of inadequate incubation when, in fact, incubation had not yet begun. Eggs removed from the parents because of improper incubation may be returned to the nest at or before pip for parent-rearing if the pair has continued to adequately incubate a dummy egg during the period the egg was in the incubator.

Several methods may be employed to successfully and uneventfully remove eggs from the nest. Boxes with peep holes or rear access can allow for easy monitoring and removal. Burrows with access solely through the burrow opening may necessitate removal of the incubating parent before the nest can be inspected.

Captive management can be facilitated through fostering of eggs, or hand-rearing of one egg in fertile two egg-clutches. One successful method is to foster one egg from each fertile clutch to pairs with infertile clutches such that each incubating pair has one fertile egg. This gives younger or less experienced pairs an opportunity to rear a chick.

Egg size differences.

When a size difference exists between eggs in the same clutch, combined with hatch asynchrony, there can be a large weight differential between chicks in a brood.
If maximum productivity is desired one egg can be removed from pairs and either fostered or artificially incubated.

Parent / chick management.

Hatch asynchrony resulting in disparate size between first and second chicks can lead to trouble for a second chick under parental care. However, Humboldt and African penguins have been reported to easily rear two-chick broods. [Magellanics ?]

Feeding during incubation.

It is extremely important to remove all dropped fish if parents are fed on the nest. The ease with which fish can be removed should be considered when the decision is made to offer food at the nest. If feeding or removal of fish elicits excessive aggression from the parents, perhaps an alternative to feeding on the nest should be considered.

If nesting birds are in an off-exhibit area or do not have access to water, it is a good idea to give the non-incubating partner the opportunity to swim sometime during the day. Most penguins quickly catch on to this routine and are willing to leave the nesting area for short periods.

Introduction of chicks to the colony.

Hand-reared Spheniscus chicks can be introduced into the colony when they are nearly fledged (approximately 80 days). It is best to introduce chicks in a group or in pairs if possible. It is advisable to supervise the interactions of the newly-introduced birds during the initial visit to the colony. Chicks can be left unattended after a few days provided they are able to emerge from the water without trouble and are not being harassed by other birds. Juveniles tend to congregate together and will fight to establish a hierarchy of their own. Chicks should be encouraged to join the other birds at the feeding station rather than be provided with special treatment. It may be a few weeks before they are regularly feeding with the others.

Some institutions find it advantageous to use an off-site area to introduce the chicks to members of the colony. A plexiglass barrier can also be used at first introduction within the exhibit.

Hand-rearing.

General Comments.

It is advisable for all institutions managing penguins to gain experience in hand-rearing. It may be necessary to remove an egg or chick for hand-rearing in the event of the death of a parent or the failure of a chick to thrive in the nest. Success with hand-rearing chicks can be as high as 90% once a well-defined protocol has been established. Hand-rearing may be used to maximize founder representation within a colony, particularly if unrepresented birds do not exhibit successful parental behaviour. Hand-rearing can also be used to increase productivity; parents will often breed again within one season if chicks or eggs are removed.

Hand-reared chicks seem to be more tolerant of handling than parent-reared chicks. Depending on the routine husbandry practices of the facility, this may or may not be important. It should also be stressed that penguins are social animals and need to be in the company of conspecifics or congeners, even at a very young age, if they are to develop socially and not imprint. Therefore, if possible, chicks of similar age should be reared together.

Prior to undertaking hand-rearing of penguin chicks, managers should consider the time and cost involved in hand-rearing penguins because this is a labour-intensive undertaking. Staff hours
required to tend to the chicks along with the cost of the necessary equipment (brooder, formula, etc.) may have an impact on the decision whether or not to hand-rear chicks.

Hatchlings / hatcher.

Once chicks hatch, they should be allowed to dry in the hatcher for at least 12 to 24 hours. Immediately following hatching, the chicks should be checked for yolk sac absorption and closure of the seal. If the yolk sac is not properly absorbed and / or the umbilical opening is not properly closed, be extremely careful handling the chick. The umbilicus should be

swabbed with a sterile poividone-iodine swab by rolling the swab gently over the area. This should be continued at each feeding until the umbilicus is completey dry / healed.
It is important to continue to monitor the absorption of the yolk; slow absorption or a tight distention of the abdomen might be an indicator of a yolk sac infection.

Brooder

Once dry, chicks can be moved to an open brooder affixed with a heat source. Some types of brooders used (in order of prevalence) include:

* human infant incubator/modified with the top kept open
* painted plywood box
* plexiglass box
* ice chest type plastic cooler
* plastic box
* plastic wash basin

Primary concerns when choosing a brooder include:

1) adequate air circulation: penguin chicks require a dry rearing environment and should never be reared in an enclosed area where humidity is high.

2) ease of maintenance and disinfection: brooders should be cleaned at least twice daily. If wood is used, it should be sealed; however, be sure that the sealer is compatible with the heat source that will be used, to prevent combustion. It is advantageous to correspond cleaning with feeding to reduce overall handling of the chick. Additionally, toweling can be replaced as needed between scheduled cleanings.
Disinfectants should be thoroughly rinsed and allowed to dry before the chick(s) are returned to the brooder. Betadine sprayed directly on toweling and allowed to dry before adding the chick may reduce fungal spores.

3) size and temperature gradient: there should be an approximate 5° C (10° F) temperature difference from one side of the brooder to the other to allow the chick to adjust its behaviour to meet its own thermoregulatory needs (after 5-7 days of age). If the brooder is too large, chicks may venture too far from the heat source and suffer serious cooling. Chicks under 7 days of age tend to wander away and get lost from heat; a rolled towel that functions as a barrier can keep them near the proper heat range. Chicks younger than 14 days of age should be kept at approximately 26.7-32.3C° (80-90° F) depending on age, weight and thermoregulatory needs. Chicks older than 14 days are usually kept at approximately 21.1.-26.7 ° C (70-80 ° F), again depending on the individual chick's needs.
As a general rule Humboldt penguin chicks can be set on their first day on 30-32°C whilst bringing the temperature down with two degrees each week, so that on day 21 they should have an ambient temperature of 24° C.
For African penguins the first week temperature should be set at 33°C , gradually shifting to 30° C after one week, 28° C after two weeks, and 20° C after four weeks.

The most common heat source provided is a heat lamp (such as a 250-watt infrared heat lamp); a heating pad and electric heater can also be used. To prevent burns, heat lamps should not be situated closer than three feet of the brooder. Heat sources should be adjusted to maintain 26.6 -32.2 C (80 - 90° F) in the brooder for the first 14 days post-hatch. Dependent on ambient brooder room conditions, the temperature may need to be lowered as the chick approaches 14 days of age. Severely overheated chicks often lay flat with flippers and feet outstretched and may be panting; other subtle indicators of overheating are slight dehydration and unexplained inappetence.

4) number of chicks to be reared together: it is recommended that no more than 2-5 chicks be reared in a single brooder, providing size difference is not too great. Overcrowding can lead to overheating of the chicks and increase the likelihood of transferring disease.

Typical early brooder dimensions can be 40 cm wide x 83 cm long x 38 cm high to accommodate one to four chicks.

Cloth toweling is the most commonly used substrate in the brooder for the first two weeks of rearing. Towels are readily available and can be easily laundered, using bleach, for adequate cleanliness. Roughly-textured or frayed towels should not be used because of reports of leg injuries resulting from snagged toenails. Other early brooder substrates include matting, paper toweling and surgical drape material
It is important that the substrate not be so smooth that the chick's feet slide out from under it. Temporary or permanent damage to muscles, tendons, and joints can result from improper footing. A layer of anti-slip matting (like the ones used under rugs in bedrooms, showers etc.) can be placed under the towels to give the chicks better traction.

Older chick handling and bin requirements

As chicks grow, larger brooder accommodations will be required. Usually this takes place around day 15-16. Most institutions utilize an in-house design plywood box. Wood should be painted or sealed with a suitable product. Some designs incorporate a 1/4 inch wire or mesh flooring and are elevated from ground level on legs or casters. Typical dimensions might be 2.4 m long x 1.2 m wide x 0.6 m deep with wooden dividers which allow partitioning based on chick requirements. This size can accommodate eight chicks in four sections or four chicks in two sections.
Bins should be cleaned twice a day too. Chicks are placed either in an empty, clean section of the bin or in another holding area with towels during cleaning.
Clean mats and towels are placed on top. Towels need to be changed at every feeding or more often if excessively soiled or wet.
As chicks grow older and more timid, it may be useful to supply some type of shelter or cover. One method is to provide half of an air-kennel or a sheltered area can be built right into the brooder design. To expedite habituation to handling and desensitization to external stimuli, shelter should be removed for portions of the day.

Generally, dependent on the chick's response and ambient temperature conditions, a heat source may not be required at this stage. However, birds should be able to choose their preferred temperature and therefore there should be a temperature gradient from 27° C (heat lamp) to about 10° C.
Addition of a fan or air conditioner to the area can improve thermoregulatory conditions and air quality. Previously described symptoms of overheating are the best indicator of a chick's thermoregulatory needs.
At this stage, the bin substrate most commonly used is indoor/outdoor carpeting. It is easily hosed for cleaning and can be soaked in a disinfectant and rinsed before drying. Other substrates used include rubberized matting and cloth toweling. Surfaces that are too smooth should be avoided to allow chick proper traction.

Heat lamps

When setting up or adjusting a heat lamp, always make sure that the lamp is secured, and that wires are not touching the lamp. Heat lamps should be placed no closer than 0.9 meter to chicks, or other surfaces, otherwise severe burns may result. The temperature in a brooder or a bin with a newly installed heat lamp should be stabilized for several hours before putting in a chick.

Temperature regulation.

The temperature is lowered in brooders as chicks approach 500 gram body weight. They will begin to appear warm in brooders and may be moved to a bin where they may stay in an environment with an average room temperature of 18.3-21.2° C (65-70° F) with a fan to circulate the air.
At approximately 6 weeks the temperature is reduced further as needed. At 7 weeks of age the birds can be housed in unheated quarters and eventually outdoors, at around 8 weeks of age. At this stage of development one should be focused on the reduction of dust due to the moult the birds are going through. For this reason one should place large extractor fans or hose the enclosure with water several times a day.
Then, as chicks approach completion of first moult (80-90 days) , they are given access to a small pool. However, as long as the birds are not able to swim properly they should be carefully observed and kept indoors during the night. They should also be kept there during rain and cold weather. In case of good weather and at the moment the birds are able to swim properly, they can be kept outside overnight, but with access to shelter.
Always be aware of the possibility of over/under heating in the chicks. Overheating may be indicated by any of the following: a spread out posture, with feet and flippers extended and / or very warm to the touch; panting; lethargy; dehydration and disinterest in food. If underheated, the chick may shiver, huddle against the side of the brooder directly under the heat lamp, have feet and flippers drawn in and / or cool to the touch, and be slow to respond to the feeding stimulus.
Many of the above signs can also be indicators of illness in a chick. Keepers should be on the lookout for any behaviour or physiological sign that deviates from normal. Be conservative and wary: problems are often much easier to solve if caught early. Chicks can be reintroduced into the colony at 4-5 months of age.

Overfeeding / underfeeding

The problem of overfeeding / underfeeding is best caught by careful evaluation of the chick's weight gains. Generally, expected weight gain could range from 10% - 15% per day (individual variation will occur) until the chick reaches approximately 1000-1500 grams, at which time, depending on the individual chick and species, growth rate will slow. Behavioural signs of overfeeding might be indicated by the chick refusing food, being lethargic, spitting-up repeatedly etc.
When giving a normal, healthy feeding response, a chick should be eagerly swallowing the food and stretching up to reach it. When giving a poor feeding response, a chick will not open its bill to eat and will often move its head away from the feeder's hand to avoid food.

Aspiration.

Though tube feeding has been successul in the past and present, the most critical drawback of it is the risk of aspiration of formula into the lungs. Aspiration is usually caused by feeding young chicks too quickly. This is an easy mistake to make and it is common amongst new or inexperienced handlers. The entire process of tube-feeding is dependent upon the developed skills of the feeder, who has learned through experience how to offer the formula properly, taking into account the energy or abilities of each chick. If formula is offered faster or in larger quantities than young chicks can handle, it backs up in the esophagus and enters the trachea and lungs. The chick's inability to resist taking a breath during feeding bouts is increased by the insertion of the tube itself which causes a continuous feeding response. Also, improperly inserting the feeding tube or removing it too quickly can incerase the likelihood of aspiration. Another risk, although rare, is that the chick may swallow a catheter that has accidentally separated from the syringe during a feed. [44]

Hydration.

Hydration should be monitored carefully throughout the chick's development and particularly as the chick begins eating fish pieces / whole small fish. The morning is a critical time to check hydration. Hydration signs in both adults and chicks appear as lethargy, loss of appetite and excessive skin-tenting. Chicks are most likely to begin showing signs of hydration and stress around 12-14 and 40-45 days of age. Around 12-14 days they begin to thermoregulate, walk and move about, and their second coat of down begins to emerge. Around 45-50 days they begin moulting again into feathers. These physical developments place a short intense strain on their body systems and they are more likely at this time to have hydration problems. To determine hydration, a four-point system can be used:

-skin-tent test: pinch skin up at the top of the chick's back – the skin should immediately fall back into place. The longer the skin stays "tented" up, the more dehydrated the chick is.
-eyes: eyes should appear bright, wide and moist (not runny). If they are dry or "drawn" around the edges, the chick could be dehydrated.

[44] Ryan & Drieschman

-feet: the skin on the feet will have normal scaling associated with rapid growth, but it should appear soft and smooth; if skin is “shriveled” and /or appears dry, the chick could be dehydrated
-feces: thick or pasty feces may also indicate dehydration

Water feedings of appropriate amounts will improve the condition.

Splayed leg condition.

Aptly named, this condition describes the outward turned position of the chicks' legs. Although not often seen in penguins, this condition can result in serious and long-term complications. Therefore, early detection is important. The brooder or nest substrate should be textured enough so the chick's feet do not slip out from underneath it. Some facilities have had good results treating this condition by tying the legs together with a soft material. If using this treatment it is important to maintain a normal spacing between the legs. Another successful method used is to place the chick into a bowl approximately the same size as the chicks body so that the legs cannot splay. In very young chicks this often corrects the situation in 5-7 days.

Eye Irritation.

Penguin chicks at any age can develop eye irritations attributable to a variety of factors, e.g., bacteria, injury, foreign matter. Keepers should take note if the chick's eyes tear excessively, appear red, swollen or become cloudy. If eye irritation is noticed, the eyes should be examined carefully for foreign materials. Chicks that are actively losing downy feathers also release tiny flecks of skin or dander that can adhere to the surface of the eye and cause damage to the cornea. In some cases simply flushing the eyes with water or saline solution can provide relief. If necessary, ophthalmic drops can be prescribed by the veterinarian.

Feces.

It is important to examine a chick’s feces routinely. A normal young chick (on formula, not fish) will have slightly runny feces that “squirt out” a good distance during defecation. An older chick which is eating fish will have slightly thicker feces, but still quite soft in appearance.
Feces should not be pasty, dry, pellet-like, excessively green, black or yellow, or contain blood; any of these indicate a problem.
In a young chick (first few days of life) all defecations should be recorded.
It is normal for a chick to defecate at least once between every feeding, often while being fed. If any doubt exists as to whether a chick is defecating normally, it should be stimulated to defecate by gently massaging the cloaca with a wet finger. If a chick is suspected of being ill, it should be isolated from other chicks; this way defecations can be positively identified.

Safety.

Chicks should not be left on a high surface (i.e. counter, table, scale) unattended, even in a container.

Hygiene.

Keepers' hands should be washed with Betadine surgical scrub or other bactericidal/virucidal hand wash before feeding or handling any chick.

Record-keeping.

Complete records for each chick are of utmost importance. Record the amount fed, the quality of the feeding response, the activity level and other behavioural observations at each feeding. Important information regarding the chick's development should also be recorded in its file (e.g. record when the chick's eyes first open, the stages of moult and the date when the bird is 100% moulted).

Weighing.

There are three critical values related to the weight of a chick which, when monitored accurately, will help determine the exact growth rate. These values are derived from weighing the chick before and after every feeding. They are:

-the first weight of the morning before any feeds
-the difference in weight found when measuring a chick before and after a feeding
-the change (loss) in weight between each feeding throughout a singel day.

Comparing each mornings' first weight to the first weight of the previous day yields the two most important indicators of how the chick's development is progressing:
-overall net weight gain after a full day's diet and
-the base amount of food required for each feed that day to maintain proper growth rates.

The difference found between what a chick weighs on a current day, and the previous day's weight will also give the percentage value of how much the chick has gained over the last 24 hour period, letting you know whether you are in the 10-15 % range or not. [45]
It is recommended that young chicks be weighed with the scale in the brooder so that they do not get cool. For the first 2 days post-hatching, often the weight decreases slightly.
Once the chick is left in the exhibit full-time and is eating well it is weighed every 5 days, unless more frequent weighing is indicated. Weighing continues until the bird is judged to be acclimated to the exhibit and its weight has stabilized. Each bird is evaluated on an individual basis. If at any time there is concern regarding the health of a bird, more frequent weighing is resumed.

[45] Ryan & Drieschman

Feeding.

Formula.

Normally, Spheniscus penguins are being hand-reared with a liquid formula diet through a syringe and feeding tube, which is later followed by giving solid fish. There is, however, a considerable difference in growth rate of chicks amongst institutions which is mostly due to the time that the liquidised food is removed and replaced by solid fish.
For reasons of completeness we will give a few recepies giving different growth rates but all with apparently equal success of survival.

There has been some discussion regarding the amount of water needed in the diet in addition to the formula. When fish is added to the diet, there is sometimes a concomitant need for water in addition to the formula. Those managing chick rearing should evaluate a chick's needs and give water accordingly. In the following protocols, water is mentioned, but may or may not be required.

Preparation and hygiene.

All utensils, containers etc. used to prepare the formula are thouroughly washed in dish-soap and hot water, soaked in a disinfectant, rinsed in hot water, and air-dried before use. Unheated formula should be refrigirated until use and will remain fresh for approximately 24 hours. The formula to be fed is heated by setting the container in hot water until the temperature reaches approximately 35º C (95° F). For very young chicks or finicky chicks, formula may need to be heated to 36.7º C (98° F). Formula must be stirred continually during the heating process to prevent curdling. If curdling occurs, dispose of that formula. Do not boil and do not reheat. The unused portion of heated formula should be discarded. When feeding several chicks, the formula container is placed in warm water bath to maintain temperature.
The concistency of the formula is important. If it is too watery, chicks older than 3-4 days may regurgitate during or after feeding. When made properly, formula should be the consistency of a thick milkshake.
Each chick should be fed with its owns syringe. The size of the syringe used is increased as the chick grows: e.g. 1cc, 3cc, 6cc, 12 cc, 60 cc with catheter tip.
Syringes need not be affixed with feeding tubes. However, it is often convenient, when using the 6cc and 12 cc syringes to affix a section (no longer than 1 inch, 2.5 cm), of feeding tube. For this purpose, use size 12 or 14 french (4.0-4.7 mm). Glue the feeding tube to the syringe with instant bonding glue to prevent the tube from coming off and being swallowed by the chick.
Syringes are washed, soaked in disinfectant, rinsed, and air-dried between each feeding. Syringes do not need to be dipped in disinfectant between each drawing up of formula; the feeder can wipe the syringe with tissue or a towel to remove residue. Some institutions warm the syringe before using it. Separate containers of formula are used to feed from for each “group” of chicks (chicks living in the same brooder or bin).

Chicks are fed from youngest to oldest so that the youngest chicks receive the warmest formula. The exception is in the case of an ill bird, which is fed last to avoid contamination the feeding area.

Early feeding.

Chicks generally begin with a schedule of five feedings per day, delivered every three hours; e.g., 0600, 0900, 1200, 1500, 1800. A chick's total intake per feeding can be determined either by the gram differences in weight before and after feeding or by measuring the total amount delivered in the syringe.
It is best to wait at least 12 hours after hatching before offering a penguin chick its first feeding. It is recommended that the first feeding be only water in order to assess the chick's feeding response and ability to swallow. Chicks with a large, unabsorbed yolk sac should only be given water for the first two or three feedings to allow time for yolk absorption.
Young chicks should be fed in a clean, warm, draft-free area. All feeding materials should be prepared before bringing a chick out to feed. It is preferable to feed chicks in the brooder or bin to minimize handling. To elicit a feeding response, the feeder should hold the syring filled with the specified amount of formula in one hand, then extend the first and second fingers of the other hand in an inverted “V” shape over the chick’s bill and wiggle the fingers. The chick should respond with a feeding response by opening its bill and pushing into the “V” at which time the syinge should be placed in the chick’s mouth and the formula fed. In some chicks this occurs on the first or second feed and in others it takess much longer to establish.
The rate at which formula is fed and the amount fed at a “bout” will depend on the age of the chick and how quickly the chick is swallowing. The feeder should continually look down the chick’s throat while feeding, to ensure that formula is not being fed too quickly. As long as the chick is swallowing the trachea is closed and formula can be fed. The chick should be standing upright during feeding, and the feeder should continue to elicit a feeding response for a few seconds following feeding, to ensure that all formula has been completely swallowed.
A feeding response should not be elicited until the feeder is ready to feed immediately, as giving a prolonged feeding response will tend to unduly tire a young chick. The feeder should also take care to have the tip of the syringe or extension tube at the back of the chick’s mouth, and take care not to go too far down the chick’s throat and not touch the inside of the chick’s mouth or throat with the syringe or tube.

Feeding

Feeding protocol nr.1 [46]

This feeding protocol is characterised by a rapid growth rate, with an early introduction of solid food. In this protocol the 10% rule is therefore not fully applied.
For the first week or so the chick is fed at 8.00, 15.00 and 23.00 hours, using a 60 ml syringe (without tube).
The syringe is placed at the back of the mouth, but during the “gobling/pumping” motion of the feeding response, the trachea is closed. Initially only small amounts of food are administered, 0.5 ml to 1 ml at a time. However, as the penguin progresses, more can be delivered in one bout, up to 10 ml quite easily but this may be rather excesive. The chick does

[46] Field, D and C.G.Thomas (Penscynor)

feel better with short feeding bouts. The total amount of food is dictated by the penguin and by the tautness of its abdomen. A full penguin is quiet and has a full, tight abdomen.
The formula itself consists of 250 gram of liquidised sprats with about 100 ml of Hartmanns solution []. Two Mazuri fish eater tablets are crushed and added to the mixture, which is liquidised to a smooth consistency.
Between seven to ten days, the chicks are introduced to whitebait. The change in diet is simple and can be accomplished in two to three feeds. Using the feeding response, a small fish can be placed in the mouth. The occiasional chick which does not show a feeding response should be coaxed or even forced to take whitebait by opening the beak and putting the fish to the back of the throat. Soon all chicks will take whitebait perfectly and will prefer this to syringe feeding. Each individual chick is daily given a crushed Mazuri Fish Eater tablet sprinkeld on a fish. After a few days they will take a whole tablet.
Gradually the whitebait can be increased and in a matter of a week or so they will be taking 100 gram of whitebait per feed. At this stage it is impossible to feed them fast enough and since satiation is the only way to cease the incessant high-pitched whistling, one begins to use sprats as a food medium.
At age 17-18 days (or eating 100 gram whitebait), whole sprats can be offered. Larger sprats should be cut into appropriate lenghts. As penguins grow, they will take larger sprats. It is impossible to introduce sprats earlier. At this stage the penguin may demonstrate a reduced intake of food and, therefore, the daily feeds should be reduced to two.
This is normally around the age of 22-24 days. By about 45-50 days the penguins are feeding once a day on full-size sprats. They will take fish without the use of the feeding response. Some individuals can be persuaded to take fish at around day 20 by simply rubbing the fish against the side of the beak. Once outside, the penguins are encouarged to play with the fish in the water and can be taught to feed themselves in this way. More usually, they pick it up watching others feed.
Though whitebait has a lower nutritional quality than sprat, whitebait is easily handled and utilised. Preparation time and feeding time is drastically reduced as compared to the liquidised sprat. The penguin chicks themselves do appear to prefer the whitebait to syringe feeding, the latter being more intrusive. With the introduction of whitebait over only a few feeds, the feeding response becomes evident and such chicks become keen and eager to feed.

Feeding protocol nr.2 [47]

In this protocol solid fish is introduced around the age of 2 to 3 weeks. Formula is stopped at 5-6 weeks of age. Here, the formula is also a mixture of liquidised fish, a saline solution and a supplement of vitamins.
Some examples of formulas being used for this protocol are:

- 850 gram of sprats, 500 ml of normal saline (0.9%)and 1 gram of SA37.
- 50% herring, 50% physiological saline (=9 gram salt on 1 liter of distilled water),1% Gistocal. In this recepy, after a period of 10 days the distilled water is gradually replaced by normal water, while giving the chick half a salt tablet daily.
- 170 gram of sprats, 70 ml warm water, 300 mg sodium chloride tablet and 0.5 gram Vionate Vitamin supplement

[47] Emmen Zoo, Whipsnade Wild Animal Park, Birdworld Farnham, Ouwehand Zoo

Usually approximately 10% of the chick's body weight is fed. Feeding frequency is rather high with six feedings a day (7.30, 9.30, 11.45, 14.00,17.00 and 22.00 hours) giving 2cc of formula per feeding during the first day.
Each feeding thereafter the amount of formula is increased with 1cc, until the 6th day. From this day onwards each feeding is increased with 2cc of formula. The introduction of solid fish is done with whitebait or filleted strips of sprat. Gradually the strips are being replaced by whole, smaller sprats and the amount of formula is decreased accordingly. Later, sprats are gradually increased in size. As growth progresses, strips of herring are given as well as sprats and eventually whole herring.
After 5 to 6 weeks the chicks will no longer require formula. At that time the number of feedings can also be reduced to five by leaving out the one of the late night. Some zoos then start giving complete Mazuri Fish Eater tablets daily once liquidised food is withdrawn from the protocol, while other institutions start giving them (i.e. starting with a dosage of 1/8 tablet) much earlier, i.e. after approximately 10 days of age.

Feeding protocol nr.3 [48]

In this protocol, the use of liquidised food is much more prolonged than in the other protocols. In addition, the 10% rule is strictly followed.
Feeding is based on a calculated percentage of the morning weight of the chick before the fisrt feeding, as follows:

Day 1. 50:50 formula /water, with the total intake per feeding totalling 1-5 gram (cc), but not to exceed 10% of the morning weight. (1 gram formula is 1cc formula). Day 1 is here defined as the first day of feeding; this may differ from the chick's age where day 1 equals day of hatch. In these early days the chick may still be absorbing yolk sac.
Day 2. 75:25 formula / water, not to excceed 4-8 gram (cc), total intake per feeding. This will depend on the chick's morning weight.
Day 3. Introduce straigth formula, not to exceed 4-10 g total intake per feeding. If not well accepted, go back to 75:25 formula/water.
Day 4 & 5. Try 10% of the morning weight total intake per feeding of straight formula. Do not exceed this amount. Use 10% of the morning weight as a guide for each feeding's total intake. When the chick reaches 100 gram morning weight, begin adding fish to the diet as described below.
100-500 gram chick weight
Begin fish when the chick reaches 100 gram first morning weight. Herring is being introduced as fillets cut into pieces of 2.5-3.8 x 0.6 cm, then whole silversides (Atherinidae) are being used as the chick is able to swallow them whole (this may not occur until the chick is approximately 300 gram). Silversides are limited to less than 50% of the total fish intake, due to the belief that silversides may not contain enough iron to maintain adequate nutrition longterm in penguins. Dip the fish or fish pieces in formula or warm water just prior to feeding. This hydrates the fish, warms it a little, and makes it easier for the chicks to swallow. The guidelines for the amount of fish fed are as follows:
100 gram morning weight:

[48] Turner, W. & L.Plutchack (Sea World California)

1st day on fish: 3 gram of fish given once a day for the first day, at the first morning feeding. Fish is given with formula, and the total intake (fish plus formula) per feeding is not to exceed 10% of the morning weight.
2nd day on fish: a maximum of 3-5 gram fish given twice a day, with formula, at the (fisrt) morning and mid-afternoon feedings. The total intake per feeding must not exceed 10% of the morning weight.
3rd day on fish: 3-5 gram fish maximum given at every other feeding, with formula so that the total intake per feeding equals 10% of the morning weight.
4th day on fish: 3-5 gram maximum fish given every feeding.
5th day on fish: 5-7 gram maximum fish given every feeding.
6th day on fish: 7-10 gram maximum fish given every feeding.

300 gram morning weight:
10-15 gram fish maximum every feeding with formula, not to exceed 10% of the morning weight per feeding.
400 gram morning weight:
fish is 50% maximum of total intake every feeding in combination with formula, the total not to exceed 10% of the morning weight, per feeding. Begin vitamin supplements at this time (25 mg B1).
Heating formula to the full 95º F (35º C) becomes less critical as a chick is consuming a higher percentage of cold fish.
500 gram chick's first morning weight:
Decrease the number of feedings to 4 per day, every 4 hours, at approximately 500 gram first morning weight. Chicks go directly to 10% of the morning weight at each feeding.
600 gram first morning weight:
After the chick reaches approximately 600 gram or greater and has been doing well on the 50:50 fish/formula + water regimen, then the feeding schedule may be altered to increase the percentage of fish in the diet: 30 cc formula, plus fish to equal 10% of the morning weight. Water may be given as needed. The size of fish given can usually be increased at this time, with a mixture of one-half capelin (Mallotus villosus) and one-half small or cut herring replacing silversides. Keep in mind that herring is a dense-fleshed fish, and may be difficult for younger birds to process whole. Do not feed more than 30cc of formula per feeding.
1000 gram or greater chick's first morning weight:
Chicks may start to "wean" themselves from formula by refusing to feed from a syringe. This may begin to occur as the chick approaches 1500-2000 gram first morning weight. Formula may be reduced to 15cc 4 times a day.
Formula is eventually reduced to 30cc once a day (at the first feeding of the day, when the chick is most hungry), then eventually eliminated from the diet altogether.
Once chicks are off formula, the fat intake needs to be replaced by a fish with a high fat content such as herring. At least 50% of the fish fed should be a high fat fish. Fish fed to chicks which are not receiving formula should be dipped in water or hydrated by injecting water into the fish just prior to feeding. If this is not enough to hydrate the chicks, en electrolyte replacement solution should be used.

Although chicks may be on a four times a day feedings, they may not eat the full amount of fish offered at each feeding, especially at the fourth feeding of the day. Feeders should be thinking in terms of "daily intake" and whether chicks are maintaining the proper weight gains.

An additional reduction of the number of feedings per day may also be indicated at around 1500 gram. Chicks that are not hungry at the second feeding for several days are probaly ready for three feedings per day, every 6 hours or so.
When chicks go to three times a day feedings, start with 10% of morning weight per feeding, then adjust as neeed to achieve the desired weight gain. Chicks should be eager to eat at each feeding. As chicks start to moult, they may not eat the full amount offered. Once chicks have completed moult, are in the exhibit full-time and have reached a good, stable weight, fish may be fed on demand, or on the same schedule as the other birds in the exhibit.
As chicks progress through various feeding stages, they will respond differently. Sometimes chicks will not eat all the food items offered at all feedings. Never force a chick to eat. Evaluate each chick individually and then determine the cause for inappetence.
There are two stages at which most chicks become finicky: at 500 gram for a day or two, and at 1000 gram for several days. They may refuse food at one feeding or not eat full amounts at each feeding. Check for overheating. If low appetite continues for more than a few days, it is a cause for concern, not just a phase. The bird may be ill.

Penguin formula

Whole Batch

440 g	12.7-17.8 cm whole herring (w/head, tail, fins & skin removed)
440 g	krill (squeeze water out after defrosting & before measuring)
800 ml	bottled drinking water
8	7 grain [49] brewers yeast tablets
550 mg	B^1
1	5 lb. Mazuri® Sea Bird vitamins (=formulation for birds eating 5 lbs fish per day)
4	10 grain calcium carbonate tablets
1200 i.u.	VitaminE
2 ml	Children's multi-vitamin drops

Note: for chicks 3 days of age to 400 g am weight: just prior to feeding formula, stir in 1 pinch of ground B^1 per 100 cc formula prepared for feeding.

Half Batch

220 g	12.7-17.8 cm whole herring (w/head, tail, fins & skin removed)
220 g	krill (squeeze water out after defrosting & before measuring)
400 ml	bottled drinking water
4	7 grain brewers yeast tablets
275 mg	B^1
2+1/2 lb	5 lb. Mazuri® Sea Bird vitamins (=formulation for birds eating 5 lbs fish per day)
2	10 grain calcium carbonate tablets
600 i.u.	VitaminE

[49] A grain is equivalent to 65 milligrams.

1 ml	Children's multi-vitamin drops

Quarter batch

110 g	12.7-17.8 cm whole herring (w/head, tail, fins & skin removed)
110 g	krill (squeeze water out after defrosting & before measuring)
200 ml	bottled drinking water
2	7 grain brewers yeast tablets
150 mg	B^1
1+1/4 lb	5 lb. Mazuri® Sea Bird vitamins (=formulation for birds eating 5 lbs fish per day)
1	10 grain calcium carbonate tablets
300 i.u.	VitaminE
1/2 ml	Children's multi-vitamin drops

Vitamin regime

Through 1000 g AM weight

3 days of age to 400 g AM weight:
Just prior to feeding formula, stir in 1 pinch of ground B^1 per 100 cc formula prepared.

>400 g AM weight through 1000 g AM weight:
25 mg B1 twice a day

First daily weight = 1000 g - or when chick receives formula twice a day (BID)

AM:
½ children's multi-vitamin
125 mg oystershell calcium
50 mg B^1

P.M.
100 i.u. Vitamin E every other day
½ tablet B-Complex (B-SO)
125 mg oystershell calcium

First daily weight = 2000 g - start of juvenile vitamins:

AM:

125 mg oystershell calcium
I children's multi-vitamin
50mgB1

PM:
25 mg oystershell calcium
B-Complex (25 mg)
100 i.u. Vitamin E every other day

Juvenile vitamins
(after completion of first juvenile moult until 4 months post-fledge of the youngest chick)

½ 5Ib. Mazuri®Sea Bird vitamin tab twice a day
1 50 mg B1 once a day
1 50 mg B-complex once a day
100 i.u. vit E on odd days

Vitamins may be inserted into the gills of the fish before feeding, or-if no whole fish is being given-fed to the chicks with a feeding response, followed by the fish fillets.

Feeding protocol nr. 4 [50]

This protocol, though not yet used for Spheniscus penguins, is characterised by the immediate introduction of solid food. For reasons of completeness it is mentioned in this manual as it might be an option for Spheniscus penguins too (except for Humboldt penguins as krill is involved) in the future.
So far it has been used with Gentoo penguins only and with considerable success.
The diet uses three types of solid food which are common in penguin hand-rearing diets: herring, capelin and krill, as well as liquid formula.
Herring is one of the main ingredients in the formula and, after deboning and skinning individual herring, the meat can be cut into various sized fillets which will become the main source of food for the young penguins. Capelin is used as a supplemental fish late in the developmental stages as the chicks become more accustomed to eating whole pieces of fish. Krill is also used as a main ingredient in the formula, but its primary role is a major solid food source, along with the herring fillet, in the early stages of rearing.

The difference between this diet and the more “traditional” ones is the roles the food supplies play throughout the diet. In a traditional diet, the emphasis is on the nutrient value and intake volume of formula. Fish do not play a primary role until the fledglings are being weaned, prior to introduction into the adult colony. In this new diet the main emphasis is placed on the chicks being hand-fed fish fillets and whole krill from day one.
The formula performs several supportive functions, but it only accounts for 10% of total intake. Its main purpose is to act as a coating or lubricant for the fillets and krill. Because it is still necessary to heat the formula and the young chicks still require to be fed a diet above

[50] Ryan & Drieschman

refrigerator or room temperature, the formula provides a natural and simple way to warm up the herring and the krill without having to heat or cook the solid food itself.
While the formula is being made as it is normally done, most of the time is taken by cutting the fillets. During the first ten days the fillets cannot exceed 12.7 mm in length. The difficulty is in thawing the herring sufficiently to allow skinning and deboning without the meat becoming too soft, otherwise it will crumble when cut. Preparing the krill is an easy task, simply thawing it completely before feeding. Shortly after Day 35 the formula is no longer required; herring and capelin are fed either whole or cut in half and krill is removed from the diet after fledging, which greatly decreases the preparation time needed before feeds.
Each feeding station requires a container of formula and a food bowl of fillets and krill. The formula is heated to 32.2 – 35.0 C° C just prior to starting each feed, and then it is poured over the top of the fillets and krill. This method provides a natural lubricant as well as heating the food up to proper temperature. The formula, being kept warm in a heated warm bath, is reapplied throughout the feeding whenever the fillets or krill begin to cool down.
Feeding is done by stimulating the feeding response with the fingers and then by placing the food inside the birds mouth.
In general, the methology used for the Gentoo penguins, using the 10% rule for feeds, was:

Day 1-3: 8 feeds over 14 hours with each feed consisting of 2 grams (one small fillet (32. x 12.7 mm) and one krill.
Day 4: 7 feeds over 12 hours
Day 6: 6 feeds over 12 hours
Day 7: chicks begin to eat consistently 10% of their daily weights per feeding
Day 10: 4 feeds a day over 12 hours
Day 11: size of the herring fillets is increased
Day 25: (1500 grams) loss in appetite; introduction of less “warm food”. 3 feeds a day
Day 33: (>2000 grams) removal of formula and krill, introduction of cut fish (not filleted)
2500 grams: introduction of whole fish
day 40: signs of fledging; only fish fed (700-950 gram per day)0; average daily weight gain between 1-5%
Day 45: fledging until Day 60: 2 feedings

Removing chicks from the parents for complete hand-rearing.

If eggs are fully incubated by the parents, but chicks are being fully hand-reared, a stressful event is taking place for the adult pair when the chicks are being removed.
However, leaving chicks with their parents for 48 hours or so slightly depresses growth rate, but not significantly so. This does demonstrate that leaving chicks with parents does not significantly disadavantage them. This has important consequences for asynchronous hatchings, since the removal of the first chick to hatch can be delayed until the second chick has hatched. This means that the parent does not have to be disturbed at this crucial time and there is no possibility of her abandoning her second egg if the first chick has been removed.

However, a disparity of more than 48 hours between the hatching of the chicks will neccessitate the removal of the first chick.

Combination of parent rearing and hand-rearing.

For reasons of management (one is sure of having fed enough fish to each penguin, the observation of its condition is facilitated, giving the proper supplements is assured, severing the parent-chick bond etc.) some institutions feed their adult penguins individually by hand. In order to be able to do so, parent-reared chicks need to be taught to take fish from the keeper's hand. Therefore, chicks have to be "weaned" at one stage.
This timing, as well as the intensity of doing this, is highly variable amongst institutions. Some start by doing so at 35-42 days, others at around 50 days of age. As a priority, force-feeding should be avoided by trying to get the birds to eat the fish from the water, for instance by having it moved by the movements of the water, or either by hand.
In removing the chick at an earlier stage (35-42 days) the chick is less independent and therefore more prone to learning, its hasn't gone through the stressful period of moulting yet and the thermoregulation has developed far enough for the chick in order to be able to cope with this situation. By starting the whole procedure after moulting, the separation from the nest and the parents seems to be more stressful for the chick and its reaction will be a flight, which in its turn will make feeding more difficult. [51]
Having hiding places for the chicks to turn to has a calming effect at this period of development. In addition, it is ideal to have two or more chicks in the nursery at the same time.
The usual removal of the chicks of the parents, however, starts by force-feeding them during about three days, 5-6 times a day. From that time, until about 7 days, the chicks still need a kind of fixation in order to be able to take the fish, until they will be able to take it from the keeper themselves. After a few days the number of feeds can be diminished to 3 a day. After moulting the chicks can be fed in the water only. Gradually,they should learn to be able to pick out the fish from the keeper underwater. Eventually the birds should be able to pick out the fish underwater by themselves. The whole process takes 4 to 7 weeks, before the birds are ready to be introduced into the adult colony. The average time in the nursery is usually around 42 days.

In situations where a second clutch is laid, however, there have been cases that the parents were able to feed the two generations at once. The parent-chick bond does break eventually, but by waiting for it to break naturally, an unexpected variability in its duration can be expected. [52]
In case the chicks keep on begging for food for too long, the parents cannot avoid the chicks altogether like in the wild and therefore will go into moult in a less optimal condition as they could have done.

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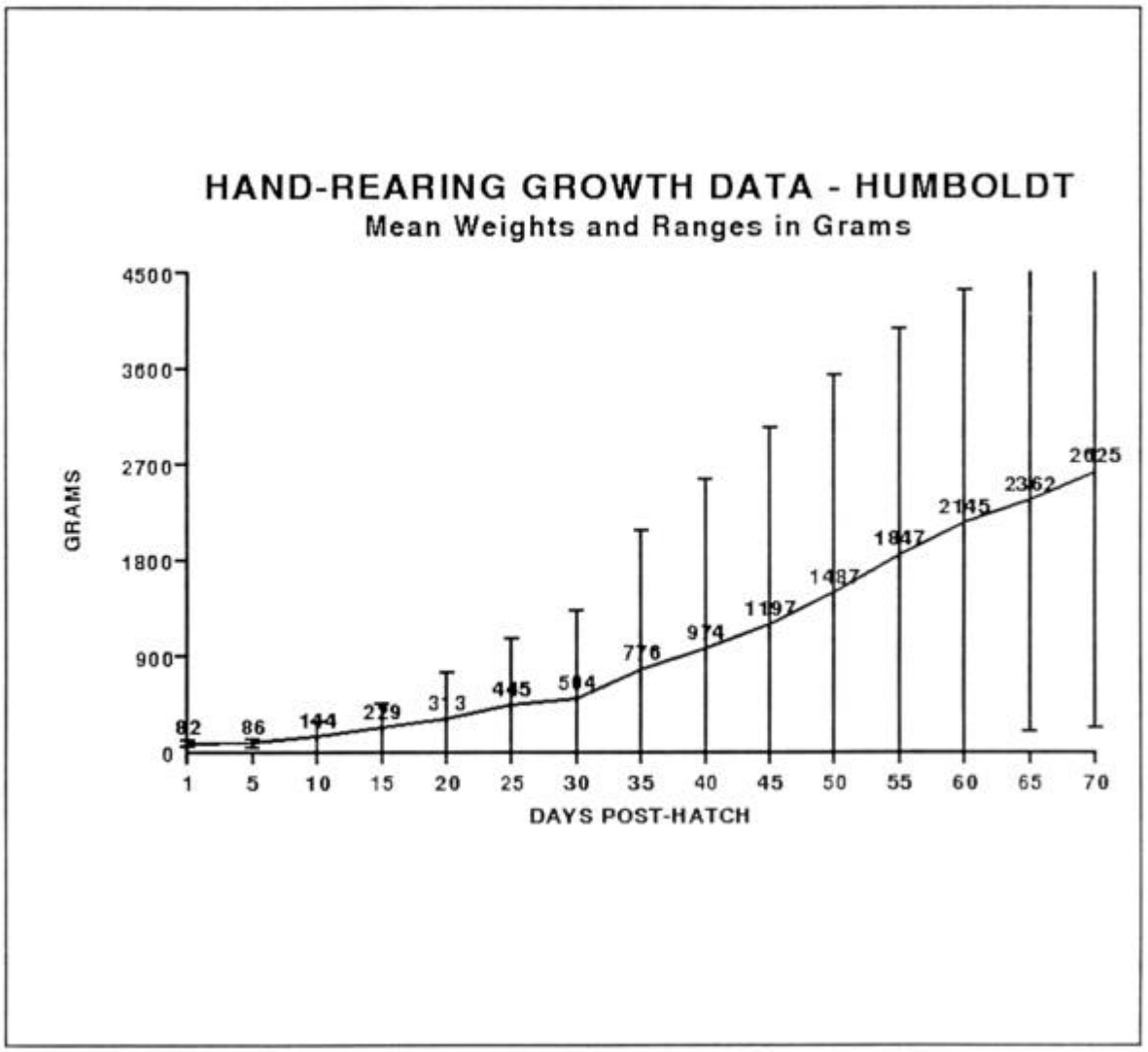
[51] Spretke, manuscript. The Baltimore Zoo even separates the African penguins for hand-rearing at around 28 days of age. Cf. Gailey-Phipps
[52] H.Moore

At some institutions even parent-reared chicks are being regularly weighed. This is carried out after the adults birds are fed (2-3 times a day), in case the chicks show signs of stress or lack a sufficient weight gain. In case of a lack of sufficient food intake, the chick is supplemented with formula (during weighing) and /or solid fish, depending on the stage of development of the chick.

In general, there may be nutritional factors involved in the high mortality of chicks. This issue needs to have more attention. Research needs to be carried out on the amount of regurgitant that being fed, at which frequency and how digested it is when fed. In this way it may be possible to compare parameters of successful and unsuccesful colonies.



Spheniscus penguin husbandry manual

First edition

Edited and compiled by the Penguin TAG

A publication of the EAZA

Section B: Management in captivity

Nutrition

Nutrition

Meeting the nutritional needs of penguins is essential if they are to survive and reproduce in captivity. Developing appropriate dietary guidelines involves using information

1) from feeding ecology data
2) from published nutrient requirement data
3) on food availability to zoos and
4) on food preference.

It is also essential to store and process food items correctly and provision the birds on appropriate schedules.

Feeding ecology.

Knowledge of food habits and feeding ecology of penguins in the wild is relatively recent, and is still limited. Although some data are available on all species, quantitative characterization of the diet is available for very few. Information on species of prey used, seasonal or annual variation, and sex or age differences is also very limited. So, in general there are no data which precisely dercribe the nutrient requirements of (Spheniscus) penguins. Careful studies of wild diets and the nutrient content of those diets especially during the breeding season for these penguin species would be particularly valuable to our understanding of captive management.

Spheniscus species tend to rely much more heavily on fish than do the high latitude species. The prey fish used are often small-bodied surface-schooling forms.

Of the few species that have been studied at more than one site or during more than one season, there are suggestions of variation in diet within a species. Of course there are also great fluctuations in seasonal intake which reflect periods of tasting during moult and incubation. Many of the differences in diet may relate to differences in prey availability between sites. Seasonal differences in quantities of specific prey items are recorded in African penguins. However, these patterns are not completely understood; in a few species

populations from different sites take remarkably similar diets, and in African penguins there seem to be seasonal variations that are not entirely related to prey availability.

Broadly similar patterns in diet seem to remain from year to year with little annual variation, particularly in the higher latitude species. However, in species such as Humboldt penguins, prey species (fish in particular) may shift with major oceanographic events such as El Nino. Historical changes in diet composition may occur related to changes in prey abundance, as has been documented for African penguins. Competition with local fisheries operations may also affect the proportions of prey items in penguin diets.

The implication of known intraspecific variation in diet for captive management of penguins is that diets must be constituted to balance nutrients over time, not to mimic single reports of wild food items. Simple records of prey items taken do not necessarily reflect preferences nor evolutionary patterns.

In captivity, it is generally accepted that there is individual variation in food preferences among penguins. Both the number and types of food species offered to the captive animal are artificially limited so that the animal will never have the selection that would be available under free-ranging conditions. Nonetheless, the animal may have an equivalent degree of variety in the captive diet, comparable to that actually consumed in the wild. Data from the wild suggest that the food items most consumed may not be those most preferred, but may be most available. Some differences in food choice may be based on physiological condition.

Selection of individual items in the diet may allow an animal to be selective within food categories. Animals probably do not select food items based on overall nutrient content; therefore animal preference is not necessarily an indicator of nutrient content. Food preference, or actually the refusal of food may be an indicator of quality, however. If fish is being refused, it should be checked for quality.

Fish handling and preparation. [53]

Since reliable availability of fish is critical to the success of captive programs, most fish purchases are made in bulk. This necessitates that the items are frozen and stored until use. Given the perishable nature of fish and seafood, food handling procedures are critical.
To offer a variety of fish at any one time, it is often difficult to avoid storing the item for more than a year. Many of the fish species used as food items are caught only seasonally; it is important to ask the supplier when a particular batch of fish was caught. Otherwise purchasing fish several times throughout the year does not ensure that a fresh catch has been obtained.

Practically, there are two basic approaches to offering fish as food: offering one species of fish on a seasonal basis or offering several species of fish throughout the year. If one fish species is offered seasonally, a new species should be rotated into the diet. The rotation may

[53] Crissey, S.D. Handling fish fed etc.

occur as often as quarterly. The advantage of the seasonal approcah is that relatively fresh fish would be fed. The disadvantages include:

-Offering only one type of fish at a time may provide a nutrient profile that is not nutrionally balanced (for example, to fatty or too lean, low or high in nutrient).
-the quality of the one type of fish may happen to be poor or unaccepatble and there is no backup supply
-the supply may run out with no backup supply
-the fish may be unpalatable to one or more of the animals in the collection
-some species are harvested only at specific times or once a year

Given the goal of a balanced diet, it would be preferable to offer more than one species of fish, but holding stored fish for prolonged periods may cause nutrient losses. The objective is to provide a balanced diet utilizing the freshest fish possible.

Another approach is to obtain the catch seasonally, but store the fish for up to a year and spread usage evenly throughout the year. The advantages include:

-several fish species are available and fed simultaneously for a nutritional balance
-backup supplies are on hand in case of palatability problems or poor quality

The disadvantage is that frozen fish may lose nutrients over time.
Uncertainties in the future availability of fish stocks, reliance on farm fish, and the development for marine mammal diets: these factors make selection of appropriate fish and their handling of utmost importance. Such uncertainties and possibilities require an awareness and evaluation of the nutritional content and quality of diets.

Fish that are purchased should be packaged in plastic-lined boxes with date of catch printed on the box. Fish may be block frozen, individually quick frozen (IQF) or in a shatter pack. The optimal size for packages should be 10-20 kg to allow for proper thawing. It is suggested that package size provide one day's supply without leftovers.
Package size is also determined by the type and usage of fish. Those fish used in smaller quantities should be purchased in smaller packages or should be prepared in a manner that allows for easy access to smaller quantities. Size of the individual fish may be important to avoid the necessity of cutting. Cutting fish causes a greater nutrient loss, as well as increased hours for preparation. If the entire fish is not fed, the nutrient content is altered. There may be a substantial decrease in the calcium content of the fish if the heads are removed, for example.

Storage.

Once a fish shipment has been accepted, it should be placed immediately in the institution's storage facility. This facility should be designed to adequately protect supplies from

deterioration or contamination. It is crucail that the length and conditions of storage minimize contamination and ensure that the product retains its nutrtive value and wholesome quality.

Prior to storing a new shipment, the storage freezer should be inspected to ensure that it is in good working order. There should be no potential for contamination by chemicals or other items that may also be stored in the freezer. Any older stock remaining in the freezer should be placed so that it will be used before the new stocks - a “first in, first out” basis. Always rotate shipments of the same species of fish to help ensure freshness. Optimally, the date received should be stamped or written on a box or pallet of boxes.

Because they can support microbial populations, fish are included in the definition of potentially harzardous foods; to decrease or inhibit growth of such micro-organisms, proper storage temperatures are required.
It is recommended that fish stored for prolonged periods (up to a year) should be in a freezer with temperatures maintained at -23º C (-10º F) or lower.
Refrigeration is used only for thawing of fish and short-term storage until fish are fed. Once removed from the freezer for thawing or thawed under refrigeration, fish ***must*** be used within 24 hours. Several sources report a refrigerator temperature requirement for storing potentially hazardous foods of 0 to 10º C (32 to 50º F).

There are no studies reporting shelf-life recommendations for particular species of whole fish. However, following the procedures below will help to ensure that contamination conditions are minimized and that the fish retain their nutritive value and wholesome quality.

-refrigerators and freezers designated for fish storage must be used for perishable food only. No substances that are known to be or may be toxic or hamrmful to marine animals should be stored or maintained in the animal-food storage areas.
-adequate and proper cold air circulation is required for maintaining the desired uniform temperature in all areas of the freezers and refrigerators where fish are stored. Check to be sure that cold air ducts are not blocked when items are placed in the storage area. Allowing at least 60 cm between the top of stacks and opening of air ducts usually provides the circulation needed to maintain the proper range of temperature.
-proper temperatures in refrigerated and freezers should be:
freezer: -30 to –18 º C (-22 to 0 º F) or lower
refrigerator: 4 to 6 º C (40-43º F)
-set up a schedule for routinely checking temperatures in several locations in the refrigerator and freezer. Document the temperatures in writing.
-relative humidity should be maintained at 85 to 80 percent in refrigerated spaces. A high humidity in the freezer helps to decrease dehydration of the frozen items.

Thawing.

The thawing process is critical to the product’s final quality. Therefore, it must be carefully controlled. Incorrect thawing increases the potential for nutrient loss, lipid peroxidation (rancidity), microbial buildup, and loss of palatability. The safest and most preferable way to thaw fish is in a refrigerated space. Freezing tends to break down tissues, making the food much more susceptible to bacterial invasion after thawing.
Thawing in cold water is not preferable. Possibilites for thawing fish include:

1. the preferred method is in refrigerated units so the temperature of the fish themselves does not exceed 7º C (45º F). This method can be documented by placing a thermometer with the fish.

2. under potable running water at a temperature of 21º C (70º F) or below, with sufficient water velocity to agitate and float off loose partciles into the overflow. This is not as desirable as method nr. 1 because running water over thawing fish increaese nutrient loss, especially of water-soluble nutrients, and therefore is not recommended. Thawing fish in standing water is not recommended because of loss of nutrients and the possibility of increased microbial buildup and contamination.

3. In a microwave over set to defrost. This method is used only when the food will be immediately transferred for consumption but is not preferred.

Fish should never be thawed at room temperature. Frozen foods should not be thawed by exposure to excessive heat or thawing in standing water. These methods cause an increased loss of nutrient. The use of fans to speed thawing causes loss of fluid through dehydration. Ideally during thawing fish should be kept in wrapping or a container, which provides insulation and allows the fish to thaw uniformly. The container may include the original shipping box or covered plastic container.
All fish should be fed to the animals within 24 hours following removal of freezers for thawing.

Handling thawed fish.

Frozen foods, once thawed, should ***never*** be refrozen. If not fed, fish must be discarded 24 hours after removal from freezer or, if thawed under refrigeration, 24 hours after being thawed. Fish must be processed immediately upon removal from the thawing stage and as close as possible to the feeding time. Minimize the time the fish spend at room temperature. Please note that fish can be processed while still frozen just prior to thawing. There usually is a span of time between processing and feeding. Care must be taken to minimize this time while continuing to store fish under cool conditions. Feeding frozen fish is undesirable because they may not be palatable, they are rigid in physical form and the availability of nutrients to the animls may be decreased.
Fish should be fed cold but not frozen.

Feeding.

Food must be wholesome, palatable, free from contamination, and of sufficient quantity and nutritive value to maintain the animals in good health.
The recommended method of feeding is to hand feed to individual animals, especially the supplemented (pilled or injected with supplements) fish. This will ensure each bird obtains adequate nutrients and allows the institution to monitor consumption. Pilled fish should not be fed in the water. In addition, feeding penguins by hand will prevent predators (like herons and gulls) from flying in. This method of feeding also facilitates any medical preventive treatments (aspergillosis and malaria).

Points of interest which can be considered in hand-feeding penguins are:

-birds can be trained / conditioned to accept fish from (a) specific place(s) in the enclosure. This can be restricted to feedings for supplemtation and /or medication, at other times birds can be fed in the water. The need for several feeding places in the enclosure can be caused by differences in dominancy of birds.
-penguins may be able to learn by example from others within the group though there is not a lot of proof for this.
-hand-reared birds will readily accept hand feeding when they are adult if they continue to receive this regularly
-introduction of hand-reared birds into a group of parent reared birds will allow these parent reared birds to follow the example of the hand-reared ones
-hand-feeding can be used as a daily event for visitors
-when birds are sitting on the nests they should be hand fed.
-teaching and training of birds to take food from hand is highly dependent on the patience and consistency of the keepers

Depending on the size of colony some zoos feed all birds by hand individually, or only those which are on the nest. Otherwise, penguins can be fed in the pool or by trays with fish.
The methods of feeding must ensure that fish remain cool, clean (no feces or other debris) and are consumed within a short time frame. In exhibits that are held below 4 º (40 ºF), fish could be kept out in trays for several hours as long as birds are not defecating nor walking in the tray. However, care should be taken to avoid leaving fish in standing water.

If the animals are fed outside in hot, humid or sunny weather, it is important to feed only the amount that will be consumed immediately or while still iced to avoid microbial build-up, nutrient loss or contact by disease-spreading pests.

The feeding schedule for adults used by most institutions is to feed twice per day, early and late. Some institutions increase the number of feedings during pre-moult and breeding. Birds should be fed ad libitum, though amounts fed vary strongly in time, i.e. a increase in intake should be expected pre-moult and a decrease during moult.
The quantity of food consumed per day can be estimated based on body size. An average, active adult penguin's food consumption on an as-fed basis is approximately 10-14% for Spheniscus penguins, that is a daily intake of 450- 500 grams per bird. The specific quantities consumed, however, depend on the activity level and physiological state of the individual.

The size of food items should be appropriate for easy manipulation and swallowing. Use whole fish or every portion of the fish. Most Spheniscus penguins prefer smaller herrings (12-15 cm) and full-sized sprats (10-12 cm). Smaller fish are easier to digest and this may strongly influence the amount of pre-digested which is given to the chicks.

In case penguins are fed by hand individually, the keepers identity plays a key role. Consistency in having the same keepers for the penguins gives the birds a higher feeling of confidence and therefore a far higher intake than in a situation of changing keepers.

Nutrient requirements and possible toxicities.

The discussion and background information on nutrient requirements and nutrient content of food items are presented on a dry matter basis. Note, however, that the recommendations are given on a fresh weight basis to avoid additional calculations when putting together the actual diet.
Despite consumption differences among species, it is likely that penguins have similar qualitative nutrient requirements for tissue metabolism.
If consumed in its entirety, the diet should contain the nutrients listed in the following table on a dry matter basis. These should be considered target nutrient levels until more specific nutrient levels are defined .

Recommended nutrients for adult penguins, expressed in quantity per unit of diet (dry weight) (based on calculated analysis).

NUTRIENT	**QUANTITY/day (range) ***
Energy (kcallg)	4-5 **
Crude protein (%)	20-25
Fat (%)	***
Fiber (%)	-
Linoleic acid (%)	1.11
Vitamin A (Juig)	1.67+
Vitamin D (lUig)	0.222-0.5
Vitamin E (lUig)	0.4 ++
Thiamine (mg/kg)	100-120++
Riboflavin (mg/kg)	2-4.44
Niacin (mg/kg)	12.2 – 61.22
Vitamin B6 (mg/kg)	2.9 – 3.3
Folacin (mg/kg)	0.28 – 0.8
Vitamin B12 (mg/kg)	0.003
Pantothenic acid (mg/kg)	11.1
Choline (mg/kg)	1000-240
Biotin (mg/kg)	0.111
Vitamin C (mg/kg)	-
Vitamin K (mg/kg)	-
Calcium (%)	0.778-2.5 +++
Phosphorous (%)	0.33-0.44
Magnesium (%)	0.056
Potassium (%)	0.333
Sodium (%)	0.167
Iron (mg/kg)	66.7 - 80
Zinc (mg/kg)	38.9 - 50
Copper (mg/kg)	6.67
Manganese (mg/kg)	33.3 – 44.4
Colbalt (mg/kg)	-
Selenium (mg/kg)	0.111 – 0.156
Iodine (mg/kg)	0.389

Amino acids ~+	
Arginine (%)	1.6
Tryptophan (%)	0.256
Lysine (%)	1.33
Methionine (%)	0.556
Cystine (%)	0.478
Phenylalanine (%)	0.8
Tyrosine (%)	0.689
Histidine (%)	0.389
Isoleucine (%)	0.889
Leucine (%)	1.5
Threonine (%)	0.889
Valine (%)	0.911
Taurine (%)	0.04 (for cats)

* Recommendations are based on requirements for domestic poultry as well as those for carnivorous mammals, except as noted below. Usually the higher of the ranges are shown.

** Energy requirement is based on that found in commonly fed fish and values for krill. It appears that if lipid content is maintained between those figures found for krill and commonly consumed fish:
6 and 15% (fresh weight), it should supply sufficient kcals (as long as enough fish are consumed). Kcals should run between 4-5 kcal/g (1.0-1.7 kcal/g fresh weight). Animals should be fed ad libitum.

*** Requirements for fat for many animals is between 3-5% dry matter basis. The fat content of fish may range from 15-40 %. Thus an appropriate range for fat in a penguin's diet may be from 20-30% The requirement for fat corresponds to a requirement for energy as well as specific essential fatty acids.

+ See discussion on special considerations for more vitamin information.

- No NRC requirement stated for this nutrient. This does not mean there is no requirement, just that studies have not been performed.

+ + For fish eating animals this level of Vitamin E and Thiamine supplementation is recommended due to poly-unsaturated fats and thiaminases respectively in the fish.

+++ The higher value is for laying geese.

* + Amino acid requirements are based on domestic poultry and are higher than those for carnivorous mammals.

Water. Penguins acquire their water requirement through both their foods as well as free water.
Because of their nasal salt glands, penguins can consume salt water. However, they can also easily consume fresh water to meet their needs. If the birds are held in only fresh water, salt can be added to the diet to ensure development of the nasal glands. There is some controversy

over the necessity to give salt to penguins kept in freshwater pools. Some believe the absence of salt in the diet merely renders the nasal gland defunct, while others believe the nasal glan can become clogged and infected leading to further medical problems.

Energy. It is thought that birds eat to meet their energy needs and it is not recommended to limit energy intake of penguins unless the animals are unnaturally overweight. Several types of food items should be offered such as several species of fish and/or krill and/or squid in order to provide enough metabolizable energy to meet the animals' needs.
Penguins should consume higher quantities of less energy dense foods than of energy-rich foods. Nonetheless, limited fill capacity should not be a problem, given the energy content of most fish. The literature shows penguins carrying up to 20-30% of their body mass in their stomachs as they bring food to their chicks. Thus, penguins appear to have a great capacity for filling their stomachs.
Energy intake is known to be associated with moult. Captive penguins increase body fat and thus body mass prior to moult. There are several cues the animals use to begin moulting. These may include environmental temperature, light cycle, food resource availability or possibly even food nutrient content, and hormones. It appears that if fed an adequate diet, most captive penguins will cycle their own intakes and moult normally, presumably if the other cues are present.

Vitamins and minerals. Vitamin A dietary requirements for most adequately-studied avian species are between 1.5 and 4.0 IU/g of diet on a dry weight basis. Based on limited data, the requirement for non-human primates and cats is 10 IU/g of dry diet. However, it is possible that fish-eating birds may have a higher tolerance for vitamin A because comparatively high levels occur in their natural diet.
In general, Vitamin A plasma-levels as well as levels of Vitamin E vary seasonally through changes in food consumption and weight, which in its turn is related to moult. For this reason levels of both vitamins decrease and increase parallel to the weight of the bird. From captive Humboldt penguins it is known that their retinol levels vary between 68 and 130 mcg/100 ml. [54]

Vitamin D3 dietary requirements for most adequately studied species are between 0.2 and 1.2 IU/g of diet on a dry weight basis.
Based on the destruction of vitamin E which takes place over time in stored marine food products, it is felt that the vitamin E supplementation for marine animals may be 0.1 IU/g of the diet on a wet weight basis or approximately 0.4 IU/g of the diet on a dry weight basis. From captive Humboldt penguins it is known that their a-tocopherol levels vary between 1500 and 2500 mcg/100 ml. [55]

Based on the presence of thiaminase in fish, it is felt that supplementation for a marine animal for thiamine (vitamin B1) may be 25 - 30 mg/kg diet on a wet weight basis or approximately 100 - 120 mg/kg diet on a dry weight basis.

[54] Wallace et al.
[55] Wallace et al.

Whole fish fed to penguins contain adequate levels of calcium. Thus supplementation should not be required under normal conditions. This includes breeding/laying unless there are multiple clutches laid and it is felt that the female may be at risk of calcium deficiency. It has been reported by some institutions that problems have occurred which were felt to be due to a calcium
deficiency. Some institutions thus supplement with additional calcium with no apparent ill effect. However, care should be taken to determine the actual calcium level in the diet (by analyzing the fish) and examining the Ca:P ratio as well as the vitamin D levels, since these nutrients can interact and interfere with the metabolism of each other and, subsequently, deficiency symptoms.

Sodium is an essential nutrient for all animals however; it is thought by some that the requirement for sodium is a special consideration for the development of nasal glands of marine birds held in fresh water conditions. If the penguins are held in salt water conditions, they probably receive enough salt to utilize their nasal glands. Some institutions, with fresh and saltwater environments, supplement penguin diets with salt, approximately 0.25 gr of Sodium chloride per bird every other day, without apparent harm. This topic continues to be debated.

Vitamin toxicities.

Although supplementing some nutrients in an all-fish diet may be recommended, it is possible to include toxicities from over-supplementation.

Fat soluble vitamins (A,D,E,& K) are stored in the body and thus it is possible to feed these vitamins to toxic levels. It is felt that vitamin E is not extremely toxic although recent reports have shown that there may be problems with over-supplementation of vitamin E at 1,000 to 2,000 mg/kg of dry diet. Vitamin K has also been shown to be non-toxic in its natural form (phylloquinone) and the toxic level of menadione (the most available commercial form) is at least 1,000 times the dietary requirement. Vitamins A and D may have toxic effects when fed in excess, however, though definitive vitamin A or D toxicity parameters have not been outlined for penguins.

With vitamin A, chronic toxicity typically results from intakes 100 to 1000 times nutritional requirements for a prolonged period. The symptoms associated with chronic vitamin A toxicity include: alopecia, anorexia and weight loss, general weakness and fatigue, bone changes, hepatocellular damage, excess mucous formation, inhibition of normal keratinization, thickened skin, and dermatitis.

Vitamin D3 is 10 to 20 times more toxic than D2 in many animals. Vitamin D3 is the vitamin form available in animal products and many vitamin supplements. Most domestic animal species appear to be able to tolerate 10 times the level of vitamin D3 they require for prolonged periods of time. Catfish and rainbow trout can tolerate as much as 20 and 500 times their requirements, respectively. Symptoms associated with chronic vitamin D toxicity include abnormal calcification of soft tissues especially kidneys, aorta and lungs.

Formulation of appropriate diets.

When formulating diets for captive penguins, flexibility is needed to account for animal preferences, weight, exercise, physical condition, environment, and behavioral considerations as well as food availability. Thus guidelines for nutrient content rather than recommending specific food items in set quantities is appropriate. The guidelines allow flexibility in diet formulation while assuring that a nutritious diet is consumed.

Nutrient content of the food item also may affect selection of which foods to offer. Ideally, the
items chosen and supplements fed should complement each other in order to offer the animal a diet which meets the nutrient requirements of that animal.
Ideally a zoo would purchase the fish and other species preferred by their penguins in the wild, and feed these in a ration similar to their selection by wild penguins. However, logistical practicalities demand that curators utilize locally available fishes which can be provided in appropriate sizes at the appropriate times of year.
In order to avoid ultimate dependence on one particular food item, it is prudent to offer a variety of items to the animal. If the animal becomes imprinted on a specific food item and if that supply for some reason becomes unobtainable, it may be very difficult to coax the animal to change. In addition, offering a variety of food items will help assure a complimentary nutrient profile in the diet.

Limited information is available on the nutrient content of whole fish fed to penguins. It must be noted when examining the nutrient data for these items, that nutrient content can vary radically among species, among individual lots within a species, among individual fish within a lot, as well as during storage. Thus, published values may/may not reflect the nutrients actually fed to penguins at any one specific time.

Types of fish selected can be chosen for specific nutrient content, availability and price, and for animal preference. It also is wise to consider quality a major factor. The facility holding penguins must make certain their food is of the highest quality. Human quality items should be insisted upon and the holding conditions must be monitored. Any item which, upon receipt, appears to have undergone degradation or shows evidence of thawing should not be accepted.

The following table shows a compilation of data available for a number of food species commonly given to Spheniscus penguins. All values are presented as averages in percent of the item on a dry matter basis (except energy which is presented as Kcal/g dry matter basis)

Nutrient	**Herring**	**Anchovy**	**Mackerel**	**Requirement**
Dry matter (% of fresh fish weight)	27.72	29.7	33.59	-
Energy (kcal/g)	6.33		6.24	4-5
Protein (%)	45.34	55.9	38.43	20-25
Fat (%)	34.00	16.16	39.46	20-30

Calcium (%)	1.66		1.37	0.6 – 2.0
Phosphorous (%)	0.39		0.34	0.3 – 0.4
Vitamin A (IU/gm)	56			1.67
Vitamin E (IU/gm)	0.034			0.4

It can be seen that to formulate a diet which meets the probable nutrient requirements, a good mix of fish should be offered. It is important to be aware of the possible seasonal nutrient variations between different species offered, as well as to take into consideration the size of fish. Penguins generally accept only whole fish, therefore larger fish are often difficult to feed to many of the smaller penguin species. Of the fish presented, any will meet the protein requirement. However, in order to provide enough fat and energy, a combination of low fat fish with high fat fish is optimal. The ratios can be changed depending on availability and bird intake.

Vitamin E and thiamine as well as any water soluble nutrients such as trace minerals may leach out of the fish while thawing, therefore in order to ensure provision of adequate nutrients, it is advisable to supplement the fish diet with these supplements. Please refer to the section on nutrient supplementation.

It is possible to achieve the nutrient levels outlined above by offering a diet consisting of a variety of food items. Fish that are commonly used by institutions housing Spheniscus penguins are: herring (Clypea harengus), sprat (Sprattus sprattus), whiting (Merlangius merlangus), mackerel (Scomber scombrus) and scad (Trachurus trachurus).
One should be aware, however, that birds achieving a high speed to capture their prey (like penguins) show a poor digestive efficiency. They show a specialisation in their choice of food / fish. If food / fish is chnaged, there will be a decrease in digestive efficiency.

Nutrient supplementation.

As mentioned earlier, storage can affect the nutrient content of fish. The greatest concern with respect to this, is the loss of thiamine (vitamin B1) and vitamin E. Some species of fish contain the enzyme, thiaminase, which destroys thiamine during storage. Species thought to have recognizable quantities of thiaminase are all species of Cyprinidae (carp, rudd, tench, minnow), herring, smelt, bream and clams. Sprats are thought to be free of thiaminse, while there is disagreement or doubt about mackerel and whiting.
Symptoms of thiamin deficiency include neurological disorders, edema and anorexia.
Marine products also contain high levels of poly- and mono-unsaturated fatty acids. Vitamin E is recognized as an essential nutrient due primarily to its role as a fat-soluble, non-enzymatic antioxidant.
One primary factor that increases vitamin E requirements is dietary levels of polyunsaturated fatty acids. The levels of these acids found in unsaturated fish olis can dramatically increase the need for supplemental vitamin E, especially those fish oils that have undergone rancidity

or those in the process of oxidative rancidity prior to being consumed. Oils from raw fish are likely to exhibit some degree of rancidity prior to being consumed.

Considering the value of penguins and our mission of captive propagation, most institutions supplement the diets of their penguins with vitamins and minerals. It is felt by many that, if there is a variety of high quality fish fed and if those items are stored and thawed properly, there may be no need for additional supplementation, other than vitamin E and thiamine. However, most institutions supplement with a variety of additional multi-vitamins and minerals. This is presumably to provide for any possible losses due to thawing or to ensure these nutrients are always present on a daily basis regardless of fish offered.
The supplements can be provided in pill form, hidden inside the fish and hand fed to each animal. Most institution employ this method. Other institutions inject the fish with a vitamin supplement slurry through a reptition-injector which can be set at a specific quantity. Please refer to the comments regarding parent rearing of chicks for notes on considerations during chick rearing.

There are many dietary supplements on the commercial market. Several products have been marketed specifically for marine animals. Because a general supplement like that shown in the following table provides a large number of nutrients in comparison to other supplements and it appears that the levels of nutrients provided in a general supplement are moderate, this type of basic supplement (along with additional vitamin E and thiamine and possibly salt), should adequately meet the nutrient requirements of penguins.

Recommended multivitamin / mineral supplement per animal every day:

Vitamin A	1250 IU
Vitamin D	100 IU
Vitamin C	15 mg
Vitamin E	3.8 IU
Folic acid	0.1 mg
Thiamine	0.375 mg
Riboflavin	0.425 mg
Niacinamide	5 mg
Vitamin B6	0.5 mg
Vitamin B12	1.5 mcg
Biotin	2.5 mcg
Pantothenic acid	2.5 mg
Vitamin K	1.25 mcg
Calcium	25 mg
Phosporous	25 mg
Iodine	0.0375 mg
Iron	4.5 mg
Magnesium	25 mg
Copper	0.5 mg
Zinc w/gluconate	3.75 mg
Manganese	0.625 mg
Potassium	9.5 mg
Chromium	2.5 mcg

Molybdenum	2.5 mcg
Selenium	2.5 mcg
Chloride	8.5 mg

Vitamin A: Since complete fish contains considerable quantities of vitamin A, many supplements which contain additional vitamin A may put the animal at risk of toxicity . The best option would be to use a vitamin supplement which contains no vitamin A. This option is not available in multivitamins at this time.
In case “empty fish” is used the use of a Vitamin A supplement should be seriously considered.

Vitamin D3: Since D3 levels in fish, although quite variable, can be considerable, the supplementation problem is also one of possible excess quantities in the diet. Again, the option may be to decrease supplements containing vitamin D3, and again, this option may not be available in multivitamins at this time.

Vitamin E: Here the concern is for adequate levels in the diet to account for destruction in frozen fish. Most multivitamins contain lower than recommended level of 0.4 IU/g (dry matter basis) of vitamin E. Therefore, additional supplementation of Vitamin E is suggested. The recommended supplementation schedule is 100 mg per bird every other day for birds consuming 500 grams of fish daily.

Thiamine: Thiamine is provided in adequate quantities in some multivitamin supplements. The recommended supplementation schedule is 250 mg of thiamine every day per bird for birds consuming 500 grams of fish daily.

Relation to Mazuri fish eaters tablets:

Vitamin A	10.000 i.u.
Vitamin D3	2000 i.u.
Vitamin E	160 i.u.
Vitamin B2	1.2 mg
Vitamin K	0.5 mg
Nicotinic acid	5.7 mg
Pantothenic acid	6.7 mg
Folic acid	0.16 mg
B1	50 mg
B6	1.5 mg
Biotin	0.0.28 mg
Vitamin C	47 mg
B12	1.5 mcg

Special considerations.

Marine fish versus fresh water fish.

Historically, most penguins have typically been fed marine fish. Given current problems with commercial fish availability, it is becoming more common to offer fresh water fish as food to penguins. This trend may continue as commercial hatcheries increase in number while the yield from marine fishing declines.
In general, however, it is not recommended to feed fresh water fish to penguins, without giving it a reason. The problem may not be the fresh water fish, but the fact that the penguins must adjust to an extreme change in fish in general (see above).

The reported differences include the following:

Protein.

It should be noted that protein content can be overestimated in marine fish due to analysis methodology (Kjeldahl) and the contribution of non-protein nitrogen present in the cells for osmoregulation, especially in fish such as herring. Also marine invertebrates contain more free amino acids than the vertebrates which may increase the availability of these nutrients. However the overall amino acid composition of fish and invertebrates is generally similar to other animal protein.

Cystine and methionine.

Cystine and methionine, the sulfur amino acids which are important for feather production, may be the limiting amino acid in marine fish. Crustaceans may be lacking in cystine; however it is usually plentiful in fresh water fish.

Fat (lipid).

Fish lipid is highly unsaturated. It has been reported that freshwater fish in general contain twice as many ClO and C18 fatty acids but less than half the quantity of C20 and one seventh the quantity of C22 fatty acids than marine fish. Krill is high in unsaturated fatty acids and squid has 2-4 times the content of hexanoic and pentanoic fatty acids.

There are data appearing which discuss the topic of omega fatty acids and possible special requirements for these fatty acids for fish eating animals. This subject is continuing to be investigated and specific requirements for penguins have not been determined at this time. However, a short discussion is still in order.
It is true that it is crucial to provide the essential fatty acids in the diet. Omega 3 fatty acids may be important in the diets of penguins. Krill and herring have substantial quantities of eicosapentaenoic acid (EPA) while krill, herring, rainbow trout and squid possess substantial quantities of dihomo-g-linolenic acid (DHA).
The contribution of the omega 6 fatty acids also differ. Possibly these may be a factor since some of these can be converted in the body to other fatty acids.

This protein (amino acid) and lipid (fatty acid) information serves to stress the importance of offering more than one type of food item to penguins at any one time. It also should be emphasized that as more information is generated on the nutrient content of food items consumed both by the free-ranging and captive penguins, actual requirement estimations should be refined.

Reported problems.

Anchovies.

Demoic acid has been found in anchovies. Demoic acid is a toxic by-product of algae which was found in anchovies in 1991.
Additionally, it has been reported that anchovies, because of their size and fleshiness, have soft bellies upon thawing and if not fed very quickly after thawing may cause problems, particularly histamine responses. These cases have not been documented and remain anecdotal at this time.

Fresh-water fish.

The feeding of live fresh-water fish may cause serious complications for (young) Spheniscus penguins, i.e. in the infection with Trematodes (Cotylurus pileatus). Being not a regular parasite in Spheniscus penguins, these birds appear to be highly susceptible. The infection causes birds to produce blood stained faeces and death.
In case of such an infection, Droncit (praziquantel) can be used very effectively as treatment.[56]

Parent rearing of chicks.

The most important aspect of nutrition and parent-rearing of chicks is to offer enough fish to the parents to adequately feed the chicks and themselves. Thus the quantity of fish offered to parents rearing chicks should be increased. It appears that during chick rearing, parents should be fed ad libitum.

Although the actual levels of fat and energy in the diets of free-ranging penguins are unknown, it appears that they consume an array of fish species containing varying levels of nutrients. In particular however it was noted that large quantities of anchovy were consumed by some free-ranging penguins.
Anchovy, a common food item for some penguins in the wild, is not a particularly energy-rich fish. Krill contain 26 to 65% fat, on a dry matter basis.
This suggests that it may not only be the nutrient content of the fish fed, but possibly more importantly, the quantity of fish fed that leads to successful breeding and rearing of penguins.

Until more is known, it appears wise to feed a variety of whole fish to penguins in quantities adequate to supply energy and protein needs. If problems arise, the method of feeding and supplementing each animal should be reviewed. It does not appear necessary to supply additional fat in the diet. Remember too, that if fat or oil is added to the diet, thereby increasing the energy content of the diet, other nutrients will be diluted.

[56] Bos, J. etc.

There is a concern that if parents feeding chicks are fed their supplements at one time, they may regurgitate that feeding and thus all the supplements to the chicks, resulting in a potential toxicity problem for the chicks. To remedy this concern, some institutions spread out the supplementation schedule offering supplements in many fish, several times per day; others eliminate supplements altogether; and some make no changes.

Hand-rearing.

Please refer to the husbandry section for hand-rearing schedules and protocols.

Spheniscus penguin husbandry manual

First edition

Edited and compiled by the Penguin TAG

A publication of the EAZA

Section B: Management in captivity

Health

Health

Introduction.

Penguins, like all wildlife, are adapted for survival. Initial symptoms or signs of illness may be hidden or inconspicuous, unless the condition is acutely serious. Therefore, it is imperative that staff working with penguins be highly-trained and attuned to subtle changes in behavior and physical conditions. Though aspergillosis, avian malaria and bumble-foot play a major role in penguin mortality and morbidity, zoo clinicians should keep in mind that penguins experience a wide range of infections and conditions which can go undiagnosed.

The most commonly reported behavioral manifestations of most illnesses are inappetence, lethargy and isolation from the group. These observations, in combination with other indicators such as respiratory difficulty, weight loss, plumage condition, coloration of the mucous membranes, fecal appearance, etc., can lead to early diagnosis. Although there may be a long list of clinical signs for any given disease, all may not be present in every case. Some of the parameters used to detect illness may also be an indication of normal cyclic patterns, i.e., moult or breeding, therefore all behavioral, physical, and seasonal conditions need to be considered.

Some illnesses or injuries may necessitate isolation of an individual from the colony for treatment. However, considering the social nature of penguins, one should always attempt to provide conspecifics as company during the period of treatment or convalescence. Alternatively, conspecifics can be kept within visual and vocal range of an isolated individual. This approach to decreasing the stress of isolation should be weighed against the potential of illness transfer to an unaffected individual if pathogenic organisms are involved.

Diagnostic techniques.

The most important factor for successful diagnosis and treatment is the early detection of abnormalities by the animal care staff. A solid working relationship should be established between animal care and veterinary staffs to promote early intervention and so that both groups can learn from each episode of illness. Records should be maintained on each illness including initial symptoms (clinical signs), diagnostic techniques, treatment and response to therapy. The following diagnostic techniques can be used depending on the signs present and the technology available:

observations of the birds in an undisturbed state
physical exam
blood analysis - CBC, chemistry panel (designed to include uric acid and urea), serology
culture - tracheal, oral and cloacal
cytology- fecal exam

radiology - foreign bodies, granulomas
endoscopy

Observable manifestations of illness.

The following are important parameters in observable abnormalities:

* inappetence or decrease in appetite
* lethargy or increased irritability
* isolation from group
* plumage condition
* observable weight loss
* lameness
* dehydration
* abnormal feces

Other parameters may include a change in posture, lying down for extended periods at abnormal times, changes in respiratory character (open-mouthed breathing, extended neck, increased air sac distention in neck, increased rate and depth of respiration), loss of vocalization, increased coughing or sneezing, changes in fecal character, limping, or decreased swimming activity.

Physical exam abornamilites.

Each bird should be weighed regularly, including pre- and post-moult periods. This allows for comparison during periods of illness. It is useful, when available, to have weights recorded during different seasons since an individual penguin's weight may vary throughout the year, e.g., pre- and post-moult, nesting period, etc. Parameters which may be important include:

* body weight
* palpable and visual signs of weight loss in areas such as the keel, back, pelvis and shoulders
* pale mucous membranes
* difficult breathing (dyspnea)
* decreased response to handling
* depression
* feet abnormalities

Common disease problems.

Aspergillosis.

Aspergillosis is one of the most commonly reported illnesses in penguins. It is a fungal disease caused by a common mould fungus, A.fumigatus or less commonly A.flavus.
This fungus has a world-wide distribution from Arctic to Antarctic and may be present in any rotting or moist vegetable material; spores may be present in sacks or other containers which have become damp or have held materials of this kind. The fungus is much more frequent in moist surroundings and unlike some other fungi, is not usually encountered in dry conditions. The disease results from inhalation of spores of the fungus which become lodged either in the lungs or in the air sacs. In susceptible birds, the spores grow rapidly and within 10 days can produce large tubercle-like nodules. In the air sacs which are usually more moist the fungus produces mycelium and they become lined with a thickish dirty white felt or fungal hyphae. The hyphae permate the air sac walls which eventually develop a cheese-like consistency.

In susceptible penguins the course of the disease is rapid: within a few weeks birds will breathe with a gasping wheeze and within a few days will be dead. There is abundant evidence that many penguins which become acclimatised and survive for long periods have at some stage suffered from aspergilosis and recovered. Regressive lesions are often found in penguins which have died from other causes. Such lesions are usually located in the lungs, but may be found in abnormal sites such as kidneys, bowel and liver. Thus, good condition at the receiving end, could have beneficial effect. [57]
Bird to bird transmission does not seem to be an important factor in Aspergillosis.

High standards in exhibit air quality are an important consideration in prevention of the disease. Aspergillus is often commonly found in many areas and can exist in low numbers without causing problems if the birds are adapted and healthy. Problems may occur if one or more of the following parameters are present with stressed or debilitated individuals:

- social incompatibility
- poor moult
- extreme weather conditions (heat exhaustion, extreme cold)
- bacterial infections
- introduction of a new aspergillosis species
- change in location, which may expose birds to new fungal species
- substandard air quality, poor ventilation and elevated ammonia levels
- inappropriate, prolonged or stressful relocation
- nutritional stress (malnutrition, thiamine-deficiency)
- prolonged anti-biotic and cortico [?] treatment

[57] Fiennes

Symptoms: Open-mouth breathing, coughing, foul smelling breath, loss of vocalization, inappetence, lethargy, standing with the head tucked under the wing, weight loss, isolation, long periods of lying down.

Diagnostic: Symptoms are often nonspecific. Lung sounds are rarely detected in Aspergillosis and are more common in malarial pneumonias. If heard they are ususally drier than malarial associated rales. The vet must be careful however to distinguish the dry rales of aspergillosis from the dry sounds heard in a stressed bird during handling.
Complete blood count (CBC), chemistries, cultures (throat or air sac), radiology, serology fungal titer (difficult to differentiate acute infection from exposure) may be helpful.

Prevention: As aspergillosis can be stimulated by environmental stress, strong attention must be paid to reducing moist environments, improving ventilation, lighting regimes, temperatures and the availability of nest-boxes.
Post- shipment birds seem to be especially vulnerable to aspergillosis. Therefore, strong consideration should be given to shipping birds together, the conditions in the new enclosure and the quarantine setting.

Treatment**:** Since the ability to definitely diagnose aspergillosis in the early stages is often difficult, the approach to diagnosis and therapy must often be individually tailored by the veterinarian. The appropriate drug used and its dose should be determined by a veterinarian working with the bird staff and when appropriate, by consulting experienced veterinarians in the field.
The most important consideration when an aspergillus case is diagnosed is to evaluate the penguin facility and husbandry program in detail to identify areas which might be preventing birds from maintaining adequate resistence to infections. The possibility of other underlying diseases must also be considered. [58]

Symptomatic support: for rehydration, fluids may be given orally by tubing or subcutaneously. Fish gruel can be used for nutritional supplementation for short periods of time; weight loss should be closely monitored.

Antifungal : systemic; nebulization; intratracheal. Drugs utilized with some measure of success include:

* itraconizole - oral
* fluconizole - oral
* Ancoban - oral alone or in combination
* Amphotericin - intratracheal directly into affected air sac as well as nebulized
* Enilconizole - nebulize

[58] Stoskopf

Antibacterial: (for concurrent bacterial infections)

Prevention:

* Fungal vaccination - efficacy not proven
* Proper air quality
* Avoidance of complicating factors and stress
* Regular fungal air cultures in exhibit area

Historically, many major outbreaks of aspergillosis have occurred after major environmental changes. Early intervention may yield a better survival rate in Aspergillosis cases. It has been observed that serious outbreaks may follow a common die-off pattern with acutely affected birds expiring in a "bell-shaped curve,"t as shown by a periodic loss of individuals initially, a central period of increased loss followed by a period of decreased loss. This period of decreased mortality is often followed by another rise in mortalities targeting birds that were chronically affected. Birds may have severe air sac granulomas present. If it is necessary to shut down the air filtration system in a penguin exhibit it is recommended to run the system for at least a week after restart as a preventative measure for Aspergillosis. Preventative treatment for Aspergillosis pre- and post-transport is an option to consider before transporting penguins.

Malaria. [59]

Avian malaria is caused by several species of Plasmodium, which is a blood parasite. It has a worldwide distribution and is present wherever the vector, the mosquito (mostly of the genus Aedes, Culex or Anopheles) , is present. The parasite is not very pathogenetic in birds that have evolved with the parasite, often causing no clinical signs. However, it causes varying degrees of pathology and can cause high mortalities in species of birds that have not evolved with the parasite. These are species that come from areas without the vector, such as very cold, dry or windy environments,like penguins. Avian malaria in penguins is caused by Plasmodium relictum and elongatum.
Most cases of penguin malaria therefore occur in animals that are or have been housed outside. The mortality rate from malaria infection is high therefore a regular screening program of birds in outside facilities is recommended. Malaria can occur anywhere in Europe and therefore is not restricted to a typical environment in this region.
Avian malaria seems to affect mostly young, first year birds, as well as very old ones. This indicates an immunity of some kind is involved. The disease has little potential for spread from penguin to penguin, but comes from reservoir birds to penguins. House sparrows, robins and several other small passerines act as a reservoir. It is carried by the mosquito.
The mosquito takes a blood meal from the reservoir host and ingests micro and macro gametocytes. These develop into oocysts in the gut of the mosquito. The oocysts then produce numerous sporozoites, which migrate to the salivary gland of the mosquito. These are injected into the blood stream of the penguin when the mosquito is taking its next blood meal. The cycle through the mosquito takes approximately 13 days.

[59] Stoskopf and Petit

The sporozoites, on entering the blood stream of the penguin are picked up by macrophages and reticulo-endothelial cells where they develop into merozoites and then further on to schizonts.Schizonts break apart shedding several more merozoites, which sets up the asexual tissue phase of the infection. After several cycles through the tissue, the merozoites are picked up by the red blood cells and develop into trophozoites and then on to either the sexual stage of gametocytes or the asexual stage of schizonts. There are, therefore, two cycles going , a tissue phase and a blood phase. Within the blood phase, there is a sexual cycle and an asexual cycle.

Symptoms: The clinical signs of disease are caused by the tissue phase, causing tissue damage. There is not enough destruction within the red blood cells to cause clinical anaemia. The clinical signs (usually 2-3 days before death) are lethargy, inappetence, ingestion of sticks, feathers etc., dyspnea, respiratory distress, anoxia, regurgitation, stereotypic behaviour, pale mucous membranes, solitary behaviour, acute death without signs.

Diagnostic: Parasites can sometimes be demonstrated on thin blood smear within erythrocytes. However, failure to detect parasites on thin smears should not automatically rule out infection. Parasitemias in penguins are routinely very low, and it is often necessary to examine over 400.000 red cells to locate a single parasite.
The diagnosis on live birds is extremely difficult. For this reason post mortem diagnosis is of great importance. Gross pathology will reveal a very enlarged spleen, a swollen liver and congested and extremely edematous lungs. Impression smears from these tissues often reveal schizonts. Schizonts are present in several tissues throughout the body. Histologically, the lungs have an acute sever interstitial pneumonia with schizonts present.

Treatment: Infected birds should be immediately placed on anti-malarial drugs. Chloroquine alone may be used but most zoos treat with a combination of chloroquine (against the blood phase) and primaquine (against the tissue phase). An example of treatment:
Initially chloroquine 10 mg/kg, at 6,18, 24 hours: chloroquine 5 mg/kg plus primaquine 1 mg/kg. Daily, for 9 days: chloroquine 5 mg/kg plus primaquine 1 mg/kg

Prevention: Either do not keep penguins outside during mosquito season or bring them inside before mosquitos emerge in the evening. If neither of these options is possible, test for malaria regularly. Environmental actions aiming at avoiding mosquitos is crucial. For instance:

- the use of fans to circulate the air in outdoor exhibits
- water sprays
- selection of exhibit site (cool area, no stagnant water)
- plantation of walnut
- removel of overhanging branches. These seem to encourage mosquitoes

Various zoos, though a minority, have developed prophylactic drug programs. Chloroquine is rarely used; Pyrimethamine is used (10 to 12,5 mg/bird, once or twice a week), or Primaquine (1-2 mg/kg are given once a week to once a day). These drugs are given from April / May to October.
Prophylaxis is only possible in case the birds are individually identified and individually hand-fed.

However, the results of these programs need to be tested in the long term to prove whether they are really effective. Zoo managers and keepers should be aware of the disease and should take it into consideration especially in case of sudden deaths during the summer months.

Pododermatitis (bumblefoot).

Bumblefoot or pododermatitis is a bacterial infection of the foot usually considered to initiate in the damaged epithelium of the plantar surface. Foot problems are common in many species of birds. Penguins, like other birds, may be predisposed to pododermatitis by the following factors:

* change in normal behavioral patterns (decreased swimming; sedentary)
* prolonged standing on hard, abrasive surfaces with excessive moisture, and fecal contamination.

Once the epithelium becomes compromised, secondary bacterial invasions may occur, resulting in deep soft tissue infections. Osteomyelitis and deep granuloma are possible sequelae.

Initial examination should include evaluation of:

* attitude and posture - lying down
* walking - presence of limp
* foot exam - pad ulceration/scab formation
  - epithelial thinning
  - laceration/puncture
  - drainage
  - swelling
  - increased heat, redness
  - discomfort

Treatment is often geared to three areas:

* protection of the area from further damage
* systemic and local treatment
* prevention

Many treatments for penguins are similar to those utilized in raptors. The original lesion may be the result of bacterial infection through a puncture wound or soft tissue damage in relation to pressure necrosis.

Treatments that have been used include:

* systematic antibiotics - used with presence of swelling, heat, or drainage.
* local antibiotics with or without DMSO (it should be noted that chronic exposure to DMSO in a bandage form can affect skin quality).

* surgical removal
* cryotherapy
* chronic wrapping used in conjunction with various ointments accompanied by intermittent debridement of devitalized tissue.

Historically, bumblefoot treatments have cycled in popularity. The results may differ dramatically depending on the experience level of the staff but all have one characteristic in common. While there is often initial improvement with many of the techniques, there is also a tendency for reoccurrence once therapy is discontinued. Since most treatments involve wrapping the affected feet, it is helpful to provide padding to minimize pressure on the wound site. If the wound site is not surgically closed, the area should be kept moist to encourage granulation. These parameters have been approached utilizing gauze, ointment, vet-wrap and waterproof tape or booties made from soft material. Healing efficiency can also be improved with proper debridement and the use of hydroactive dressings which may retain moisture better than gauze and ointment. Long-term preventative measures should be geared toward encouraging swimming and avoiding rough, wet surfaces that retain contaminated water.

Preen gland infections.

Diagnosis is based on the presence of an enlarged, swollen gland containing purulent or caseous material. Early diagnosis and treatment may prevent impaction.

The specific etiology of preen gland infections is unknown but, it is suspected there may be many potential factors including:

sedentary birds, with decreased swimming patterns
poor plumage; non preening birds who do not moult regularly
inadequate diet components

Cultures of preen gland fluid have contained numerous bacteria. *Candida* is commonly cultured even following antifungal therapy. Histologic examination of the gland suggests the possibility of vitamin A deficiency although supplementation of vitamin A has not resolved the condition. While a limited number of birds may respond to symptomatic therapy such as flushing the glands or infusing it with Chloro-elase, surgical removal may be needed to avoid eventual rupture and secondary septicemia. It is important to encourage birds, particularly those who are nesting, to swim regularly as a preventative measure.

Gastrointestinal disease.

Penguins have intestinal diseases similar to other birds; diagnosis and treatment are also similar. Problems have included:

* regurgitation
* foreign body ingestion of coins, plant material, feathers, rocks and pieces of wood, occasionally resulting in perforation of stomach. Radiography and endoscopy may serve as diagnostic tools for foreign objects.

* gastric ulceration: bacterial, yeast
* bacterial enterocolitis- salmonella, and other bacteria
* cloacitis, prolapse, fecoliths

Pulmonary disease.

While aspergillosis is probably the most common problem involving the respiratory system, there are occasionally air sacculitis problems that are primarily related to bacterial pathogens. In some cases, it is difficult to distinguish between primary or secondary aspergillosis involvement. Upper respiratory diseases also include sinusitis. Cultures and antibiotics used should be tailored accordingly.

Renal disease.

The diagnosis of severe renal disease by serum chemistries is difficult. In some cases, the uric acid levels are elevated. Fluid supplementation either orally or subcutaneously may be helpful although systemic or visceral gout may result in rapid death with very few prior symptoms. On post-mortem there may be bright white flecks of uric acid deposits in the muscle, air sac or serosa. Uric acid crystals can be visualized under polarized light. For histologic verification, tissues should be placed in alcohol since formalin will dissolve the deposits.

Articular gout also occasionally occurs in penguins. Lameness is the primary clinical sign. Nephritis may be present without clinical signs of gout. Amyloidosis has also been seen.

Nervous system.

Incoordination and "stargazing" are occasionally reported as clinical symptoms. Thiamine deficiency has been implicated as a cause when fish quality is compromised. Non-specific signs of central nervous system involvement should suggest as possibilities those disease problems seen in other species, including thiamine and viral encephalitis.
Penguins are also subject to central nervous system infections due to aspergillosis. These birds are usually robust and feeding when first presented but may show severe visual deficits and/or varying degrees of ataxia. Early in the disease it may be difficult to differentiate it from inner ear infections. The disease is progressive and as the fungal lesions in the brain enlarge, neurological deficits and seizures become more severe. [60]

Reproductive system.

Complications in this area are not common, although egg binding is always a potential problem during the nesting season.

[60] Stoskopf

Trauma.

Problems with trauma include: bill injuries, punctures, lacerations, eye lesions, leg injuries, toenail damage and hemorrhage and fractures of the humerus from handling.

Treatment is similar to other species. Excessive hemorrhage of the bill or toe nail may require compression, bandaging, or cauterization. Care should be taken when using silver nitrate around mucous membranes to avoid excessive chemical burn of the soft tissues. If hemostasis is achieved using silver nitrate, it can be neutralized with saline. Superglue has also been used to cover small wounds or stop low pressure hemorrhage. A weak Betadine solution can be used to flush wounds after injury and during therapy.

Lameness.

Limping or lameness may be acute or chronic and may occur for a variety of reasons, including developmental anomalies, trauma, infection, and gout. Some birds with sore feet fail to stand and should be differentiated from birds with systemic disease, who may also avoid standing. In cases of traumatic foot injury, the individual may be held within a small, contained area for a few days. Diagnostic techniques are similar to other species.

Skin anomalies.

Uncommon in enclosed facilities, parasites such as fleas, lice, ticks, and mites, may be seen in wild birds or those maintained outside. Treatment includes dusting with pyrethrin products, Sevin dust (5% used lightly), or the use of Ivermectin where appropriate.

Excessive horny layers on the bill develop with age and are normal. When they reach a point of growth they normally break off on their own, causing no problem.

Moulting

Abnormal, inconsistent or incomplete moults have been noted in various species under different circumstances. Birds from the wild, or those recently acquired from another institution, may skip a moult the first year in captivity or at a new location. Moult could be affected by illness in an individual. Theories as to why moult problems have occurred have included:

* Light cycle
* Light intensity - coverage throughout exhibit
* Light spectrum - % UV, type, natural
* Nutrition - weight gain, vitamins, protein components - fatty acids
* Humidity

The potential role of circulating thyroid and hormone levels have also been investigated. Treatment with medroxyprogesterone compounds has been shown to induce or speed up moulting though there is some concern that this is symptomatic relief rather than a true cure.

Timing of its use should coincide with the peak portion of the light cycle in the wild.

Some improvement has been seen in facilities that have increased light intensity and spectrum however investigations related to the various factors are still ongoing. Timing of moult should be considered when relocating birds to a new facility. It is important that detailed records be kept in relation to moulting abnormalities as further research is needed in this area.

Chick-related problems.

Newly-hatched penguins may present a number of problems not encountered in the adults.These concerns include:

* yolk sac infection or retention
* enteritis
* septicemia (any age)
* poor appetite
* dehydration
* constipation
* hypothermia
* hyperthermia
* weakness
* trauma

Early treatment must be based on the caretakers' observations and intervention must be rapid. Initial signs of chick morbidity may include lethargy, inappetence, dehydration and loss of thermoregulatory abilities.
Diagnosis should be based on both oral and cloacal culture results. Treatment should include:

* proper temperature maintenance
* treatment for bacterial and yeast infection
* maintenance of hydration and nutritional intake

Systemic antibiotics may need to be stated during early onset of a problem. Some institutions have improved the speed of intervention in hand-reared chicks by maintaining a consistent caretaker who is responsible for 'round the clock care.

Immobilization.

Individuals without experience may want to contact their colleagues if there are concerns related to anesthesia. Isoflurane is the most commonly used gas anaesthetic. Induction may be accomplished by use of a facial cone with intubation to follow. It should be noted that the trachea bifurcates at different levels in some species and the use of a standard length endotracheal tube can result in unilateral intubation if the clinician is not careful. Maintenance

of anesthesia may be complicated by shallow breathing in the patient, resulting in a chronic excitement phase indicated by swimming like behavior. A smoother plane of anaesthesia may be achieved by assisting ventilation two to three times per minute. Ketamine has also been used although recovery can be prolonged when compared to Isoflurane.

Blood parameters.

It is advisable for each institution to establish their own normal blood parameters for the species maintained, preferably on MedARKS software. Outside laboratories will often have different normal values. Techniques for blood collection include inter-digital, medial tarso-metatarsal, flipper, and jugular. It appears that more facilities are utilizing the jugular because of the speed and ease of acquisition. The amount of blood removed depends on the size of the individual and the tests required. Complete blood counts (CBCs) are usually done by hand with estimates from a smear considered less accurate. Chemistry profiles should include glucose, alt, ast, calcium, urea, and uric acid.

Parameter	Erythrocyts	Haemoglobin	Haematocryt	Leucocyts
Humboldt penguin	3,0 T/l	182 g/l		14,6G/l
African penguin	2,2 T/l	182 g/l	42%	16,3 G/l

Post mortem evaluation.

Any individual which expires should be examined to determine the cause of death. This should include gross examination, histologic examination and cultures (where indicated). Standardized necropsy protocols should be developed within each institution.

Spheniscus penguin husbandry manual

First edition

Edited and compiled by the Penguin TAG

A publication of the EAZA

Section B: Management in captivity

Population management

Population management.

Humboldt penguin

Nowadays, the Humboldt penguin is regarded as vulnerable according to the new IUCN criteria. The species is included in appendix I of CITES since 1981.
In Peru, governmental authorities consider that the Humboldt penguin is in danger of extinction. In Chile the Humboldt penguin is considered vulnerable.

Historical distribution.

Essentially no definitive information exists regarding their natural history or numerical status, past or present. R.C.Murphy in his authorative work of 1936, suggests the penguins were previously abundant and the noted British ornithologist A.W.Johnson (1965) stated that the species formerly was found in the waters of the Humboldt current in the hundreds of thousands.
Therefore, it is assumed that the world population of Humboldt penguins in the middle of the nineteenth century could have been in excess of a million birds.
By the time Murphy published his work in 1936, the population decline of penguins was already very evident. The initial decline began around the 1850's with the intensive and destructive exploitation of the guano islands of Peru. Guano (bird dropping) was removed for use as a fertilizer. This disruption of their breeding habitat represented a long-term change that decreased nesting quality, and consequently had a negative impact on their breeding success. [61]
According to Murphy the northern limit of the species was then Punta Aguja and Sechura Bay, with penguins migrating during certain seasons northward to the latitude of the Gulf of Guayaquil (ca.3ºS). In Chile the breeding range of the species was from the Peruvian boundary south to Algarobbo (33º21'S), Valparaiso, spreading in winter south to Corral (39º50'S). Hellmayr reported in 1932 a small island in Algarobbo (at present known as Isla Pájaros Ninos) as the most southerly colony of the species.
Johnson reported in 1965 that the species occurred along the coast of Chile from Arica to Corral and nest from Pupuya islet northwards.[62]

Population trends.

In Peru the population was in 1981 estimated to be 9000 birds.
The 1982-1983 El Nino (see below) reduced the numbers in Peru to 2100-3000. The latest estimate (1996) is of 5500 birds.
In Chile, in 1982 there were 10.000 – 12.000 birds. After the 1982-1983 El Nino, the population there decreased to 3080 birds.
By 1985 the number of birds in Chile was estimated at 10.000, decreasing again to 5000-6000 in 1986.
In the latest census done by Araya in 1995-1996, the population was conservatively estimated to be about 7500 birds. However, more detailed censuses of that period give the following

[61] Hays.
[62] Penguin Camp document, 1997

numbers: 8850 in Chile and around 4200 in Peru. [63] It is believed that the current total population numbers between 10.000 and 12.000 birds, after the recent severe El Nino of 1997-1998. However, the results of this El Nino for the penguin population are not known yet.

In general it seems that the population is continuing to decline. Between 1980-1981 (pre 1982-83 El Nino event) and the present, there has been an overall drop of 35% in 15 years. Extinction is likely within 100 years according to the latest computer modeling. However, under some scenarios, a remnant population might remain at Punta San Juan, Peru's largest penguin colony.
The primary causes are low reproduction success in Chile (0.4 fledglings per nest per year at Chanaral, as compared to about 1.4 at Punta San Juan) and the high rate of mortality due to entanglement in fishing nets.

In determining numbers of birds, however, in some cases surveyors are basing their numbers upon nests, and others on counts of individual birds. In addition, taking accurate censuses can be very hard due to the inaccessibility of breeding sites (rough terrain and sea, no roads etc.), the absence of birds (due to foraging) and the absence of a clear breeding season. An extensive data base collected by CONAF for Pan de Azucar Islands and observations made by several researchers has shown that great fluctuations occurred in numbers of birds on the colony, decreasing to ca. 50% in winter with respect to the summer.

Threats.

The main threats to the species were and are:

Climate. Heavy rain in some regions where it is not common, causes nest desertion with the total loss of eggs and/ or chicks. This is independent of rains due to El Niño.

Possible decline in prey species by overfishing resulting in a drop of prey availability. Additional studies are needed.

Drowning by net entanglement. A high number of Humboldt penguins is being caught by fishermen in gill nets in some localities such as Punta San Juan (Peru) and Central and Northern Chile.
Based on actual data a yearly average of 342 penguins die by entanglement (2.85%); given the limited nature of the data collection 5-7% may be the reality. For this reason, entanglement is a primary threat to Humboldt penguins, though more additional studies are needed.

Hunting for human consumption. Adults are still being hunted (mainly Peru and northern Chile) and eggs collected for human consumption and baiting purposes. Egg collection by fishermen and tourist activities also provoke nest desertion.

[63] Peru: Punta San Juan 3400 and Isla Pachacamac 800. Chile: Isla Pan de Azucar 1750, Isla de Chanaral 2500, Isla Pajaros 1000, Islote Cachagua 2000 and ex-Islote Pajaro Nino 1600. See: Cheney

Human interference due to tourism and disruptive effects derived from scientific work and ringing activities.

Loss of nesting sites due to guano exploitation by large-scale mining. Where burrowing into soil or guano is impossible, the birds seek shelter in sea-caves, among jumbled boulders or under vegetation. Those nesting in the open, in unsheltered scrape-nests,suffer extremes of temperature, exposure to heavy rains (Chile), more predation and more intense intra-specific fights and disturbances.

Marine perturbations due to El Nino (or ENSO).
Humboldt penguins are endemic to the area associated with the nutrient rich Humboldt Current which flows north along the coast of Chile and Peru. This current is characterized by cold and highly productive waters. The coastal upwelling provides a continuous supply of nutrients which in turn allows high primary productivity to be available for the food chain. This abundant food supply supports vast schools of fish and seabird populations.
The ecosystem of the Humboldt Current is affected by the recurrent oceanographic phenomenon known as El Nino. [64]
This phenomenon is an anomaly in the behaviour of the marine current, with an influx of warm water probably from the north, and, as the thermocline sinks, taking the nutrients further down with it, the productivity slumps, even though the upwelling itself does not actually cease.
Normally, El Nino strikes every two to seven years beginning around Christmas time. That is why Peruvians gave it the name El Nino, or Boy child, in reference to the birth of Christ (El Nino effects were first noticed off the coast of Peru).
No one knows what triggers an El Nino. The first indication is a change in the atmospheric pressure in the tropical Pacific, which affects the trade winds. Normally, the trade winds blow from east to west along the equator, piling up warm water in the western Pacific. The ocean there is about 14 degrees Fahrenheit warmer than off the coast of Peru, where upwelling draws water to the surface from the cold ocean depths. This cold water is rich in nutrients and supports major fisheries and large populations of marine mammals and seabirds.
When an El Nino begins the westward blowing trade winds weaken or even change direction entirely, and no longer hold the huge pool of warm water in the western Pacific. Released by the slackening winds, the warm water comes sloshing back toward the coast of South America. In a matter of weeks, the warm water has formed a layer some 80 feet deep, covering the cold, nutrient-rich waters of the region. The warm water evaporates quickly and the equatorial sun, forming huge storm clouds that alter the patterns of atmospheric heating, provoking shifts in the jet streams, and disrupting weather worldwide.
Meanwhile, the warm surface water is poor in nutrients, so anchovies, sardines, and other cold water fish must move to deeper, colder waters to feed. These fish become less available to marine mammals, seabirds, and human fishermen, which must spend more time and energy searching for prey.

The El Nino of 1982-1983 was the most severe in this century, because of its intensity and duration.

Although El Nino causes breeding failure and high mortality among the seabirds, there is evidence to suggest that this phenomenon exerts a selection pressure on the seabird population, favoring the ability to increase rapidly in numbers after each event.

[64] Hays

However, the ability of the Humboldt penguin to rebound from natural aberrations like this is likely to be impaired by the effects of habitat destruction, entanglement, human predation and fishery competition.

Interspecific competition with pelicans.

Predation. There are reports on considerable predation by rats, foxes, dogs and feral cats.

Pollution due to increasing mining, industrial activities and problems derived of urbanization and inadequate planning of growing human activities (recreation, tourism etc.)

Trade. There is no current trade. It has been estimated that 9264 Humboldt penguins have been exported to several zoos in the world within a period of 32 years. This does not include birds which died during capture and transport. Exportation is now prohibited from Peru and Chile.

Recommendations (CAMP document 1997):

1) One of the recommendations in the 1997 CAMP document was to convene a PHVA workshop in Chile in November of 1997 or early in 1998. This PHVA has taken place from 28 September until the 1st of October 1998 under the sponsopship of SERNAPESCA (Servicio Nacional de Pesca, the National Fisheries Service of Chile) and the Conservation Breeding Specialist Group (CBSG).
The purpose of PHVA workshops in general is to bring together biologists and others with relevant expertise in a collaborative effort to assess the extinction risk and develop better management strategies for particular endangered species.
Having listed the factors known to be affecting the Humboldt penguin population, a number of recommendations were drawn up (see p.)

2) A complete population assessment (census) as soon as possible and the timing and methodology used for this assessment must be standardized (e.g. count moulting birds).

3) Protection of breeding locations and enforcement of existing legislation where these penguins breed should be given high priority, including improved funding and support of wardens charged with enforcing regulations.
Though Chilean laws offer significant protection to the Humboldt penguin, in actuality the prosecution of violators of these laws is difficult. In addition marine reserves only include the land areas while the jurisdiction over marine reserves is divided over three agencies, the national forestry corporation (CONAF), the fisheries agency (SERNAPESCA) and the navy.
In Peru, the principal Humboldt penguin colonies are under the legal protection of PROABONOS, the guano extracting agency governing all the guano islands and pensisulas. The harvest of this guano must be regulated in order to preserve nesting habitat and reduce disturbance during the nesting seasons; improved predator control in mainland sites, including maintenance of predator enclosure systems.
SERNAPESCA, CONAF and PROABONOS can do much to reduce the impact of factors as human disturbance, predation and lack of protected burrow-sites by working closely together.

4) Support conservation oriented research including patterns of reproductive success, recruitment into the breeding population, studies of foraging ecology, and studies of migratory behavior.

5) Genetic studies to determine whether Humboldt Penguins from the distributional area have the same genetic background and whether there is continuous mixing of population.

6) Marine reserves should be created around the major breeding colonies.

7) Establish conservation education programs oriented at reducing hunting pressure and by-catch.

8) Husbandry research in order to stabilize captive populations and preclude the need to remove birds from the wild. The long term intention of captive propagation should be to reintroduce juveniles into secure sites in the wild, particularly where local extinction may occur (pending results of PHVA).

9) Investigate incidence of potential hybridization with Magellanic Penguins where the species' ranges overlap.

10) Reduce fish harvests during ENSO events.

11) Recommend enhanced industrial and mining waste treatment efforts in coastal regions where the species occurs.

Recommendations given at the latest PHVA meeting:

1. Conservation and habitat management.

   a) With respect to the unavailability of adequate nests, the working group recommended the creation of articial colonies in places located away from the tidal influence. In addition, actions should be taken towards the protection of native vegetation in those localities, as well as replanting in areas where the vegetation has been destroyed.

   b) Regarding the impact of predators, the group recommended elimination of introduced animals; at the same time, native predators should be captured and set free in areas far away from the colonies.

   c) Recommendations regarding human disturbance primarily were directed to guano companies, mainly in Peru. The group agreed that these companies should perform their guano extraction activities with minimal impact on the bird colonies. In addition, measures should be taken to reduce the negative impact from colonies of fishermen, tourists, and researchers (e.g., fencing protected areas, placement of warning posters that deny access to colony areas). In this context, it is recommended that places where the main penguin colonies are located in Peru and Chile be declared as reserves or marine parks according to the legislation of each country.

   Fisheries Interactions

   a) To address the effects of extractive fishing activities on penguin populations, the group recommended that authorities, fishermen and industries be involved so as to carry out palliative measures to ensure that negative impacts are decreased, especially

entanglement in nets. Among the recommended measures are: the design of artifacts that scare the bids away from nets and encouraging the modification of artesanal fishing, fishing customs and the timing of fishing activities.

b) With respect to competition for marine resources, the group recommended involving the authorities, informing them about the ecological implications of high extraction of one or more marine resources, in this particular case, of the prey resources used by penguins and other protected species.

c) When the group examined human consumption, including the use of penguins as pets, it recommended that educational programs and mass media be used to inform the public of the impacts of these practices on penguin populations. The group also suggested involving fishermen in ecotourism programs, which could help increase the species' intrinsic value, thus avoiding their capture.

d) Because there is a lack of reliable information about the interactions between different fisheries and Humboldt Penguin populations, research focusing on this topic is essential, including penguin foraging patterns, transit routes, behavior near/in front of nets, and effects on the Humboldt Penguin on declines in anchovy populations, among others.

Research and Monitoring

To surmount the challenge presented by different conceptual interpretations of data emerging from population studies, one recommendation was to standardize the terminology to be used. This will permit comparison of the penguins' situation with respect to other resources (e.g., fish populations) with which penguin populations interact. The group recommended a standardized methodology for censusing and monitoring, which is presented in the Group Report.

b) Some of the causes for penguin mortality have been identified, but it has not been possible to quantify them. Among those that deserve attention are entanglement, the El Niflo phenomenon, illegal hunting of chicks and adults and egg recollection.

c) Participants discussed their experiences related to the species' reproductive ecolo(specifically the determination of reproductive success and the factors that affect it, such as food availability, nest quality, and chick mortality.

d) To identify the most relevant aspects of the interaction between penguins and the fishing industry or other human activities, it is necessary to undertake studies aime at determining the species' energetic requirements during key periods of its natural history. In this context, other research items identified included migration patterns, dispersion, genetic structure, re-population and pollution, both environmental and C the individuals themselves.

Legislation and Education

a) Regarding the need for stronger governmental commitment to protect Humboldt Penguin colonies, the group recommended that authorities create special protectio areas wherein fishing is prohibited, such as parks or marine reserves, in those areas that harbor the principal colonies. Likewise, it is essential to generate the political will necessary to implement international agreements regarding the protection of endangered species, as

well as providing the data and resources needed to undertake required actions. It was suggested that, if necessary, a special agency be created, where all nature conservancy activities would be concentrated.

b) With the goal that the general public, especially artesanal fishing communities living close to penguin colonies, become conscious of the need to protect this Vulnerable species. The group recommended targeted formal and informal education; actions to achieve this goal are outlined in the working group report. NGOs can play an important role in the process as well, through communication with governments and the funding of educational and public awareness programs.

VORTEX Models

VORTEX models showed that current rates of reproductive success and survival in Chilean populations of Humboldt Penguin would cause their slow decrease, even without severe El Nino phenomena and human extraction. An increase in the percentage of penguin pairs with successful annual reproduction, or a reduction of mortality, are needed to promote positive growth in the population. Based on the best reproductive rates observed (in Punta San Juan, Peru), Chilean penguin populations could be expected to grow in the absence of additional threats.

If severe El Nino events cause penguin mortality rates of 50%, or even 25%, then the long-term growth of the populations in Peru will be slow (but still positive). The decrease of the Chilean population will be faster *(2.34.4 %* annually, in the absence of extraction by humans) and the species would be projected to decrease in abundance, becoming vulnerable to extinction. An improvement in reproductive success is essential to allow population recovery between El Niflo years.

Intentional or deliberate human-induced penguin mortality (extraction) above I % annually was not generally sustainable in simulated populations. Thus, under present mortality rates, suggested by the workshop as being the most probable, human impact would cause (or accelerate) population decrease, and possibly extinction. If the average annual extraction rate is 5% or higher, the species' rate of decline, even in years without El Niflo is projected to be 2% annually.

It is believed that movement rates between Humboldt Penguin colonies probably are very low. With low dispersion rates between populations, a modest benefit was obtained in some simulations, as penguins from growing populations (in Peru) could periodically supplement those populations in decline (in Chile). However, with dispersion rates above *1%* annually, the potential population growth could decrease due to loss of individuals and its attendant effects on overall species abundance. Thus, high dispersion rates among reproductive colonies do not effectively protect local populations from decline.

It is uncertain if currently available reproductive trends and feeding habitats can sustain Humboldt Penguin populations. However, even if there were abundant and unoccupied habitats, low reproductive success and high mortality rates would prevent the species' expansion into vacant habitat. Similarly, present Humboldt Penguin numbers are not precisely known because the number of individuals that survived the El Niflo Phenomenon in 1997-98 has not yet been established. The simulation model shows that the species is in danger of decline and possibly extinction, even if estimated present

numbers (as well as carrying capacity) are doubled. The main threats faced by this species are not the result of random events that can cause instability and extinction in small populations. Instead, and in the long term, current reproductive rates are not sufficient to maintain population growth under continued high rates of fledgling mortality, adult mortality due to enmeshment. and overall mortality during severe El Nino years.

In conclusion, the predictions based on our best estimates of fertility and mortality in Humboldt Penguin populations indicated a continuous decline of the species, with high probability of extinction for individual colonies, and even entire populations in some cases. To reverse this tendency, the following management strategies are recommendable:

1. Limit extraction of adult penguins (accidental capture in fishing nets) to less than *1%*.

2. Increase the reproductive success of Chilean colonies and increase first-year survival rates.

3. Our ability to understand the threats facing Humboldt penguins, and thus design effective management plans for them, is limited by the uncertainty regarding reproduction and mortality rates, the impacts of El Nino, current population size and the possible variability in demographic rates among reproductive colonies. Whereas management action is currently focused on improving reproduction and survival, additional field studies need to be carried out in such a way that future management decisions are based on refined population-dynamics models.

Success of the PHVA Process

The success of this process relies on a final product in which all participants "win" and are in agreement with, despite different ideas or interests. It is important that any solutions recommended be applied at a local level and that those responsible for management in each territory be responsible for the field application of conservation measures.

Recent field studies.

Peru:

Carlos Zavalaga and Rosana Paredes (WCS) are conducting work on the breeding biology and foraging ecology on birds from Punta San Juan.

J.C. Riveros Salcedo is conducting a long term survey on different colonies along the Peruvian coast evaluating the status of the seabirds, including the Humboldt Penguin.

Chile:

Since 1980, Brauho Araya and Mariano Bernal (1995) have been conducting a yearly census on the main Humboldt Penguin colonies along the Chilean coast.

Between 1988 and 1991 the Chilean Forest Service (CONAF, Corporacion Nacional Forestal) conducted a survey on the conservation of the Humboldt Penguin at Pan de Azucar National

Park. The main researcher was Mr. Hector Oyarzo. Final results are available (in Spanish) in the CONAF III Region (Copiaeo).

During August and March 1992, Mr. Yerko Vilina conducted a study on the reproductive biology of the Humboldt Penguin at Chanaral Island (Vilina 1993). Mr. Arturo Mann studied the parasite fauna of the Humboldt Penguin at Cachagua Islet. Ecto- and endoparasites were described (Mann 1992).

Since 1990, Miss Javiera Meza, CONAF V Region, Valparaiso, has been censusing the colony at Cachagua Islet. During 1990 and 1991 Carlos Guerra conducted a study on the effects of summer and winter nesting on selected life history parameters of Humboldt Penguins from Pan de Azucar Island. (Guerra 1991, 1992). Since 1993 Roberto Aguilar (Univerisdad de Antofagasta, Chile) has been conducting a post-doctoral study on the physiology of embryos and their growth rate in captivity.

Since January 1995 Mariano Bernal and Alejandro Simeone Valdivia, Chile) have been conducting a survey on dynamics and resource partitioning among Humboldt Penguins, Chilean Brown Pelicans and Kelp Gulls during the breeding season at Pajaro Niflo Islet, Algarrobo.

Since 1993 Boris Culik (Kiel, Germany) and Guillermo Luna-Jorquera have been conducting ecophysiological, bioenergetic and behavioral studies of penguins at sea on birds from Pan de Azucar Island. Since 1994, E. Diebold ,et al. (1994) of the Milwaukee County Zoo together with Chilean researchers (B.Araya, A Simeone and M. Bernal) have been conducting a long term survey on the colony of penguins at Pajaros Ninos Islet. The main goal is to enhance the conservation of Humboldt Penguin in the wild and in captivity.

In 1998 Gabriele and Werner Knauf, under the supervision of the Insitute of Oceanography in Kiel, Germany, have been carrying out research on the breeding conditions in the nests of Humboldt penguins.

Captive management.

Generally, where captive programs for Spheniscus species are recommended in the Penguin CAMP 1997, these programs should be treated as integral parts of meta-populations that are managed by conservation strategies and action plans.
Captive populations should be a support, not a substitute for wild populations. In some cases application of “captive technology” (e.g. cross-fostering, artificial incubation, hand-rearing) may be sufficient to allow for species recovery and may prove to be not more cost-effective but more feasible in the long term. [65]

[recommendation for captive breeding from PHVA; moderate difficulty (level 2) is appropriate for the Humboldt penguin due to problems with aspergilosis, temperature and humidity inside the nest, nutritrional factors affecting the high mortality of parent-reared chicks]

[65] Ellis.

The aim of the captive breeding programs in Europe, Japan and the USA must be to manage a population sufficient so as to preserve 90% or more of the genetic diversity of a population for a minimum of 100 years. Consequently, it is not necessary to remove new birds from the wild in the future.
The CAMP document highly recommended a complete estimation of birds existing in captivity. The current numbers are mentioned below.

Species Survival Plan (SSP), North America.

Coordinator:
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USA
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Though the Humboldt penguin was listed as a SSP species several years earlier, in 1987 Patricia McGill was appointed as the species coordinator. The studbook is kept by Gail Perkins of Brookfield Zoo.
During the period 1981 – 1991 the population fluctuated between 160 and 200 birds without any consistent pattern of increase. Though the SSP has never been suffering from any serious inbreeding, during its first few years it has been suffering from successful reproduction not keeping pace with deaths. This, as well as a high chick mortality and a high post transport mortality, resulted in an aging population. In addition, a significant fraction of the population was already entering years of declining reproduction and increasing mortality.
However, as the reproductive success improved since 1990 the population grew from 209 birds in 1990 on to 252 birds in 1992. Due to the fact however that the carrying capacity of the SSP was reached, a breeding moratorium was set in for the period 1992-1995, except for unrepresented founders.
Since 1993 the shortage of space was somewhat relieved due to the response of both new and existing institutions to increase or dedicate space for the species, but in general the program still struggles to find adequate space for a viable population. Since that year the population has gradually increased from 236 to 269 birds on 31 December 1998 in 13 institutions
Projections for maintaining 95% of genetic diversity for 100 years suggest a minimum viable population of about 300 birds. The original challenges of a slow population decline and high mortality have been resolved and from a biological perspective the population is thriving. The critical need to find additional SSP spaces is a high priority.
Apart however from the capacity problem, the SSP population is facing problems related to the aging of unrepresented founders, the identification of sexes, the diagnosis and treatment of aspergillosis and malaria and the presence of some possible hybrids in the population. The need for research, especially on nutrition (supplementation, levels of nutrients) and appropriate and efficient genetic management of colonial birds is of high priority.

European Endangered Species Program (EEP), Europe

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The EEP for the Humboldt penguin has effectively started in 1993. Despite the fact that the population is also faced with a high chick mortality, the population has continuously grown from 899 birds in 1993 (205.178.516) to 1186 birds in 1998 (422.413.351). In this period the number of unsexed birds has dropped from 57% to 30%
The current number of participating institutions is 69. Six percent of them do not match the minimum social grouping of three pairs.
The population is demographically very sound, but from the genetical point of view some bloodlines are over-represented and other founders are poorly or not breeding. Apart from the genetics, this program is also dealing with problems related to sexing of birds and mortality due to aspergillosis and malaria, as well as the lack of research on social behaviour and nutrition. There is a minor problem of hybridization. External marking of birds is often still lacking, and therefore vital pedigree information is sometimes missing. In addition, the population has reached its carrying capacity, and for this reason a core population of 600 birds has been defined. While this core population is encouraged to breed, all remaining birds have a very low or non-breeding recommendation.
The Humboldt penguin is a very popular bird in European zoos (55 zoos in 1993 and 69 in 1998) and doesn't seem to compete in sheer numbers with the African penguin.

Species Survival Plan of Japan (SSPJ), Japan

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The SSPJ for the Humboldt penguin was established in 1991 and the studbook itself followed two years later.
Like in Europe, the species is very popular in Japan: in 1992 there were 904 birds (291.261.352) in 73 institutions, while in 1997 the number had grown to 1309 birds (369.374.566) in 73 institutions.
One of the major issues in the SSPJ, due to the fact that a lot of birds came from dealers in the past three decades, is the fact that the origin of a lot of birds is unknown.

Further inbreeding is occurring in several institutions. The transfer of individuals between institutions with small colonies has not contributed to increased genetic diversity of the population. Moreover, in many cases consanguineous pairs were broken up for transfer, and remaining birds have been subjected to heavy stress and failed to re-pair. For this reason, foster-rearing is a serious consideration.
In addition, the problem of hybridization seems to be more serious than anywhere else in captivity, as Spheniscus species have been housed together in the same enclosures. DNA analysis is therefore urgently needed.
[recent information missing]

In 1996 the Penguin Conference Japan got together and formulated a statement for the conservation of the Humboldt penguin, in captivity as well as in the wild. The recommendations of committee program are:

1.Establish a communication network for the research for conservation of the species as follows:
Secretariat: Penguin Conference Japan (PCJ) Executive office Representative : Masao Furihata

Representatives of the regional captive programs:
The United States : AZA / SSP (Patricia McGill)
Europe: EAZA/EEP (Pierre de Wit)
The United Kingdom : FZG/JMSG (Simon Blackwell)
Japan : JAZGA/SSCJ (Michio Fuikuda)

Representatives of research and conservation in the wild
Chile : Brauho Araya
Peru : Patricia Majiuf (tentative)

2. The network will take the following actions
2.1 Exchange information on the research for conservation of the species periodically and make public when appropriate.
2.2 Plan and practice all the necessaiy activities to suport the research for conservation of the species, including conflicts with fishery, oil dumping, degradation of breeding habitat and other emergent issues.
2.3 Cooperate with the penguin TAGs residing in Europe, theUS and Japan.
2.4 Support the objectives and actions recommended by tile 1996 CAMP workshop held in Cape Town, South Africa.
2.5 Encourage IUCN to designate Humboldt Penguin as "Vulnerable" immediately, as recommended by the 1996 CAMP workshop in Cape Town, South Africa.
2.6 Expand the network with any other people in favor of our aims.

3. Try to accomplish the following tasks to improve the captive conditions of the species
3.1 There are four captive programs for the species in different regions: the North American continent, the European Continent, the United Kingdom and Japan
The species coordinator of each program will make a maximum effort to maintain a maximal genetic diversity and optimal demographic structure in the population of his/her respective program.

3.2 Arrange good educational programs by zoos and aquariums which will increase public awareness of the conservation of the species and its habitat; share materials that are developed among regions.
3.3 Promote biological, veterinary and any other research which will make a significant contribution to the conservation of the species in the wild and in captivity.
3.4 Review the possibility for and potential for consequences of reintroduction to the wild;
3.5 Seek agreement on how to cope with the problem of hybridization in captivity.
3.6 Develop husbandry guidelines for keeping the species in captivity.
4. Try to accomplisli the following assignment in 10 years
4.1 Promote permanent research and conservation activities.

5. These additional clauses come into effect on 28 November 1996.

African penguin [66]

Nowadays, the African penguin is regarded as vulnerable according to the new IUCN criteria. The species is included in appendix II of CITES since ---.[add]
In South Africa the species is listed as endangered in terms of the Nature and Environmental Conservation Ordinance, no.19 of 1974 of the Province of the Cape of Good Hope. This now applies to the Northern Cape, Western Cape and Eastern Cape Provinces. In Namibia, the species has no official legal status.

Population Trends

% Change in Years: There were an estimated 222 000 adults (birds in adult plumage) in the late 1970s, 194 000 in the late 1980s and 179 000 in the early 1990s. This gives a mean annual rate of decrease between the late 1970s and the early 1990s of 1.3 %, and between the late 1980s and the early 1990s of *1.5 %*.

% Change in Generations: Adult survival is estimated to be about 0.90 p.a. Therefore, average life expectancy of breeders is 6.6 years. Mean age at breeding is about four years. This gives an average age of breeders of 10-11 years. Birds have been known to live to more than 24 years in the wild. The overall decrease in breeders between the late 1 970s and early 1990s, i.e. about 15 years or *1.5* generations, was 19.4 %. Therefore, the mean recent decrease per generation is 12.9 %.

Trend over past 100 years: In 1910, there were probably 1.4 million adult birds at Dassen Island. In the mid 1950s, the overall African Penguin population was estimated to be about 300 000 adults. This included 145 000 at Dassen Island, which may have underestimated the population there by as much as 70 000. By the early 1990s, the world's wild population had decreased to about 180000 adults.

World population: In 1991-1994, the world's wild population was estimated to be 56 000 breeding pairs representing 179 000 adults. The number of adults was estimated from the ratio between birds in adult plumage and breeding pairs at Robben Island.

[66] Penguin Camp document, 1997

Regional populations: There has been regional variation in trends in the abundance of African Penguins. In Narnibia, there has been a 30 % reduction since the late 1970s, the most severe declines being south of Lúderitz, where colonies continue to decrease. Populations at Mercury, Ichaboe and Halifax Islands now appear to be stable. In South Africa, numbers fell by 17 % between the late 1 970s and early 1 990s, with especially severe decreases near Saldanha Bay and at Dassen and Dyer Islands. These decreases have been arrested, except at Dyer Island. Three new colonies were established in the Western Cape Province in the early 1980s, and now support about 10 000 adult birds. At islands in Mgoa Bay, the estimated number of adults increased by nearly 30 000 between the late 1970s and the early 1990s, with large increases at St Croix and Bird Islands. The estimated numbers of breeding pairs and adults at localities in 1991-1994 are 55.919 and 178.943 respectively.

Recent field studies.

Breeding cycle: off southern Africa the main breeding season is January to September; most birds moult between October and January. The annual cycle farther north lags this by a few months.
Population surveys: Namibia's Ministry of Fisheries and marine resources (MFMR) counts annually the number of breeding pairs at Mercury, Ichaboe and Possession Islands. South Africa's Sea Fisheries Research Institute (SFRI) monitors the number of breeding pairs at Stony Point are counted by a committee of the local municipality. Port Elizabeth Museum (PEM) counts breeding pairs at Bird Island, Algoa Bay. Other breeding localities are surveyed less frequently by MFMR,SFRI and PEM.

Count of moulting birds are taken at two-weekly intervals by MFMR at Mercury, Ichaboe, halifax and Posession Islands, Cape Nature Conservation (CNC) at Dassen Island, SFRI at Robben Island and nature conservation authorities of eastern capre Province at Bird Island, Algoa Bay. Counts during the peak moult are also made at Boulders by SFRI and at St.Croix Island by PEM.

The relationship between counts of breeding birds and counts of moulting birds, that will enable the adult population to be estimated from counts of breeding birds, is being investigated for Algoa Bay by PEM.

Population parameters:
Demographic parameters of African penguins have been measured at Robben Island. Adult survival was between 0.82 and 0.90 in 1993/4, but fell to 0.75 in 1994/5 when many birds at the island were oiled following the sinking of the Apollo Sea in June 1994. Some penguins initiated breeding when two years old, and all probably bred at age five. The proportion of mature birds that bred in a year varied between about 0.70 and 1.00 During the breeding season, pairs laid their first clutch between January and August, mostly in February and March. The average clutch was 1.86 eggs. Of lost clutches 32% were replaced, whereas 23% of pairs losing broods relayed and 21% of pairs that succesfully fledged chicks relayed. On only one occasion was the laying of a third clutch during a breeding season recorded, and this was unsuccesful. The mean number of chicks fledged per breeding pair varied between 0.32 and 0.59 per annum.

Success of rehabilitation efforts: The return to islands and breeding success of penguins rehabilitated after being oiled following sinking of the Apollo Sea has been monitored by ADU and CNC. Of penguin flipper banded after rehabilitation, 65% had been seen at islands

within two years of their relaese. At Dassen island, there were some seasonal differences in the breeding success of rehabilitated birds and birds not affected by oil. Moulting and breeding cycles were affected.

Diet: The diet of the African penguin is monitored by SFRI at three islands, Dassen, Robben and Dyer. Anchovy (Engraulis capensis) is the main prey item at Robben Island. At Dyer Island there has been a trend to replacement of Anchovy by Sardine (Sardinops sagax).
Foraging range: The foraging range of breeding penguins at different localities is being investigated using transmitters to satellites. An adult rearing chicks at Dassen Island moved as far as Boulders and Marcus Island, but normally foraged closer to Dassen island.

Threats:

Climate: Heat: African penguins are subject to heat stress. In hot, humid, cloudless and windless conditions, parents abandon clutches and broods for the sea to cool and prevent further dehydration. Losses to Kelp gulls (Larus dominicanus) and other predators of eggs and chicks then frequently occur. African penguins apparently reduce heat stress by breeding in shade, e.g. under bushes and in burrows. However, as a consequence of removal of acumulated deposits of guano, in which burrows can be excavated, penguins have been forced to nest in the surface at many localities, increasing their susceptibility to heat stress.

Rain: Heavy rain result in flooding of nests, drowning of small chicks and losses of older chicks to hyperthermia.

There has been a change in the centre of distribution of the breeding population of African penguins. Much of the breeding population is now in Algoa Bay, where conditions are warmer than elsewhere, both on land and at sea.
Should ambient temperatures increase as a result of global warming, increased desertion of nests and decreases reproductive success can be anticipated. Should rainfall increase, greater flooding of nests will occur.

Parasites and disease:
This section deals with parasites and disease in the wild and in captivity. Most of the information arises from studies of captive populations and birds in rehabilitation centres. The possibility exists that diseases contracted by rehabilitated birds can be passed to wild populations.
Endoparasites: various worms occur in the gastro-intestinal tract, and some in the kidneys and lungs. Most can be treated with standard anti-worm medication. Cerebral symptoms may be seen with gastro-intestinal worms, whose eggs may be encysted in any part of the body, or endoparasites that lodge in liver, spleen, brain, lungs etc.

Strigeid digenian trematodes (Cardiocephaloides physalis) were responsible for large numbers of chick mortalities at St Croix Island in July 1981.

Ectoparasites: Lice, ticks and fleas are common, but not usually a problem.

Aspergillosis.

Bumblefoot.

Haematozoa: The most important is avian malaria (Plasmodium relictum). Mortality is high, but, if diagnosed, birds can be treated with Chloroquin plus Doxyxycline or Proguanil. The latter can be suspended in Keltrod, a mix of Hydroxy-benzoates, which makes it easier to administer. All penguins should be given prophylaxis during their stay in rescue stations, especially in summer, but controlled scientific assessment of the best drug and dose has not been done in South Africa.

Leucocytozoon (commonly present in many flying birds) occasionally affects penguins. Possibly responds to Chloroquine.

Babesiosis is endemic in African Penguins and has been reported elsewhere. Probably causes no symptoms, except under stress conditions.

Newcastle Disease: A virus with very high mortality and very contagious. A vaccine can be prepared, but its efficacy is unknown.

Avian cholera: Avian cholera (Pasteurella multocida) has killed penguins at Dassen Island .

Infections: Pneumonia (viral or coccal) is common. Usually treated with amoxycillin. Steps need to be implemented to minimise the risk of rehabilitated penguins returning disease to wild colonies.

Fishing: Commercial purse-seine fisheries off South Africa and Namibia catch large quantities of sardine and anchovy, which are important prey items for African Penguins. Sardine stocks off South Africa and Namibia collapsed in the 1960s, respectively contracting to the southeast and north as they did so. A consequent reduced availability of prey was probably the main reason for the large decrease in numbers of penguins between Ltideritz and Dassen Island. The decrease in number of penguins at Possession Island, southern Namibia, from 23 000 pairs in 1956 , fewer than 500 pairs in 1987 was exponential, with decay equivalent to the natural mortality rate of adults. Recruitment to the colony in this period appears to have been minimal.

At Robben Island between 1989 and 1995, African penguins fed mainly on anchovy. The number of chicks fledged per breeding pair was significantly related to estimates of spawner biomass for the South African anchovy resource. Numbers of immature birds immigrating to the colony were also significantly related to anchovy biomass. The proportion of adults breeding in any year at Robben Island was related to the biomass of the South African stock of sardine.
Development of a purse-seine fishery in Algoa bay may decrease availability of prey fish to the large African penguin population there.
Limited mortality results from entanglement of penguins in fishing nets. There is potential for this to increase if gill nets are set in proximity to breeding colonies. In South Africa, gill nets are only used in small fisheries for mullets and sharks.

Competition with other predators for food: in addition to fishing, greatly expanded herds of Cape fur seals (Arctocephalus pusillus) have decreased availability of food to African penguins.
Hunting for food or other purposes: Collection of penguin eggs was primarily responsible for the very large decrease in numbers of African penguins at Dassen Island between 1910 and

1956. It is estimated that in the first half of the 20th century 48% of eggs produced at Dassen Island were harvested. The lat sanctioned egg collections were in 1967.
There are unconfirmed reports of penguins being killed as use for bait in rock-lobster traps. Apparently they are attractive as bait because their flesh and skin is relatively tough compared to that of fish and other baits. The extemt of this practice is unknown. Most reports emanate from the Namibian Islands.

Human interference or disturbance: Exploitation and disturbance by man is the probable reason for penguins stopping breeding at four colonies, one of which has since been colonized. At other localities, egg collecting caused large decreases, especially at Dassen Island and in Algoa Bay. Historically, guano collection has been a major cause of disturbance at many colonies. Disturbance may also arise from tourism, mining, management and research actions, and other activities at breeding localities, such as maintenance, angling and swimming.

Disturbance is most damaging during breeding, at times causing panic and desertions of nest sites with losses of eggs and small chicks to Kelp Gulls. Young birds may also be deterred from breeding. Where there are burrows, humans moving about may cause burrows to collapse, thereby destroying breeding habitat and sometimes causing mortality.

Modelling has shown that regular searches for oiled birds have potential to severely depress populations if not properly controlled. At some localities (e.g. Boulders) African Penguins show remarkable tolerance of humans, whereas at others (e.g. Seal in goa Bay) they are readily disturbed. Some of the human residents adjoining the colony at Boulders do not show the same tolerance to penguins. They seek a reduction in the number of penguins at the colony.

Loss of habitat: Competition for breeding space: Competition with Cape Fur Seals for breeding space is the probable reason for cessation of breeding at five former breeding colonies. Expanding seal herds have displaced large numbers of penguins at other breeding localities, including Hollams Bird, Mercury and Sinclair Islands. Displacement of penguins by seals has recently been countered to some extent by a policy of seal-scaring and placement of artificial shelters at breeding colonies African Penguins compete with other seabirds for breeding space. At Bird Island in Algoa Bay, they were displaced from a portion of prime breeding habitat by Cape Gannets (Morus capensis*)*. The projected rise in sea level may further reduce breeding habitat of African Penguins.

Marine perturbations, including ENSO and other shifts: In addition to fishing, environmental change is thought to have influenced alternating regimes of high and low abundance of sardine and anchovy worldwide, including the Benguela system. Longterm trends of African Penguin populations in the Benguela system may to some extent be linked to regimes of sardine and anchovy. For example, the decreasing numbers of penguins at Dyer Island since the mid 1980s have matched a decreasing trend in the biomass of the South - African anchovy stock. In the same period, the stabilisation or increase of colonies between Stony Point and Lambert's Bay has corresponded with an increasing trend in the South African Sardine stock.
These trends are the opposite of trends that followed the collapse of sardine and rise of anchovy off South Africa in the 1960s.

Predation: Detailed examination of injuries sustained by penguins at St Croix Island indicated they were inflicted by Great White Sharks (Carcharadon carcharias). At St Croix Island, these injuries were second only to oil pollution as a cause of mortality of penguins.

Seals: There are many accounts of Cape Fur Seals killing penguins. This phenomenon has been recorded at Ichaboe, Halifax, Possession, Malgas, Dassen and Dyer Islands. The phenomenon is thought to be regional and periodic in occurence. Mortality may be high – at least 25 penguins were killed on one day at Dassen Island.

Killer whales: There are isolated records of Killer whales (Orcinus orca) preying on African penguins. Their influence is likely to be minor, because they are uncommon in southern African inshore areas.

Kelp Gulls and Sacred ibis: Kelp gulls prey on eggs and chicks. Most of their takings constitute scavenging, such as deserted clutches, infertile eggs and dying chicks. They have learnt to capitalise on disturbance, preying on eggs and chicks that are temporarily exposed when parent birds take fright at human activities. The desirability of controlling Kelp gulls at particular localities needs investigation. Sacred ibis (Threskiornis aethiopicus) also have potential to scavenge eggs and small chicks.

At Robben Island, mole snakes (Pseudapsis cana) eat penguin eggs. If this predator attains high levels of abundance, the desirability of control should be researched.
Feral cats: Feral cats (Felis catus) prey on eggs or chicks of penguins at Dassen and Robben islands and probably also at Bird Island, Lambert's Bay, Boulders and Stony Point. Control programmes are underway at Dassen and Robben Islands and are successful in maintaining cat populations at moderately low levels. Ideally cats should be eliminated at these islands.

Other mainland terrestrial predators: various small predators prey on young stages of penguins at mainland localities and at the two islands (Bird at Lambert's Bay and Marcus) now joined to the mainland. Leopards (Leopardus pardus) have eaten adult penguins at Stony Point. At this locality, predation is thought to have caused a decreasing trend. Some small predators have been trapped and released elsewhere. Black rats (Rattus rattus) occur at Marcus Island and probably other localities linked to the mainland. They are potential predators of eggs.

Pollution:
Oil. Oil spills have major impact on African penguins, especially when the oil washes ashore at breeding localities. Oil kills penguins by impairing the insulative capacity of their feathers, so that they die of hypothermia in water or of starvation on land because hypothermia makes it impossible for them to feed at sea. Ingested oil may produce a range of physiological abnormalities and is associated with a greater diversity of potentially pathogenic bacteria . Catastrophic oil spills occur irregularly, but there is persistent chronic oiling. Of 689 dead penguins found at St Croix Island over a 10-year period, oil pollution accounted for more deaths (44 %) than any other factor . Cleaning oiled penguins has been undertaken with considerable success, notably by the Southern African Nafional Foundation for the Conservation of Coastal Birds (SANCCOB). Development of a proposed harbour near to St Croix Is land, will place this large colony at increased risk of pollution.
Chemicals: Residues of polychlorinated biphenyls (PCBs) and the organochlorine pesticides DDE and Dieldrin have been found in penguin egg . In all cases the residue levels were low and unlikely to cause reproductive impairment.

Catastrophic events. Fire: At Robben Island and Boulders, the two new colonies where African Penguins breed under wooded vegetation, fire could cause extensive loss of breeding habitat and mortality of birds, eggs and chicks. The risk of fire should be minimised by clearing old wood.

Comments: Classification of the African Penguin as "Vulnerable" according to IUCN Red List Categories (Ala, A2b, E) is straightforward. "Endangered" status is approached, based on a probable decrease of 40 % in the last three generations, and a possible decrease of 40 % in the next three generations, extrapolated from the present rate of decrease.

There is little evidence that the annual loss of birds has slowed as the population has decreased
If the present loss (40 000 adults in the last 15 years) continues, extinction in the wild will occur within 70 years.
Future trends in the overall population of African Penguins are difficult to predict. The recent decrease has been driven by large losses at Dyer Island and at colonies in the south of Namibia. It could be argued that as these colonies become smaller, further decreases will have less impact on the world population, and may indeed be offset by increases at expanding colonies. Similar reasoning in the early 1980s would have held that increases at then expanding colonies, including Dyer Island, would sooner or later have offset losses elsewhere.

It can be expected that trends at the two large colonies in Algoa Bay (St Croix and Bird Islands), which between them support 42% of all African penguins, will have a large influence on the future world population. For example, a catastrophic oil spill in Algoa Bay could almost have reduced the world population. The proposal to create a port and heavy industrial complex near St.Croix group of islands will place the colonies there at high risk.

Trends in the Western Cape Province will mainly be influenced by events at Dassen, Dyer and Robben islands, which support 37% of the world population. The proposal to develop Saldana as a major port for oil and bulk carriers, with a predicted frequency of major oil spills (equivalent to or larger than the Apollo Sea spill) of once in 20 years, threatens the penguin populations within and adjacent to the area.

Mercury and Ichaboe Islands support 78% of the Namibian and 12% of the world populations. Penguins at these localities will be at risk, e.g. from displacement by seals, if island staff are withdrawn. Additional threats in this region are prospecting for and exploitation of diamonds on or immediately adjacent to breeding localities, oil exploitation along the Namibian coast, and the present extreme shortage of food for penguins.

The total area available for nesting by African penguins is less than 1000 ha (about 16 km^2). There are only 14 colonies with more than 1000 adults. The establishment of two new breeding localities in the 1980s, and a recolonisation of a third, must be offset against the loss of one colony off southern Namibia. Breeding may also soon stop at Pomona and Hollams Bird Islands.

Recommendations:

1) Population monitoring. Trends in populations should continue to be monitored at all extant colonies. At selected localities, demographic parameters should be monitored. Of particular concern is the present paucity of recruitment of young adults to the breeding population at several localities, e.g. Possession island.

2) Legal protection. All breeding localities of this vulnerable specis should be legislated as nature reseves.

3) Security of food base. Food is probably the main limiting factor at most colonies west of Cape Agulhas. Means of improving the forage base should be investigated, e.g. provision of adequate escapement from fisheries.

4) Management of oiling. A reduction in oil contamination should be targeted. Rescue of oiled birds should be supported. A co-ordinated contingency plan for the rescue of oiled penguins should be devised. A rehabilitation facility in Algoa Bay is necessary given the high proportion of the world population found in that region. The likely impact for the colony at St Croix Island of development of the proposed port nearby needs investigation. The impact on breeding colonies of searches for, and capture of, oiled birds requires research. Procedures to minimize disturbance during rescue operations should be devised. The likelihood of rehabilitated birds returning disease to wild colonies must be minimised. It is necessary to have a database of haematological values in all captive populations in southern Africa.

5) Management of breeding habitat. Breeding habitat of African Penguins must be secured, e.g. through continued exclusion of seals, and improved, e.g. through shading and drainage. No guano scraping should be allowed in and around colonies of African Penguins. Risks of fire at Robben Island and Boulders should be minimised.

6) Management of predation. The impact of seal predation at selected colonies, e.g. Dyer Island, needs fuller investigation through field observations and modelling. There is potential for remedial action through the culling of "problem" seals. Populations of Feral Cats at Bird Island (Lambert's Bay), Dassen Island and Robben Island should be eliminated. The desirability of controlling Kelp Gulls at particular localities needs investigation. Measures must be implemented to preclude introduction of rats to islands.

7) Management of mortality arising from humans. There should be no exploitation of African Penguins or their eggs. The effect of net fishing in the immediate vicinity of penguin colonies must be investigated, and no netting that causes mortality of penguins leaving or returning to colonies should be allowed.

8) Management of tourism. Tourism to selected penguin colonies should be carefully implemented, and its effects monitored. Appropriate national tourism strategies need to be developed. Management of the Boulders colony to minimize conflict with man needs attention.

9) Augmentation and establishment of colonies. Means of establishing new colonies, or of manipulating colonies to expand in a certain direction (to minimise conflict with man), should be investigated. There is a likelihood that studies of behaviour of captive populations can help in this. The possibility of returning birds bred in captivity to the wild should be investigated. The purpose of this would be to augment populations at colonies that are presently depressed of decreasing, and to establish techniques for reintroductions before the overall population has decreased to a critical level. This is a complex procedure and will require the assistance of specialist groups outside southern Africa. The technique, if established, will have value for other Spheniscus penguins.

10. Management of captive populations. African penguins in captivity (except for rehabilitation) should be kept in such a manner as to be individually recognisable, so that accurate information on ancestry can be maintained in studbooks. Export of African penguins from southern Africa should only be allowed for institutions that keep accurate records of stock and to institutions that keep similar records.

PHVA: Yes

Existing captive populations in South Africa In recent years South Africa's East London Aquarium (ELA) has sold captive born juveniles from excess stock to reputable zoos in other countries. The total number of birds traded by ELA is probably less than 30. In each instance, provincial nature conservation authorities issued the appropriate permits. The Port Elisabeth Oceanarium has sold no birds as yet, but is actively seeking buyers for its excess stock. There seems to be no trade of genuinely wild African penguins, not even rumours of such activity.

Captive management.

Species Survival Plan (SSP), North America.

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In the SSP the African penguin has shown a growth rate of almost 10% per year. In 1990 the population existed of 467 birds (122.131.214), whereas in 1995 there were 594 birds (169.175.228).
Since 1995 the main goal of the SSP is to reducce the number of birds to 500.
[recent information ?] Within this population a better representation of founder lineages is necessary. In addition, there is a need to determine the status of a number of genetically

questionable birds, as these may be hybrids. In general, this program is also facing a high chick mortality.

European Endangered Species Program (EEP)

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In 1994 the EEP for the African penguin was approved by the EAZA. The population within this program has increased from 689 birds (129.145.415) in 1994 to 850 (160.166.524) in 1997.
The number of unsexed birds is still high (in 1997 61%) as well as the number of unmarked birds. In addition the program is hampered by two bloodlines being strongly over-represented: those of Amsterdam Zoo and Baltimore Zoo. However, in recent times some unrelated birds have been imported from South Africa.
[add Jaap Govers]

Japan .

From Japan there is no detailed information available. There has been a growth of the population from 44 birds in 1985 to 196 birds (38.43.115) in 1995, distributed over 17 institutions.

Magellanic penguin.

According to the new IUCN criteria the species is at lower risk. Due to the population reduction trends at Punta Tombo and in the Falklands, it may be a good idea to list the species as lower risk, but list certain populations as near threatened, in order to “raise the flag” for this species in the international conservation community. The species is not listed in CITES.

Historical distribution

Colonies at Isla Leones and Cabo Virgenes are known from the 19th century and Puerto Deseado Islands from the 15th century. Historical records mention that a Magellanic penguin colony existed in the southwest of the Ushuaia Peninsula. This colony disappeared, for unknown reasons, during the mid 1950s.

The current state of occurence covers more than 20.000 km²

Population Trends:

Argentina:
Magellanic Penguins are found in colonies scattered along the coast of Patagonia. Little information exists on the size of colonies over time.What little information there is suggests no clear trends for the entire population. Several colonies at Peninsula Valdie have expanded in recent years. For example, the colony at Caleta Valdie was apparently new in the early 1960s when two pairs were found and continued to grow through the 1970s and 1980s. Actually, approximately 26,000 pairs nest at Caleta Valdie. Isla Deseada colony in the south of Santa Cruz province, increased from 5,000 pairs in 1986/87 to more than 12,000 pairs in 1995/96 In contrast, Punta Tombo has declined in numbers since 1987 by nearly 30 % The decline is not due to low reproductive success but probably to changes in survival ofjuveniles and young adults. Cabo Virgenes colony has been stable for at least the last ten years. A 30 % decline in the last 5 years, was detected by M. Bingham (1995) in the Malvinas Falkland Islands.

Generation Time: On average, the species begins to reproduces at around 4-5 years of age for females and 7-8 years of age for males. Varies from colony to colony. Oldest breeder at Punta Tombo was older than 17 years of age. World population**:** Approximately 1,200,000 pairs.

Regional Populations: Argentina: 950,000 pairs (assuming 100,000 pairs at Isla de los estados).
Malvinas/Falklands Is.: >100,000 pairs
Chile: >200,000 pairs

Data Quality: Argentina: 1; Malvinas/Falkiands Is.: 2; Chile: 3

Recent field studies.

Argentina:
Since 1982 research has been carried out at Punta Tombo, directed by Boersma in association with Yorio & Stokes. Several colonies have been monitored through time (Caleta Valdie and Estancia San Lorenzo, Pablo Yorio, Alejandro Carribero & Daniel Perez), Punta Tombo (Dee Boersma & Pablo Yorio), and Puerto Deseado colonies and Cabo Virgenes (P. Gandini & Esteban Frere). These studies covered almost all the key colonies for the species in Argentina. The projects include population studies, breeding ecology, habitat selection, diet and interactions with human activities, e.g. petroleum contamination until 1990. Gandini, Frere and Boersma also looked at the number of penguins found dead on beaches in the Province of Chubut. This work has been continued by Fundacion Patagonia Natural (located in Puerto Madryn), an Argentine NGO who has been actively involved in conservation issues with penguins.
Malvinas / Falkland Is: Falkland Islands Seabird Monitoring Program. Studies have been carried out on aspects of breeding biology, physiology, conservation, habitat use, oil pollution, migration, mate selection, diet, and behaviour.

Chile: Claudio Venegas is working together with P. Becker on heavy metal contamination in Magellanic Penguins in the area of Punta Arenas. B. Culik is working on the effects of tourism on Magellanic penguins in the Punta Arenas area.

Threats.

In Argentina, Gandini et al 1994, estimated that more than 20,000 adults and.22,000 juveniles are killed by oil contamination along of 3000 km of Argentine coast each year. Although legislation exists to prevent oil dumping and discharge, penguins are regularly found contaminated with oil. Oil-contaminated ballast water continues to be discharged by tankers as they approached the ports. Oil pollution along the Argentine coast could be reduced by proper treatment of ballast water and enforcement of MARPOL.

Hunting for use as bait in Punta Arenas is a threat as well.

Preliminary information suggests that incidental mortality in fishing nets is occurring. In addition, penguins may be captured in nets but some preliminary data indicates that this is not an important source of mortality. Furthermore, fisheries may have an indirect effect on the population because of the by-catch of the shrimp and hake fisheries. Most of the by-catch includes juveniles of hake (Merlucius hubsii*)* and anchovy *(*Engraulis anchoita*),* important penguin prey along the north coast of Patagonia.

In the Malvinas / Falklands Islands loss of tussock habitat that the penguins use for nesting may be restricting their population. Predation from introduced foxes is a problem on at least two offshore islands. Egg collection is continued under a license agreement and is very heavy at some sites. Egging may be having a local impact on colonies but probably is not affecting the population. Exploitation of petroleum resources is likely to occur around Malvinas / FalkIand Islands, which may cause an increase in pollution, and other effects associated with increased human population.

In general (i.e. in all areas), during some years almost all birds fail to rear chicks because of rains and lack of food for young association with ENSO events. Reduction of habitat and changes in land use reduce the quality and abundance of good breeding areas. Predation from introduced foxes, cats and rats is a problem on some islands.

Trade: Chile is currently issuing permits for export.

Comments: Magellanic penguins are relatively common which may mean it is important for zoos to assess the numbers of spaces that will be allotted to each species and to make sure that the more abundant species do not usurp spaces from species that are in very low number in the wild. Zoo-based Species Survival-type programs should determine how many individuals and how many species should be maintained in captivity with higher priority given to breeding programs of species in low number in the wild.

Recommendations.

1) National and international pressure is needed to stop petroleum discharge.
2) Continue evaluating the rate of mortality in fishing nets and in bait hunting; continue evaluating the overlap between Magellanic penguin diet and fisheries including both target species and by-catch; determine major foraging areas and potential competition with fisheries.

3) Continued monitoring is needed and should be initiated in Chile and the Falkland/Malvinas.
4) Establish marine reserves around key colonies.
5) Delineate and protect migration and dispersal routes of Magellanic Penguins, using telemetry, in order to quantify the overlap with shipping routes.
6) CONAF and the German School in Punta Arenas should be supported in their efforts to stop the hunting of Magellanic Penguins for bait.
7) Develop joint conservation strategies between Argentina, Uruguay, Brazil, and Chile.

PHVA: No

Captive Program recommendation: No

Level of difficulty: 1

Captive management.

Argentina.

The Mundo Marino sea aquarium has 100 individuals.

United States of America.

The North American Penguin TAG decided in 1993 for the controlled elimination and eventual replacement of the Magellanic penguin in favor of the expansion of captive programs for the Humboldt and the African penguin. In that year 175 birds (52.55.68) were present. However in 1997 a registry was initiated by San Francisco Zoo. [add recent information]

Europe and Japan.

In 1993 in the European Penguin TAG it was decided not to phase out the species as it took no relevant space which could be used for the other Spheniscus species. The intention was to amalgamate all the birds spread out over 9 institutions into two groups.
In December 1998 37 birds (11.12.14) were present, in three institutions.
There are no current detailed data and further information available on the status of the species in Japan. However, there has been a growth of 30 birds (3.3.24) in 9 institutions to 251 birds (72.78.101) in 33 institutions in 1995.

Spheniscus penguin husbandry manual

First edition

Edited and compiled by the Penguin TAG

A publication of the EAZA

References

References

Adams, N.J. 1994 Patterns and impacts of oiling on African Penguins Spheniscus demersus: 1981-1991 . *Biol..Conserv*. 68: 35-41

Araya, M.B. 1983. A preliminary report on the status and distribution of the Humboldt Penguin in Chile. In J. Delacour (ed.). *Proceedings of the international Foundation for the Conservation of Birds Symposium on Breeding Birds in Captivity*, Los Angeles. pp.125-135.

Araya, M.B. and Duffy. 1987. Animal introductions to Isla Chanaral, Chile: their history and effect on seabirds. *Cormorant* 15:3-6

Araya, M.B. and F. Todd 1987. Status of the Humboldt penguin in Chile following the 1982-83 El Nino. In: *Proceedings of the Third Delacour/IFCB Symposium on breeding birds in captivity.* L.A. California
Also in: *Spheniscid Penguin Newsletter* 1:8-10.

Araya, B., Garland, D., Espinoza, G. Sanhuesa, A. et al. (eds). Population and habitat viability assessment for the Humboldt penguin (Spheniscus humboldti). Final report. IUCN/SSC Conservation breeding specialist group. Apple Valley, MN 2000

Avery-Beausoleil, L. Ryan, E.A. 1985 Practical aspects of the husbandry and maintainance of the Magellanic penguins (Spheniscus magellanicus) at the San Francisco *Zoo. Animal Keeper's Forum* 12: 451-464

Barham, P. Design of plastic penguin flipper bands. In: *Penguin Conservation*, Vol.12, no.2 1999 p.4-10

Battistini, G. and R.Paredes. Nesting habits and nest characteristics of Humboldt penguins at Punta San Juan, Peru. In: *Penguin Conservation*. 1999 Vol.12 no.1 p.12-19

Beall, F.B.C. African penguin studbook. 1993 update. Penguin Conservation Vol.6 nr.3 p.16

Bennett, K.A. Molt patterns of Black footed penguins at Baltimore Zoo. In: *Spheniscus Penguin Newsletter* Vol.4 nr.2 1991 p.1-4

Bennett, K.A. Behavioural observations of captive Magellanic penguins with chicks. In: *Penguin Conservation* Vol.6 nr.2 1993 p.7-12

Berruti, A. 1986 The predatory impact of feral cats (Felis catus) and their control on Dassen island. *South African Journal of Antarctic Reseacrh* 16(3): 123-127

Berry, Seely and Fryer. 1974. The status of the Jackass Penguin (Spheniscus demersus) on Halifax Island off South West Africa *Madoqua* Ser. 113:27-29.

Bingham, M. The penguins of South America and the Falkland islands. *Penguin Conservation*, Vol.11 nr. 1 1998 p.8-15

Bingham, M. 1994 Conservation report on Magellanic enguins. *Penguin News*, 6(2): 10

Bingham, M. 1995 Population status of penguin species in the Falkland Islands. *Penguin Conservation 8*: 14-19

Blackwell, S. (ed) Penguin management: proceedings of a symposium held at Cotswold Wildlife park. Cotswold Wildlife Park Ltd. Burford, Oxford. 1990

Blay, N. and I.M.Côté Optimal conditions for breeding of captive Humboldt penguins (Spheniscus humboldti): A survey of British zoos. *Zoo Biology* 20: 545-555 (2001) pp.545-555

Bocxstaele, R.van Breeding and hand-rearing of the Black-footed penguin. *International Zoo Yearbook*, 18, p.43-46

Boersma, P.D. Magellanic penguins of Patagonia. *International Zoo News*, nr.211 Vol.35/6 pp.26-28
Boersma, P.D. Magellanic penguins decline in South Atlantic. *Penguin Conservation* Vol.10, nr.1 1997 p.2-6
Boersma, P.D. 1987. El Nino behind penguin deaths? *Nature* 327: 96
Boersma, P.D. Nesting sites for Spheniscus penguins. In: *Penguin Conservation*, Vol.4 nr.1 1991 p.8-9
Boersma, P.D. Magellanic penguins of Patagonia. *Spheniscus Penguin Newsletter*, Vol.1 nr.1 1988 p.2-3
Boersma, P.D. Plight of the penguins. *Wildlife Conservation*. Jan.Feb. 1998 pp.21-26
Boersma, P.D. Status of wild and captive penguin populations. *Trends Ecol.Evol*. 6 (12): 381-382, 1991
Boersma, P.D. The 1997-1998 El Nino: impacts on penguins. *Penguin Conservation* Vol.11 nr.3 p.10-11,19 1998
Boersma, P.D. Asynchronous hatching and food allocation in the Magellanic penguin. *Acta Congressus Internationalis Ornithologici.* XX, 961-73
Boersma, P.D., Branch, S. etc. Penguin conservation asessment and management plan, Apple Valley, MN, IUCN/SSC captive breeding specialist group. 1992
Boersma, P.D. and Davies. 1987. Sexing monomorphic birds by vent measurements. *Auk* 104: 779-783.
Boersma, P.D. Stokes, D.L. Yorio, P.M. 1990 Reproductive variability and historical change of Magellanic penguins (Spheniscus magellanicus). In: *Penguin biology*. Academic Press pp.15-41
Boersma, P.D. and Stokes, D.L. Mortality patterns, hatching asynchrony, and size asymmetry in Magellanic penguin chicks. In: *Penguin Biology* 2 (ed.P.Dann and P.Reilly). Surrey Beatty and Sons. NSW 1995
Bos, J.H., M.van der Hage and G.M.Dorrestein. Trematode infection in Humboldt penguins (Spheniscus humboldti). In: *Proceedings of the meeting of the European Association of Zoo- and Wildlife Veterinarians.* May, 1996
Boswall, J. 1973 The private life of the Jackass penguin. *Animals*. 15 (8), 340-6
Boswall, J. 1972. The South American Sea Lion *Otaria byronia* as a predator on penguins. *British Ornithologists Club Bulletin* 92 (5):129-132.
Boswall, J. & Maciver, D. 1975 The Magellanic penguins (Spheniscus magellanicus). In: *The biology of penguins.* Stonehouse, B. (ed). London macmillan Press
Bowmaker J.K. and G.R. Martin. 1985. Visual pigments and oil droplets in the penguin, Spheniscus humboldti. *Journal of Comparative Physiology* A *156:71-77*
Brandt, G. and P.McGill. Humboldt penguin SSP report 1996. *Penguin Conservation*, Vol.10, nr.1 1997 p.15-16, 18-19
Breitwesier, B.A. Fluid therapy in penguins. In: *Penguin Conservation* Vol.7 1994 nr.1 p.6-8
Broni, S.C. 1982. First recorded mainland breeding by the Jackass Penguin (Spheniscus demersus*). Cormorant* 10:120.
Broni, S.C. 1983. An apparent instance of courtship feeding in the Jackass Penguin (Spheniscus demersus). *Cormorant* 11:63-64
Broni, S.C. 1985 Social and spatial foraging patterns of the Jackass penguins: what is the cost of a life-long commitment ? *Marine Ecology Progress Series.* 98: 209-214
Broni, S.C. . 1986. Social and spatial foraging patterns of the Jackass Penguin (Spheniscus demersus). *South African Journal of Zoology* 20: 241-245.
Brooke and Wallett. 1976. Shark predation on seabirds in Natal waters. *Ostrich* 47:126.
Brossey, J.J. Haemoparasites in the African (Jackass) penguin. In: *Penguin Conserv*ation Vol.6, nr.2 1993 p.20-21

Bulfon, M.E., N. Bee de Speroni, and J.A. Scolaro. 1986. An attempt at aging Magellanic Penguins (Spheniscus magellanicus) by histological analysis of feather follicles. *Cormorant* 13:168-171

Burger and Cooper. 1984. The effects of fisheries on seabirds in South Africa and Namibia. In D.N. Nettleship, C.A. Sanger and P. F. Springer (eds.) *Marine birds: their feeding ecology and commercial fisheries relationships.* Canadian Wildlife Service Special Publication, Ottawa, pp. 15~160.

Cairns. 1986. Plumage colour in pursuit-diving seabirds: why do penguins wear tuxedos? *Bird Behaviour* 6:58-65.

Campbell, G. Aspergilosis in captive penguins. *Irish vet.J.* 27: 29-30

Capurro, A. Frere, E., Gandini, P. , Holik, T. Lichtschein, V. and Boersma, P.D. 1988. Nest density and population size of Magellanic Penguins (Spheniscus magellanicus*)* at Cabo Dos Bahias, Argentina. *Auk* 105:585-588.

Cheney, C. The current situation of the Humboldt penguin in Chile and Peru: a report from the population and habitat viability analysis meeting. Part 1. *Penguin Conservation* Vol.11 nr.3 1998 p.4-9

Cheney, C. Banding penguins: a review of methods. *Spheniscus Penguin News*letter Vol.1 nr.2 1988 p.2+7

Cheney, C. Penguins in zoos: progression from maintenance to management. *Spheniscus Penguin Newsletter,* Vol.1 nr.2 1988 p.4-6

Cheney, C. Captive reproduction in Spheniscids: a statistical overview. *Spheniscus Penguin Newsletter,* Vol.1 nr.2 1988 p.8-9

Cheney, C. A technique for restraining and drawing blood from Humboldt penguins. *Penguin Conservation,* Vol.6 nr.3 1993 p.1-3

Cheney, C. Spheniscus penguins: an overview of the world captive population. *Spheniscus Penguin Newsletter,* Vol.3 nr. 1 1990 p.12-17

Clancey, P.A. On the penguins Spheniscus demersus and Spheniscus megallanicus. *Ostrich,* 37, p.237

Clark, M. Breeding of the Black footed penguin (Spheniscus demersus) at London Zoo. *International Zoo Yearbook*, 1994 . 33: p.1923

Collins, T.K. Black-footed penguins at the Knoxville Zoo. *Spheniscus Penguin Newsletter,* Vol.5 nr.1 1992 p.21-23

Conway, G. 1965 The penguin metropolis of Punta Tombo. *Animal Kingdom,* July-August

Conway, W.G. 1971 Predation on penguins at Punta Tombo. *Animal Kingdom,* 74: 2-6

Cooper, J. 1972. Sexing the Jackass Penguin. *SAFRING News* 1:23-25

Cooper, J. 1974. The predators of the Jackass Penguin *Spheniscus demersus. Bulletin of the British Ornithological Club* 94:21-24.

Cooper, J. 1977 Energetic requirements for growth of the Jackass penguin. *Zool.Afr.* 12: 201-213

Cooper, J. 1977 Sunning of Jackass penguins at sea. *Auk*. 94: 586-587

Cooper, J. 1978. Moult of the Black-footed penguin. *International Zoo Yearbook* 18:21-27.

Cooper, J. 1980. Breeding biology of the Jackass penguin with special reference to its conservation. *Proceedings of the Fourth Pan-African Ornithological Congress,* pp.227-231.

Cooper, J. 1982. Methods of reducing mortality of seabirds caused by underwater blasting. *Cormorant* 10:109-113.

Cooper, J. 1984. Changes in resource division among four breeding seabirds in the Benguela upwelling system. *Proceedings of the Pan-African Ornithological Congress,* pp.217-230.

Cooper, J. 1986. Runt eggs of the Jackass Penguin (Spheniscus demersus). *Cormorant* 13:112-117

Cooper J. and P.D. Morant. 1981. The design of stainless flipper bands for penguins. *Ostrich* 52:119-123.

Cordes, I. Crawford, R.J.M., Williams, A.J. & Dyer, B.M. Decrease of African Penguins at the Possession Island group, 1956-1995- contrasting trends for colonial and solitary breeders. *Marine Ornithology* 27: 129-138

Cosgrove, J.J. Dierenfeld, Ellen S. Circulating x-tocopherol and retinol in free-ranging and captive penguins: speculation on dietary influences. In: *Penguin Conservation.* Vol.12, no.1 1999 p.6-11

Cranfield, M.R., Graczyk, T.K., Beall, F.B., lateggio, D.M., Shaw, M.L., Skioldager, M.L. 1994. Subclinical avian malaria infections in African blackfooted penguins (Spheniscus demersus) and induction of parasite recrudescence. *J. Wildl. Dis.* 30(3):372-376.

Cranfield, M. et al. Avian malaria. In: Spheniscus Penguin Newsletter, Vol.4 nr.2 1991 p.5-7

Crawford, R.J.M. 1994 10.000 African penguins rescued from oil spill. *African Wildlife Update* 3 (4): 1,8

Crawford, R.J.M. and Shelton. 1978. Pelagic fish and seabird interrelationships off the coast of South West and South Africa. *Biological Conservation* 14: 85-109.

Crawford, R.J.M. and Boonstra, H.G.v.D. 1994 Counts of moulting and breeding Jackass penguins (Spheniscus demersus): a comparison at Robben Island, 1988-1993. *Marine ornithology*. 22: 213-219

Crawford, R.J.M. and Shelton. 1981. Population trends for some southern African seabirds related to fish availability. In J. Cooper (ed.) *Proceedings of the Symposium on the Birds of the Sea and Shore*, 1979. African Seabird Group, Cape Town, pp.1541.

Crawford, R.J.M., Adams, N.J., Dyer, B.M. and R.C.Laugksch. Diet of the African penguin (Spheniscus demersus) at Dyer Island, South Africa, 1982-1996 Third International Penguin Conference.

Crawford, R.J.M., Williams and Crawford. 1986. A note on mortality of seabirds off western southern Africa, October 1985-February 1986. *South African Journal of Marine Science* 4:119-123.

Crawford, R.J.M., Williams, Randall, Berruti, Ross. Recent population trends of Jackass penguins off Southern Africa. *Biological Conservation*., 52, p.229-243

Crawford, R.J.M. , Boonstra, H.G. v.D, Dyer, B.M. & Upfold, L. 1995. Recolonization of Robben Island by African penguins, 1983-1992. In: *The penguins: Ecology and management*. Dann, P., Norman, I. & Reilly, P. (eds.) Surrey Beatty & Sons, Chipping Norton, Australia: 333-363

Crawford, R.J.M.. & Dyer, B.M. 1995 Responses by four seabirds to a fluctuating availability of Cape anchovy (Engraulis capensis) off South Africa. *Ibis*, 137: 329-339

Crawford, R.J.M., Dyer, B.M. & Brooke, R.K. 1994 Breeding nomadism in southern African seabirds-constraints, causes and conservation. *Ostrich* 65 (2): 231-246

Crawford, R.J.M., Dyer, B.M. & Brown, P.C. 1995 Absence of breeding by African penguins at four former colonies. *S.Afr.J.Mar.Sci.* 15: 269-272

Crawford, R.J.M., Shannon, L.J. & Whittington, P.A. Population dynamics of the African penguin (Spheniscus demersus) at Robben Island. *Marine Ornithology* 27: 139-147

Crawford, R.J.M., Williams, A.J., Hofmeyr, J.H., Klages, N.T.W., randall, R.M., Cooper, J., Dyer, B.M. &Chesselet, Y. 1995 Trends of African penguin populations in the 20th century. *S.Afr.J.Mar.Sci.* 16: 101-118

Crawford, R.J.M., Williams, A.J., Randall, R.M., Randall, B.M., Berruti, A. & Ross, G.J.B. 1990 Recent population trends of Jackass penguins (Spheniscus demersus) off southern Africa. *Biol.Conserv*. 52(3): 229-243

Crawford, R.J.M. and J.Jahncke. 1999 Compariosn of trends in abudance of guano-producing seabirds in Peru and southern Africa. *South Afr. J.Mar.Sci*.21: 145-56

Crawford, R.J.M. , David, J.H.M., Williams, A.J. & Dyer, B.M. 1989 Competition for space: recolonising seals displace endangered, endemic seabirds off Namibia. *Biol.Conserv*. 48: 59-72

Crissey, S.D. Handling fish fed to fish-eating animals. A manual of standard operating procedures. USDA, 1998

Crissey, S.D. 1990. Supplements available and nutrient content of fish fed to Humboldt Penguins. AAZPA Regional Proceedings, 1990. Reprinted in *Spheniscus Penguin Newsletter*, Vol.3, 1: 4-9.

Crissey, S.D. Supplements available and nutrient content of fish fed to Humboldt penguins. In: *Spheniscus Penguin Newsletter*, Vol.3 nr. 1 1990 p.4-9

Croxall, J.P. The penguin conservation management plan. In: *Penguin conservation* Vol.7 nr.3 1994 p.4-6

Culik, B.M. and Wilson, R.P. and Bannasch, R. 1993 Flipper bands on penguins: what is the cost of a life long commitment ? *Marine Ecology progress series* 98: 209-214

Culik, B.M. and G.Luna-Jorquera. Satellite tracking of Humboldt penguins in Northern Chile. *Marine Biology* 128: 547-556

Culik, B.M., G.Luna-Jorquera, G.Oyarzo, H.Correa 1998 Humboldt penguins monitored via VHF telemetry. Mar. Ecol.Prog.Ser. 162: 279-286

Culik, B.M. and Luna-Jorquera, G. 1997 The Humboldt penguin: a migratory bird ? *Journal of Ornithology*. 138: 325-330

Culik, B.M. Humboldt penguins at sea: quo vadis ? *Penguin Conservation*, Vol.10, nr. 2 1997 p.2

Culik, B. , J.Hennicke & T.Martin. Humboldt penguins outmanoeuvring El Nino. *Journal of experimental biology*. 2000 (in press)

Dathe, H. The penguin cliffs exhibit at the Berlin Tierpark. *International Zoo Yearbook* .26: 140-142

Davis, D.G. Keeping penguins in captivity: the penguin paradox. *International Zoo Yearbook*, 7 p.4-11

Davis, L.S. and Darby, J.T. (Eds.) 1990 Penguin biology. Academic Press, Inc. San Diego, CA 92101.

De Bary Pereda, S.P. 1990 Influence of nest-site charcateristics on the reproductive success of Magellanic penguins M.S.thesis, University of Washington, Seattle.

Deeming, D.C., Harvey, R.L., Harvey, L., Carey, S., Leuchars, D. 1997. Artificial incubation and hand-rearing of Humboldt penguins (Spheniscus humboldt,) at Birdworld, Farnham. *International Zoo Yearbook*. 30:165-173.

Dekker, D. 1967 Keeping and breeding penguins at Amsterdam Zoo. *International Zoo Yearbook* 7: 25-27

Del Hoyo, J. , Elliott, A. and Sargatal, J. (ed). Handbook of the birds of the world. Vol.1 Lynx Edicions. Barcelona. 1992

Despin, B. et al. 1978. Surface temperatures by infrared thermography of the Humboldt penguin (Spheniscus humboldti). *Oiseau Rev. Fr. Ornithol*. 48:151-158.

Diebold, E. et al. Humboldt penguin research in Chile. In: *Penguin Conservation* Vol.7 no.3 1994 p.2-3

Diebold, E.D. , Taere, J., Grzybowski, K. Michaels, M.G., Wallace, R.S. Willis, M.J. 1998 Preliminary findings on pair fidelity in Humboldt penguins (Spheniscus humboldti) at Algarrobo, Chile. *Penguin Conservation* 11 (1): 21

Diebold, E.D. , Taere, J., Grzybowski, K. Michaels, M.G., Wallace, R.S. Willis, M.J. 1998
Nest-site fidelity in Humboldt penguins (Spheniscus humboldti) at Algarrobo, Chile. *Penguin Conservation*. 11 (1): 22-23

Dierenfeld, E.S. e.a. Retinol and a-tocopherol concentrations in whole fish commonly fed in zoos and aquariums. *Zoo Biology* 10: 119-125, 1991

Drent, R.H. and B. Stonehouse. 1971. Thermoregulatory responses of the Peruvian penguin, (Spheniscus humboldti). *Comparative Biochemistry and Physiology* 40A: 689-710

Dubach, J. Gender determination in captive and wild species of penguins. *Penguin Conservation*, Vol.9 nr.1 1996 p.14-15

Duffy, D.C. 1983. The foraging ecology of Peruvian seabirds. *Auk* 100:800-810.

Duffy, D.C. 1990. Selected bibliography of the spheniscus penguins. AAZPA Regional Conference Proceedings Pp.93-98. Also in *Spheniscus penguin newsletter*. 4(1)2-6.1991.

Duffy, D.C. 1987 Ecological implications of intercolony size variation in Jackass penguins. *Ostrich*, 58 (2) p.54-57

Duffy, D.C. 1987a: Three thousand kilometers of Chilean penguins. *Explorers Journal* 65: 1O6-109.

Duffy, D.C.. 1987b. Ecological implications of intercolony Size-variation in Jackass penguins. *Ostrich 58:54-57.*

Duffy, D.C. 1989. Seabird foraging aggregations: a comparison of two southern upwellings. *Colonial Waterbirds* 12: 164-175.

Duffy, D.C. 1990. Seabirds and the 1982-1984 El Nino/Southern Oscillation. In P. W. Glynn (ed.) *Global Ecological Consequences of the 1982/83 El Nino Southern Oscillation.* Elsevier.

Duffy, D.C. 1990. Field Studies of Spheniscus Penguins. AAZPA Regional Proceedings, 1990. Reprinted in *Spheniscus Penguin Newsletter*, Vol.4, 1:10-15.

Duffy, D.C. and Cooper, J. 1990. Distribution and survival of juvenile jackass penguins at sea: an explanation of population trends. *South African Journal of Science*.

Duffy, D.C. and Daturi. 1987. Diet rhythms of tick parasitism on incubating African penguins. *Medical and Veterinary Entomology* 1:103-106.

Duffy, D.C. and Jackson. 1986. Diet studies of seabirds: a review of methods. *Colonial Waterbirds* 9:1-17.

Duffy, D.C. and La Cock. 1985. Partitioning of nesting space among seabirds of the Benguela upwelling region. *Ostrich* 56:186201.

Duffy, D.C. and Siegfried. 1987. Temporal variations in food consumption by seabirds of two upwellings. In J. P. Croxall (ed.). *Seabird Feeding Ecology.* Cambridge University Press, pp.327-346.

Duffy D.C., C. Hays, and M. Plenge. 1984. The conservation status of Peruvian seabirds. In J.P. Croxall, P.G.H. Evans and R.W. Schreiber (eds.). Status and

Conservation of the World's Seabirds. *ICBP Technical Publication* 2, pp.245-259.

Duffy, D.C., Berruti, Randall, and Cooper. 1984b. The effects of the 1982-1983 warm water event on breeding South American seabirds. *South African Journal of Science* 80:65-69.

Duffy, D.C., R.P. Wilson, R. Ricklefs, S. Broni and H. Veldhuis. 1987. Penguins and purse-seiners: competition or coexistence? *National Geographic Research* 3:480-488.

Duffy, D.C., R.P. Wilson, M.P. Wilson, M.B. Araya, and N. Kiages. The ecology of Humboldt and Magellanic penguins in Chile. ms.

Duffy, Furness, Laugksch and Smith. 1985. Two methods of measuring food transit rates of seabirds. *Comparative Biochemistry and Physiology* 82a:781-785.

Duffy, D.C., Wilson, and Berruti. 1985. Anchovy in the diets of Dyer Island penguins: a test of two models of anchovy distribution. *South African Journal of Science* 81:552-554.

Duffy, D.C., Siegfried and Jackson. 1987b. The Benguela ecosystem: seabirds as consumers: a review. *South African Journal of Marine Science* 5:771-790.

Duffy, D.C., Arntz, Tovar, Boersma and Norton. 1988. The effects of El Nino and the Southern Oscillation on seabirds in the Atlantic Ocean compared to events in Peru. *Acta* XIX *Congresus Internationalls Ornithogici 1740-1746.*

Edgington, D.G.. 1989. Behavioural and morphological sexing of the Humboldt penguin (Spheniscus humboidli). *Spheniscid Penguin Newsletter* 2:14-20.

Eggleton,P. and W.R.Siegfried. 1979. Displays of the Jackass Penguin. *Ostrich* 50:139-167.

Ellis, S. and Branch, S. Penguin husbandry manual. First ed. AZA. 1994

Ellis, S. et al. Penguin conservation and management plan (CAMP). Report. IUCN/SSC Conservation breeding specialist group. Apple Valley. MN

Erasmus and Smith. 1974. Temperature regulation of young Jackass Penguins (Spheniscus demersus). *Zoologica Africana* 9:195-203.

Erasmus, Randall, E.T. and B.M. Randall. 1981. Oil pollution, insulation and body temperatures in the Jackass Penguin (Spheniscus demersus). *Comparative Biochemistry and Physiology* 69A: 169-171.

Field, D. EEP banding survey. 1997. *Penguin Conservation*, Vol.11 nr.3 1998 p.18-19

Field, D. and Thomas, C.G. Humboldt penguins – the early days. *Ravel*, 19 (6) 1992

Fiennes, R. Penguin pathology. *International Zoo Yearbook* 7: p.11-14

Fleischman, R.W. et al. 1968 Malaria (Plasmodium elongatum) in captive African penguins (Spheniscus demersus) *J. Am.Vet.Med.Assoc*. Vol.153 pp.928-935

Fleischman, R.W. et al. 1968 Pathologic confirmation of malaria (Plasmodium elongatum) in African penguins (Spheniscus demersus). Bull. Wildlfie Disease Assoc. Vol.4 pp.133-135

Fowler, G.S. Ecological and endocrinological aspects of long-term pair bonds in Magellanic penguin. Ph.D thesis University of Washington, Seattle.

Fowler, G.S., Wingfield, J.C. and Boersma, P.D. and Sosa, A.R. Reproductive endocrinology and weight change in relation to reproductive success in the Magellanic penguin. General and Comparative Endocrinology

Fowler, G.S. 1999 Behavioral and hormonal responses of Magellanic penguins (Spheniscus magellanicus) to tourism and nest site visitation. Biological Conservation 90: 143-147

Fraser, W.R. Penguin marking techniques: summary of SCAR-BBS workshop. *Penguin Conservation*, Vol. 10, nr.1 1997 p.9-12

Frere, E. et al. Effects on nest type and location on reproductive success of the Magellanic penguin (Spheniscus magellanicus). *Marine Ornithology*, 20:1-6

Frost, P.G.H., W.R.Siegfried, J.Cooper. 1976 The conservation of the Jackass penguin (Spheniscus demesus). *Biol.Conservation*. Vol. 9 pp.80-99

Frost, P.G.H., Siegfried, W.R. and Greenwood, P.J. 1975 Arteriovenous heat exchange systems in the Jackass penguin. *Journal of zoology*, 175, p.231-241

Frost, Siegfried and Burger. 1976b. Behavioural adaptations of the Jackass Penguin, (Spheniscus demersus) to a hot, arid environment. *Journal of Zoology* 179:165-187.

Furness and Laugksch. 1983. An attempt to use barium meals and X-ray photography to determine gastric evacuation rate and gut retention time in Jackass Penguins Spheniscus demersus. *Cormorant* 11:3-6.

Gaily-Phipps, J.J. , Sladden W. Survey on nutrition of penguins. *Journal of the American veterinary mediacl association* 181: 1305-1309, 1982

Gailey-Phipps, J.J. Management of penguins in captivity. In: *Proc.first conf.birds captivity*, Seattle p.80-92

Gailey, J.J. 1975 Raising African penguin chicks. *Anim.Keeper's Forum*. 2(5): 7

Gailey-Phipps, J. Breeding Black-footed penguins. *International Zoo Yearbook*: 18, p.28-35

Gailey-Phipps, J. & Sladen, W.J.L. Nutrition of Sphenisciforms In *CRC handb*ook Series in Nutrition and Food. West Palm Beach: CRC Press

Gandini, P., **Boersma, P.D., Frere, E., Gandini, M., Holik, T. and Lichtstein,** V. 1994 Magellanic penguins (Spheniscus magellanicus) affected by chronic petroleum pollution along the coast of Chubut, Argentina. *Auk*, 97, p.191-193

Gandini, P., E.Frere and P.D.Boersma. 1996 Status and conservation of Magellanic penguins (Spheniscus magellanicus) in Patagonia, Argentina. In: *Bird Conservation International.* Vol.6 (4), 307-316

Ghebremeskel, K. and G.Williams. 1988 Pre- and post moult plasma nutrient status of Rockhopper (Eudyptus crestatus) and Magellanic (Spheniscus magellanicus) wild penguins. Annual Proceedings of the American Association of Zoological Parks and Aquariums. 415-418

Geraci, J.R., St.Aubin, D.J. Nutrinional disorders of captive fish-eating animals. *The comparative pathology of zoo animals*. R.J.Montali ; G.Migaki, eds. Washington, DC, Smithsonian Institute Press, 1980 p.41-49

Ghebremeskel, K. Williams, G. Liver and plasma retinol (vitamin A) in wild, and liver retineol in captive penguins (Spheniscidae). *Journal of zoology*, London 219; 245-250, 1989

Gochfield, M. 1980 Timing of breeding and chick mortality in central and peripheral nests of Magellanic penguins. *Auk* 97 (1): 191-193

Grant, Leslie, and Duffy. 1990. Molecular evolution of Spheniscus penguins. *Proceedings of the Pan African Ornithological Congress.*

Graczyk, T.K, Shaw, M.L., Cranfield, M.R., Beall, F.B. 1994**.** Hematologic characteristics of avian malaria cases in African black-footed penguins (Spheniscus demersus) during the first outdoor exposure season. J. Parasit. 80(2):302-308.

Graczyk, T.K., Cranfield, M.R., Shaw, M.L., Craig, L.E. 1994. Maternal antibodies against Plasmodium spp. in African black-footed penguin (Spheniscus demersus) chicks. *J. Wildl. Dis.* 30(3):365-371.

Graczyk, T.K.; Cranfield, M.R.; Skioldager, M.L.; Shaw, M.L. 1994. An ELISA for detecting anti-Plasmodium spp antibodies in African black-footed penguins (Spheniscus demersus). *J. Parasit*. 80(1)60-66.

Grunberg, W.E. 1963 Infektionen mit Plasmodium praecox bei Humboldt's und Brillenpenguinen. *Zentralbl.bakteriol.Parasitenkd.Infektionskr. Hyg*.Abt.I Orig. Vol.189 pp.511-520

Hagenbeck, C. Penguin exhibit at hamburg Zoo. International Zoo yearbook 7, p.31

Harrington, M. Penguins in captiviy. (unpublished report) 1985

Harris, E.L. 1989. Humboldt Penguin Husbandry at Woodland Park Zoo, Seattle. *Spheniscus Penguin Newsletter*, Vol.1, 2:1, 10-13

Hays, C. 1984. The Humboldt Penguin in Peru. *Oryx* 18:92-95.

Hays, C. 1986. Effects of the 1982-83 El Nino on Humboldt Penguin colonies in Peru. *Biological Conservation* 36:169-180.

Hays, C.G. 1984. The Humboldt penguin (Spheniscus humboldti) in Peru and the effects of the 1982-1983 El Nino. M.S. thesis, Univ. of Florida, Gainesville.

Healy, M.I. Breeding in a newly established exhibit of Black-footed penguins. *International Zoo Yearbook* 18, p.4042

Heath. 1987. A method for attaching transmitters to penguins. *Journal of Wildlife Management* 51:399-400.

Heath, R.G.M. and R.M. Randall. 1985. Growth of Jackass penguin chicks (Spheniscus demersus) hand reared on different diets. *Journal of Zoology* 205:91-105.

Heath, R.G.M. and R.M. Randall. 1989. Foraging ranges and movements of Jackass penguins (Spheniscus demersus) established through radio telemetry. *Journal of Zoology* 217:367-379.

Heezik, Y. van and Seddon, P.J. Effect of human disturbance on beach groups of Jackass penguins. *South African Journal of Wildlife Research*. 20, p.89-93

Hellmayr, C.R. 1932 The birds of Chile. Field Museum of natural History, Publication 308. Chicago, 472 p.

Henry, L., and F. Twohy. 1990. Hand-rearing guidelines for the Humboldt Penguin (Spheniscus humboldti) with special emphasis on common hand-rearing concerns. AAZPA Regional Proceedings, 1990. Reprinted in *Spheniscus Penguin Newsletter* Vol.4, nr.1:2-6.

Hildebrandt, Goritz, Bosch, Seidel and Pitra (1996) Ultrasonographic sexing and reproductive assessment of penguins. *Penguin Conservation* 9: 1 6-12

Hill, L.W. Penguin exhibit at Bourton on the water Bird park. *International Zoo Yearbook* 7, p.27-28

Hockey and Hallinan. 1981. Effect of human disturbance on the breeding behaviour of jackass penguins *Spheniscus demersus. South African Journal of Wildlife Research* 11:59-62.

Hori, H. The Humboldt penguin species survival plan of Japan. *Penguin Conservation*, Vol.8 nr.1 1995 p.4-5

Huff, C.G. 1962 Natural infection of Humboldt's penguin with Plasmodium elongatum. *J.Parasitol*. Vol.48 p.495

Hui, C.A. 1985. Maneuverability of the Humboldt penguin (Spheniscus humboldti) during swimming. *Canadian Journal of Zoology 63:2165-2167.*

Hui, C.A. 1988. Penguin swimming. II. Energetics and behavior. *Phys. Zool.* 61:344-350.

Hui, C.A. 1988. Penguin swimming. 1. Hydrodynamics. *Physiol. Zool.* 61:333-343.

Hull, C.L. 1997. The effect of carrying devices on breeding royal penguins. Condor 99(2):530-534.

Humboldt penguin SSP meeting, september 1995 *Penguin Conservation*, Vol.8, nr.2 p.13-14

Jackson, Siegfried and Cooper. 1976. A simulation model for the population dynamics of the jackass penguin, *Transactions of the Royal Society of South Africa* 42:11-21.

Jarvis, M.J.F. 1970 A problem in banding penguins. *Ostrich* 41: 120-121

Jehl, Jr. 1975 Mortality of magellanic penguins in Argentina. *Auk* 92(3): 596-598

Johann, A. and E.Schulze. Haltung, Zucht und Aufzucht von Humboldt Pinguinen (Spheniscus humboldti) im Tierpark Rheine. Zeitschrift des Kölner Zoo 30. 1987 pp.134-138.

Jouventin, P.1982. Visual and vocal signals in penguins: their Evolution and Adaptive Characters. Paul Prey, Berlin.

Judson, D. 1979 Quantitative study of the behaviour of the Humboldt penguin. Unp.Thesis, Linfield College. Mc.Minnville

Kerley, G.I.H. & Erasmus, T. 1986. A note on transporting oiled penguins. *South African Journal of Wildlife Research* 16:109-ill.

Kerley, G.I.H. & Erasmus, T. 1987 Cleaning and rehabilitation of oiled Jackass penguins. South African Journal of Wildlife Research. 17: 64-69

Kerley, Bowen and Erasmus. 1987. Fish behaviour-a possible role in the oiling of seabirds. *South African Journal of Wildlife Research* 17:128-130.

Knaus, R.M. 1990. Estimates of oil-soaked carcasses of the Magellanic penguin (Spheniscus magellanicus) on the eastern shore of the Peninsula Valdes, Chubut Prov., Argentina. Hornero, 13: 171-173

Koepeke. 1970. The Birds of the Department of Lima. Livingston, Wynnewood.

Kojima, I.1978. Breeding Humboldt's Penguins Spheniscus humboldti) at Kyoto Zoo. International Zoo Yearbook 18:53-59

Krapels, B. Kunstmatige opfok van Humboldt pinguins in het Noorder Dierenpark. *Harpij*.Vol.5(1): p.4-5

La Cock. 1986. The Southern Oscillation, environmental anomalies, and mortality of two southern American seabirds. *Climatic Change* 8:173-184.

La Cock. 1988. Effect of substrate and ambient temperature on burrowing African Penguins. *Wilson Bulletin* 100:131-134.

La Cock, G.D. and Hanel, C. 1987. Survival of African Penguins (Spheniscus demersus) at Dyer Island, southern Cape, South Africa. *Journal of Field Ornithology* 58:284-287.

La Cock and Cooper. 1988. The breeding frequency of Jackass Penguins on the west coast of South Africa. *Journal of Field Ornithology* 59:155-156.

La Cock, Duffy and Cooper. 1987. Population dynamics of the African penguin (Spheniscus demersus) at Marcus Island in the Benguela upwelling ecosystem: 1979-1 985. *Biological Conservation* 40:117-126.

Landowski, J. 1967 Breeding Humboldt's penguins at warsaw Zoo *International Zoo Yearbook* 7: 40-43

Laugksch and Duffy. 1986. Food transit rates in cape gannets and jackass penguins. *Condor* 88:117-119.

Leloup, M.J. The Black footed penguin Spheniscus demerus in Artis Zoo Amsterdam 1961-1982 In: *Bijdragen tot de dierkunde*, 52 (2): 61-81 (1982)

Lensink, B. & Dekker, D. Management of Black-footed penguins. *International Zoo Yearbook*, 18: p.35-40

Lensink-Busch, F.A. 1983 De omgangstaal van de zwartvoetpinguins in Artis. *Artis*, 29 (2), p.35-39

Lint, K.C. Care of penguins at san Diego Zoo. *International Zoo Yearbook*, 7 p.37-39
Linzmeier, D. Drum pruefe, wer sich ewig bindet… Partnerwahl bei Humboldt Pinguinen. In: *Zeitschrift der Koelner Zoo* 39, 161-169
Livezey, B. C. 1989. Morphometric patterns in recent and fossil penguins (Aves:Sphenisciformes). *Journal of Zoology* 219:269-307
Luna-Jorquera, G., B.M.Culik and R.Aguilar 1996 Capturing Humboldt penguins with the use of an anaesthetic. *Marine Ornithology* 24: 47-50
Luna-Jorquera, G. & B.M.Culik. Diving behaviour of Humboldt penguins in northern Chile. *Marine Ornithology*. 27: 67-76
Luna-Jorquera, G. , B.M.Culik and Aguilar-Pulido, R. 1997 Minimizing stress while capturing Humboldt penguins (Spheniscus humboldti) Mar.Ornit.
Luna-Jorquera, G. 1996 Balancing the energy budget for a warm-blooded bird in a hot desert and cold seas: the case of the Humboldt penguin. Dissertation at the University Kiel, Kiel, Germany.
Maclean, G.L. 1966 Cephalopod beaks from the stomach of a jackass penguin. *Zoologica Africana*, 2, p.27-30
Maher, S. and E.Dierenfeld. Testing a new vitamin supplement paste on penuins. In: *Penguin Conservation* Vol. 11, nr.2 1998 p.19-21
Majluf, P. Letter from Peru. *Wildlife Conservation*. March/april 1998 p.8-9
Mama, J.N.; King, A.S. 1987. A morphometric study of the lung of a Humboldt penguin (Spheniscus humboldti). *Anatomica-Histologia-Embryologia* 16:293-297.I
Manton, V.1978. Hand-rearing Humboldt's Penguin (Spheniscus humboldti) at Whipsnade Park. *International Zoo Yearbook 18:59-61*.
Maritz, W. Breeding and rehabilitation of Black footed penguins (Spheniscus demersus) at the east London Aquarium, *South Africa. Penguin Conservation*, Vol.8 nr.1 1995 p.3
Martin, G. 1985. Through a penguin's eye. *New Scientist* 14 March 1985:29-31.
Martin, G.R.; Young, S.R. 1984. The eye of the Humboldt penguin, Spheniscus humboldti*:* Visual fields and schematic optics. *Proc. R. Soc. Lond. Ser. B Biol. Sci.* 223:197-222.
McConkey, G.A.; Li, J.; Rogers, M.J.; Seeley, D.C., Jr; Graczyk, T.K.; Cranfield, M.R.; McCuthchan, T.F. 1996. Parasite diversity in an endemic region for avian malaria and identification of a parasite causing penguin mortality. J. *Eukaryotic Micro.* 43(5):393-399.
McGill, P. Humboldt penguin SSP Coordinator's report. *Spheniscus Penguin Newsletter*, Vol.1 nr.2 p.3
McGill, P. & G.Perkins. Humboldt penguin SSP report *Spheniscus Penguin Newsletter*, Vol.6 nr. 1 1993 p.2-4
McGill, P. Humboldt penguin SSP report 1994 *Penguin Conservation*, Vol.8, nr.2 p.11-12
McGill, P. Humboldt penguin SSP report *Penguin Conservation*.Vol.6 nr.3 1993 p.13-15
McGill, P. and G.Perkins. Humboldt penguin SSP report. In: *Spheniscus Penguin Newsletter*, Vol.4 nr.2 1991 p.1+18
McGill, P. 5 year action plan: Humboldt penguin SSP. *Penguin Conservation*, Vol.9 nr.2 1997 p.20
McGill, P. Humboldt penguin SSP report 1993 In: *Penguin Conservation* Vol.7 nr.3 1994 p.19-20
McGill, P. North American Humboldts: SSP report. In: *Penguin Conservation* Vol.4 nr.1 1991 p.1+7
McGill, P. (ed) Spheniscus penguins: workshop on field studies and captive management.

McGill, P. Spheniscus penguins: paneldiscussion on field studies and captive management. In: *Spheniscus Newsletter*, Vol.3 nr.1 1990 p.2-3,11

Merritt, K. and N.King. 1987. Behavioral sex differences and activity patterns of captive Humboldt Penguins (Spheniscus humboldti). *Zoo Biology* 6:129-138.

Michelmore, A.P.G. Breeding Black-footed penguins. *International Zoo Yearbook* 7 p.37

Miller, K.A. and Searles, S. 1991 The handrearing of Humboldt penguins. Proceedings of the 16th Annual Conference, American Association of zookeepers.

Moore.1982. Humboldt Penguins: husbandry at the Washington Park Zoo. *The A.F.A. Watchbird* Vol. 9(6):7-9.

Morant, Cooper and Randall. 1981. The rehabilitation of oiled jackass penguins Spheniscus demersus, 1970-1980. In J. Cooper (ed.). *Proceedings of the Symposium on the Birds of the Sea and Shore, 1979.* African Seabird Group, Cape Town, pp.267-301

Morgan, C.E. 1996 The Boulders Park African Penguin colony: a valuable ecotourism resource. MSc thesis. University of Cape Town, Rondebosch.

Mottershead, G.S. Penguin exhibit at Chester Zoo *International Zoo Yearbook*, 7 p.29

Müller, R. Penguin exhibit at Wuppertal Zoo. *International Zoo Yearbook*, 7 p.44

Murphy. 1936. Oceanic Birds of South America. Vol.I American Museum of Natural History, New York.

Myers, W.A. 1977 Scheduled displays of behaviour in captive Humboldt penguins. *Curator* 20 (2): 102-107

Nagy, Siegfried and Wilson. 1984. Energy utilization by free-ranging Jackass Penguins *Spheniscus demersus. Ecology* 65: 1648-1655.

Nakagawa, S. Penguin exhibit at Tokyo Zoo *International Zoo Yearbook* 7, p.39-40

Nakeeb, S.M., Babus, B., Jr., A.Y. 1981. Aspergillosis in the Peruvian penguin (Spheniscus humboldtf). *J. Zoo Anim. Med.* 12:51-54.

Nel, D.C. & Williams, A.J.W. Restoration of African penguins oiled in 1994 into the Dassen Island population. *Marine Ornithology*.

Nimon, A.J., Schroter, R.C., Oxenham, R.K.C. 1996. Artificial eggs: Measuring heart rate and effect of disturbance in nesting penguins. *Physiol. and Behav*. 60(3):1019-1022.

Paredes, R. & C.B.Zavalaga. Overview of the effects of El Nino 1997-1998 on Humboldt penguins and other seabirds at Punta San Juan, Peru. *Penguin Conservation*, Vol.11 nr.1 p.5-7

Penguin TAG. North American Regional Collection Plan. 1999-2001. Detroit Zoological Institute / AZA

Pennington, V. The use of radioimmunoassays to determine gender in Humboldt penguins. *Penguin Conservation*, Vol.9 nr. 1 1996 p.16-18

Perkins. 1983. Oiled Magellanic Penguins in Golfo San Jose, Argentina. *Marine Pollution Bulletin* 14:383-387.

Perkins. 1984. Breeding ecology of Magellanic Penguins (Spheniscus magellanicus) at Caleta Valdes, Argentina. *Cormorant* 12:3-13.

Petit, Th. Penguin malaria survey. In: EEP Yearbook 19961997 p.481-482

Radl, A. & B.M. Culik Foraging behaviour and reproductive success in Magellanic penguins (Spheniscus magellanicus): a comparative study of two colonies in Southern Chile. Marine Ornithology. (1994) 133: 381-393

Rahtet, I. Growth, husbandry, demography and success of captive and wild penguins.

Rand. 1949. Some early references to the Cape Penguin. *Ostrich* 20:2-5.

Rand. 1960. The distribution, abundance and feeding habits of the Cape Penguin (Spheniscus demersus) off the south-western coast of the Cape Province. I*nvestigational Report of the Division of Fisheries of the Union of South Africa* 41.

Rand, R.W. 1960 The biology of guano-producing seabirds. The distribution, abundance and feeding habits of the Cape penguin Spheniscus demersus off the Southwest coast of Cape Province. *Invest.Rep.Div.Fish. S.Afr.* no.41, 1-28

Randall. 1983. Biology of the Jackass Penguin (Spheniscus demersus) at St. Croix Island, South Africa. Phd. thesis. University of Port Elizabeth, South Africa

Randall and Randall. 1981. The annual cycle of the Jackass Penguin (Spheniscus demersus) at St Croix Island South Africa. In J. Cooper (ed.). *Proceedings of the Symposium on the Birds of the Sea and Shore, 1979.* African Seabird Group, Cape Town, pp.427-450.

Randall and Bray. 1983. Mortalities of jackass penguin *Spheniscus demersus* chicks caused by trematode worms *Cardiocephaloides physalis. South African Journal of Zoology 18 (1) : 45-46.*

Randall and Randall. 1986. The diet of jackass penguins (Spheniscus demersus) in Algoa Bay, South Africa, and its bearing on population declines elsewhere. *Biological Conservation* 37:119-134.

Randall, Randall and Bevan. 1980. Oil pollution and penguins - is cleaning justified ? *Marine Pollution Bulletin* 11: 234-237.

Randall, Randall and Baird 1981. Speed of movement of jackass penguins over long distances and their possible use of ocean currents. *South African Journal of Science* 77:420-421.

Randall, R.M., Randall, B.M. , Cooper and Frost. 1986a. A new census method for penguins tested on Jackass Penguins (Spheniscus demersus). *Ostrich* 57:211-215.

Randall, R.M. , Randall, B.M. and Erasmus, T. 1986b. Rain-related breeding failures in Jackass Penguins. Le *Gerfaut* 76:281-288.

Randall, R.M., Randall, B.M. , Cooper, J., La Cock, G.D. and J.B.Ross. 1987 Jackass Penguin Spheniscus demersus movements, inter island visits and settlement *Journal of Field Ornithology* 58:445-455.

Randall, R.M. & Bray, R.A. 1983 Mortalities of Jackass penguin chicks caused by trematode worms Cardiocephaloides physalis. *S.Afr.J.Zool*.18(1): 45-46

Randall, R.M., Randall, B.M. and Compagno. 1988. Injuries to Jackass Penguins (Spheniscus demersus*):* evidence for shark involvement. *Journal of Zoology 214:589-599*

Rebelo, A.G. 1984 Cape fur seals (Arctocepahlus pusillis) kills Jackass penguins (Spheniscus demersus) on land. *Cormorant*, 12. p.111

Reid, W.V. and Boersma, P.D. 1990 Parental quality and selction on egg size in the magellanic penguin. *Evolution*, 44, p.1780-1786

Riveros, J.C. and L.Paz-Soldán. 1992. Moult of the Humboldt penguin (Spheniscus humboldti). *Pacific Seabird Group Bulletin*. 19(1): 53-54

Ross, G.J. 1971 The Jackass penguin on St.Croix: a census. Eastn.cape Nat. 44: 22-24

Ross, G.J.B. and Randall, R.M. 1990. Phospatic sand removal from Dassen island: effect on penguin breeding and guano harvest. *South Africal Journal of Science*. 86, p.172-174

Ryan, M and W.S.Drieschman. Hand-rearing penguins with immediate introduction of solid food. *Penguin Conservation*. Vol.12, nr.2 (1999)

Ryan, P.G. , R.P. Wilson and J. Cooper. 1987. Intra-specific mimicry and status signals in juvenile African Penguins Spheniscus demersus. *Behavioural Ecology and Sociobiology* 20: 69-76.

Saburo and Scolaro. The eye of penguins, is it an adaptation for deep diving? *Comunicaciones biologicas* 6:225-232.

Samour, H.J. et al 1983 Sexing penguins by cloacal examination. *Vet.Record*. 113 (4): 84-85

Sarro, S.J. and S.Overholser African penguin SSP report 1996. *Penguin Conservation*, Vol.10, nr.1 1997 p.16-17

Sasaki, T. 1967 Breeding and care of Humboldt penguins Spheniscus humboldti at Kyoto Zoo International Zoo Yearbook 7: 31-32

Schlatter. 1984. The status and conservation of seabirds in Chile. In J. P. Croxall, P. G. H. Evans and R. W. Schreiber (eds.). *Status and Conservation of the World's Seabirds.* ICBP *Technical Publication* 2, pp. 261-269.

Schmidt, C.R. 1978. Humboldt's Penguins (Spheniscus humboldti) at Zurich Zoo. *International Zoo Yearbook* 18:47-52.

Schmidt-Nielsen, K., and W.J.L. Sladen. 1957. Nasal salt secretion in the Humboldt Penguin. *Nature* 181: 1217-1218.

Schneider, M. Bemerkungen zur natuerlichen und kuenstlichen Aufzicht von Humboldtpinguinen (Spheniscus humboldti) im Zoo Schwerin. In: *Zool.Garten*, 56 (1986) 6 p.425-429

Schofield, N.A. The effects of diet and feeding regimen on growth rates of Magellanic penguins. *Spheniscus Penguin Newsletter*, Vol.4 nr.2 1991 p.12-17,20

Scholten, C. Een analyse van de verzorging en opfok van Humboldt pinguins in het Noorder Dierenpark te Emmen. November 1987

Scholten, C.J. 1987. Breeding biology of the Humboldt Penguin (Spheniscus humboldti) at Emmen Zoo. *International Zoo Yearbook* 26:198-204.

Scholten, C.J. Individual recognition of Humboldt penguins In: *Spheniscus Penguin Newsletter*, Vol.2. Nr.1 1989 p.4-9

Scholten, C.J. 1990. The timing of moult in relation of age, sex and breeding status in a group of captive Humboldt Penguins. (Spheniscus humboldti) at Emmen Zoo, the Netherlands. *Netherlands Journal of Zoology*.

Scholten, C.J. Choice of nest-site and mate in Humboldt penguins. *Spheniscus Penguin Newsletter*, Vol.5 ,nr 1 1992 p.3-13

Scholten, C.J. 1991. Research on seabirds in captivity: a contradiction in terminis? Sula 5:41-49.

Scholten, C.J. Humboldt pinguins, zwart op wit. *Zoo-informatie Noorder Dierenpark* Emmen.Vol.12 (2)

Scholten, C.J. De kolonie Humboldt pinguins in het Noorder Dierenpark te Emmen van 1983 tot 1986. Unpublished report

Schumann, Ross and Goschen. 1989. Old water events in Algoa Bay and along the Cape South Coast, South America. *South African Journal of Science 84:579-584.*

Scolaro, J.A. 1983. The ecology of the Magellanic Penguin (Spheniscus magellanicus): a long-term breeding study of a temperate-latitude penguin in southern Argentina. M. Phil. thesis, University of Bradford, U.K.

Scolaro, J.A. 1984. Timing of nest relief during incubation and guard stage period of chicks in Magellanic Penguin (Spheniscus magellanicus) (Aves: Spheniscidae). *Historia Natural* 4 (29):28 1-284.

Scolaro, J.A. and L.A.Badno. 1986 Diet of Magellanic penguins (Spheniscus magellanicus) during the chick-rearing period at Punta Clara, Argentina. *Cormorant*. 13(2): 91-97

Scolaro, J.A. 1987 A model life table for magellanic penguins (Spheniscus magellanicus) at Punta Tombo, Argentina. *Journal of field ornithology* 68(4): 432-441

Scolaro, J.A. 1987 A model life table for magellanic penguins (Spheniscus magellanicus) at Punta Tombo, Argentina. *J.Field Ornithol*. 58(4): 432-441

Scolaro, J.A.. 1985. Vertebrate species associated to breeding sites in a colony of Magellanic Penguins (Spheniscus magellanicus) (Aves: Spheniscidae). *Historia Natural* 5:23-24.

Scolaro, J.A. 1987. Sexing fledglings and yearlings of Magellanic Penguins by discriminant analysis of morphornetric measurements. *Colonial Waterbirds* 1O:5O~54.

Scolaro, J.A.. 1987. A model life table for Magellanic Penguins *(Spheniscus magellanicus)* at Punta Tombo, Argentina. *Journal of Field Ornithology S8:4 32-41*.

Scolaro, J.A. 1990. Effects of nest density on breeding success in a colony of Magellanic Penguins (Spheniscus magellanicus). *Colonial Waterbirds*, Vol.13,1:4149.

Scolaro, J.A. M.A. Hall and I.M. Ximnez 1983. The Magellanic Penguin (Spheniscus magellanicus): sexing adults by discriminan analysis of morphometric characters. *Auk* 100:221-224.

Scolaro, J.A. and A.M.Suburo. 1991 Maximum diving depths of the Magellanic penguin. *Journal of Field Ornithology*, 62, p.204-210

Scolaro, J.A. and A.M.Suburo. 1995 Timing and duration of foraging trips in Magellanic penguins (Spheniscus magellanicus) *Mar.Orn*. 22: 231-235

Seddon, P.J. and Y.van Heezik. 1991 Effects of hatching order, sibling assymetrics and nest site on survival analysis of jackass penguin chicks. *Auk*, 108, p.548-555

Seddon, P.J. and Y.van Heezik. Parent-offspring recognition in the Jackass-Penguin. *Journal of Field Ornithology*. 64 (1): 27-31

Seddon, P.J. and Y.van Heezik. Behaviour of the Jackass penguin chick. *Ostrich* 64: 8-12

Shannon, L.J. & Crawford, R.J.M. Management of the African Penguin (Spheniscus demersus) insights from modelling. *Marine Ornithology* 27: 119-128

Shaugnessy, P.D. 1980 Influence of cape fur seals on Jackass penguin numbers at Sinclair Island. *South African Journal of Wildlife Research*. 10, p.18-21

Shelton, Crawford, Cooper and Brooke. 1984. Distribution, population size and conservation of the Jackass Penguin. Spheniscus demersus. *South African Journal of Marine Science* 2: 217-257.

Siegfried, W.R. 1977. Packing of Jackass Penguin nests. *South African Journal of Science* 73:186.

Siegfried, W.R. and Crawford. 1978. Jackass Penguins, eggs and guano: diminishing resources at Dassen Island. *S. African Journal of Science* 74:389-390.

Siegfried, W.R. Frost, P.G.H. Kinahan, J.B.and Cooper, J. 1975. Social behaviour of Jackass Penguins at sea. *Zoologica Africana* 10:87-100.

Simeone, A. Ecology and conservation of penguins in Chile. Symposium. *Penguin Conservation*, Vol.11 nr.1 1998 p.16-24

Simeone, A. & M. Bernal. Effects of habitat modifictaion on breeding seabirds: a case study in Central Chile.

Simeone, A. and M.Bernal. 1998 Intra-annual variations in the population size of the Humboldt penguin (Spheniscus humboldti) in Central Chile. *Penguin Conservation*. 11: 22

Simeone, A. and Schlatter, R.P. 1998 Threats to a mixed species colony of Spheniscus penguins on Southern Chile. *Colonial Waterbirds* 21(3), 418-421 (1998)

Simeone, A. , Bernal, M. and Meza, J. 1998. Incidental mortality of Humboldt penguins in gill nets, central Chile. *Marine Ornithology*, 27: 157-161

Simpson. 1976. Penguins: past and present here and there. Yale, New Haven.

Sivak, J., H. Howland, and P. McGill-Harelstad. 1987. Vision of the Humboldt penguin (Spheniscus humboldti) in air and water. *Proceedings of the Royal Society B* 229:467-472.

Sladen, W.J.L. 1954 Penguins in the wild and in captivity. *Avicult.Mag*. 60: 130-142

Sladen, W.J.L. 1952 Notes on methods of marking penguins. *Ibis* 94: 541-543

Sladen, W.J.L. Sexing penguins by cloacascope. *International Zoo Yearbook*, 18, p.77-80

Sladen, W.J.L., R.C. Wood and E.P.Monagahn. 1968 The USARP Bird banding program. 1958-1965. In: *Antarctic Bird Studies* (O.L.Austin, Jr. ed) Amer.Geophysical Union, Antarctic Research Series. Vol.12. washington D.C.

Slager, Chr. and J.D. Hewitt. 1987 An overview of Black-footed penguin husbandry at Steinhart Aquarium. *Annual proceedings of the AAZPA*, 297-300

Snazle, H.A. Penguin exhibit at Chessington Zoo *International Zoo Yearbook*, 7 p.28

Soto-Gamboa, M. , M.Rosenmann, F.Bozinovic. Thermal ecology of the Humboldt penguin (Spheniscus humboldti): effects of nest-site selection on adults and chicks survival. *Revista Chilena de Historia Natural*. 72: 447-455 (1999)

Starzynski, W. and J.Krazaczynski. Intestinal parasitism in Humboldt penguins (Spheniscus humboldti), due to the Trematode Cotylurus pileatus. *Vet.Rec*.1965, 77 (45): 1309

Stevenson, M.F. Penguins in captivity. In: *Avicultural Magazine*. Vol.89 Nr.4 1984

Stoddard, P. Aspergillosis: Biologic treatment in fungus diseases. *Spheniscus Penguin Newsletter*, Vol.3 nr.1 1990 p.10-11

Stokes, D.L. 1994 Nesting habitat use, value, and selection in the Magellanic penguin (Spheniscus magellanicus). Ph.D.Dissertation. University of Washington, Seattle.

Stokes, C. and P.D.Boersma. 1991 Effects of substrate on the distributon of Magellanic penguins (Spheniscus magellanicus) *Auk* 108: 923-933

Stokes, D. L. and P.D.Boersma. Satellite tracking of magellanic penguin migration. In: *The condor*. 100: 376-381 1998

Stokes, D.L. & P.D.Boersma. Where breeding Magellanic penguins (Spheniscus magellanicus) forage: satellite telemetry results and their implications for penguin conservation. *Marine Ornithology* 27: 59-65

Stokes, D.L. and P.D.Boersma. 1998 Nest-site characteristics and reproductive success in Magellanic penguins (Spheniscus magellanicus) *Auk*, 115: 34-49

Stonehouse, B. (ed) The biology of penguins. Baltim.Univ.Park Press / McMillan Press Ltd. London 1975

Stonehouse, B. Drent, R.H. 1976 Thermoregulatory responses of the Peruvian penguin Spheniscus humboldti. *Comp.Biochem.Physiol*. 40A: 689-710

Stonehouse, B. 1967 The general biology and thermal balance of penguins. *Advances in Ecological Research 4*: 131-196

Stosfkopf, M.K. The husbandry and medicine of captive penguins. *Annual proceedings of the American Association of zoo veterinarians* 1983 p.81-96

Stosfkopf, M.K. et al. 1980 Baseline hematology of the African Blackfooted penguin (Spheniscus demersus). *Proceedings 1st International Symposium Comparative Pathology*, Washington, DC Smithsonian Press, pp.647-652

Sullivan, M.S. 1994 Mate choice as an information gathering process under time constraint: implications for behaviour and signal design. *Animal Behaviour* 47: 141-151

Thompson, K.R. 1992 Intersite variation in Magellanic penguin Spheniscus magellanicus diet in the falkland Islands: implications for monitoring. *Corella*, 16, p.151

Thompson, K.R. 1993 Variation in Magellanic penguin (Spheniscus magellanicus) diet in the Falkland Islands. *Mar.Ornit.* 21: 57-67

Todd, F. 1978. Controlled environment maintenance and propagation of penguins. *Proceedings of 1st International Birds in Captivity Symposium*, 1978. A.C. Risser, Jr. et al (eds.) pp.446-451.

Todd, F. Penguin husbandry and breeding at Sea World, San Diego. *International Zoo Yearbook*, 18, p.72-77

Todd, F. Penguin propagation at Sea World. San Diego 1979/1980

Tollini, J. Gull, gull, go away ! In: *Spheniscus Penguin Newsletter*, nov.1990 p.18

Tollini, J. 2000 Prevention and treatment of avian malaria etc. *Penguin Conservation.* Vol.13.No.1

Turner, W.A. and L.Plutchak Sea world california penguin handrearing guidelines. *Penguin conservation* Vol.11, 2 1998 p.2-9

Underhill, L.G. et al. Mortality and survival of African penguins. Spheniscus demersus involved in the Apollo Sea oil spill: an evaluation of rehabilitation efforts. *Ibis*

Venizelos, N. et al. Preliminary results of the San Francisco Zoological Gardens Magellanic penguin (Spheniscus magellanicus) program. *AAZAPA Annual Conf.Proc*. 250-269

Wallace, R.S. et al. Hematology and plasma chemistry values in free-ranging Humboldt penguins (Spheniscus humboldti) in Chile. *Zoo Biology* Vol.14 nr.4 (1995) pp.311-316

Wallace, R.S. et al. Disease surveillance in free-ranging Humboldt penguins (Spheniscus humboldti) in Chile. Proceedings American Association of zoo veterinarians. Pp.284-285

Wallace, R.S. et al. Movements of Humboldt penguins from a breeding colony in Chile. Waterbirds. 22 (3): 441-444 (1999)

Wallace, R.S., Teare, J.A. e.a. Plasma tocopherol, retinol, and caretenoid concentrations in free-ranging Humboldt penguins (Spheniscus humboldti) in Chile. Zoo Biology, 15: 127-134 (1996)

Wallace, R.S., Crissey, S.D. Willis, M.J. McGill, P. The effect of dietary vitamin A and E on serum status of Humboldt penguins. *Spheniscus Penguin Newsletter* 5(1): 14-20, 1992 p.14-21

Westphal, A. and M.K. Rowan. 1971. Some observations on the effects of oil pollution on the jackass penguin (Suppl.) 8: 521-526.

Whittingdon, P. A. The contribution made by cleaning oiled African penguins (Spheniscus demersus) to population dynamics and conservation of the species. *Marine Ornithology.* 27: 177-180

Whittington, P.A., Dyer, B.M. & Klages, N.T.W. Longevity of Jackass penguins on islands off South Africa (marine Ornithology)

Wilkinson, C.P. et al. African penguins (Spheniscyus demersus) along the Kwazulu Natal Coast. 1981-1999. *Marine Ornithology*. 27: 111-113

Willebrands, N.; Buitelaar, M.N.; Dorrestein, G.M. 1984 Plesiomonas shigelloides bij zwartvoetpinguins in Artis. *Referaat faculteit Diergeneeskunde*, Utrecht

Williams, A.J. et al. Penguins of the world: a bibliography. Cambridge, British Antarctic Survey

Williams, A.J. 1995 Factors to consider in the capture and transport of penguins. In: Barrett, J., Erasmus, Z. and Williams, T. (eds). Proceedings coastal oil spills: effect on penguin communities and rehabilitation procedures, Tygerberg Nature Reserve November 1994 (Cape Town): Cape Nature Conservation, pp.15-18

Williams, M.G. The new Humboldt penguin pool at Drusillas Park.

Williams, A.J. and J.Cooper. 1984. Aspects of the breeding biology of the Jackass Penguin (Spheniscus demersus). *Proceedings of the Fifth Pan African Ornithological Congress*, pp.841-853.

Williams, G., K.Ghebremeskel, L.F.Keymer and D.T.Horsley. 1989 Plasma a-tocopherol, total lipids and total choresterol in wild Rockhopper, Magellanic and Gentoo penguins before and after moulting. *Vet.Rec*. 124: 585-586

Williams, A.J., Crawford, R.J.M., Nel, D.C., Underhill, L.G. in press. The rescue, rehabilitation and restoration of oiled African penguins and Cape gannets in Southern Africa. In Wiens, J.A. and tasker, M. (eds): Seabirds and oil pollution. Cambridge: Cambridge University Press.

Williams, M.G., L.P. Golding, and R.R. Golding. 1987. Breeding and Rearing the Humboldt Penguin (Spheniscus humboldti) at Cotswold Wildlife Park, Burford: the development of a successful hand-rearing technique. *Aviculture* 93(2).

Williams, T.D. The penguins. Oxford University Press. 1995

Wilson, R.P. 1984. An improved stomach pump for penguins and other seabirds. *Journal of Field Ornithology* 55:109-112.

Wilson, R.P. 1985. Diurnal foraging patterns of the Jackass Penguin (Spheniscus demersus). *Ostrich* 56:212-214.

Wilson, R.P. 1985. The Jackass Penguin (Spheniscus demersus) as a pelagic predator. *Marine Ecology Progress Series 25:219-227.*

Wilson, R.P. 1985. Seasonality in diet and breeding success of the Jackass Penguin (Spheniscus demersus). *Journal fur Ornithologie* 126: *53-62.*

Wilson, R.P. and M.P.T.Wilson. 1989 Substitute burrows for penguins on guano free islands. *Le Gerfaut* 79: 125-132

Wilson, R.P. and Bain. 1984. An inexpensive speed meter for penguins at sea. *Journal of Wildlife Management* 48:1360-1364.

Wilson, R.P. and Bain. 1984. An inexpensive depth gauge for penguins. *Journal of Wildlife Management* 48:1077-1084.

Wilson, R.P. and Achlelter. *1985.* A distance meter for large swimming marine animals. *South African Journal of Marine Sciences 3:191-195.*

Wilson, R.P. and Duffy. 1986. Prey seizing in African penguins (Spheniscus demersus). *Ardea* 74:211-214.

Wilson, R.P. and M.P.Wilson. 1988. Dead reckoning: a new technique for determining penguin movements at sea. *Meeresforschung 32:155-158.*

Wilson, R.P. and M.P.Wilson. 1989. Tape: a package attachment technique for waterbirds, *Wildlife Society Bulletin* 17.

Wilson, R.P. and M.P.Wilson. 1989. A peck activity record for birds fitted with devices. *Journal of Field Ornithology* 60:104-108.

Wilson, R.P. and M.P.Wilson. 1989. A minimal-stress bird-capture technique. *Journal of Wildlife Management 53:77-80.*

Wilson, R.P. and M.P.Wilson. 1990. The foraging ecology of breeding Spheniscus penguins. In. J. Darby and L. Davies (eds.). *Penguins.* Academic Press, Orlando, Florida.

Wilson, R.P. and D.Gremillet. 1996 Body temperature of free-living African penguins (Spheniscus demersus) and Bank cormorants (Phalacrocorax neglectus). *Journal experimental biology*. 199: 2215-2223

Wilson, R.P., et al. 1995 Forgaing areas of Magellanic penguins (Spheniscus magellanicus) breeding at San Lorenzo, Argentina, during the incubation period. Marine Ecology Progress Series. 129: 1-6

Wilson, La Cock, Wilson and Mollagee. 1985. Differential digestion of fish and squid in Jackass Penguins (Spheniscus demersus) *Ornis Scandinavica* 16:77-79.

Wilson, Grant and Duffy. 1986a. Recording devices on free-ranging marine animals: does measurement affect foraging performance? *Ecology* 67:1091-1093.

Wilson, Wilson and McQuaid. 1986b. Group size in foraging African Penguins (Spheniscus demersus). *Ethology* 72:338-341.

Wilson, Ryan, James and Wilson. 1987. Conspicuous coloration may enhance prey capture in some piscivores. *Animal Behaviour 35:1558-1560.*

Wilson, Wilson and Duffy. 1988. Contemporary and historical patterns of African Penguin (Spheniscus demersus) distribution at sea. *Estuarine, Coastal and Shelf Science* 26:447-458.

Wilson, R.P., Duffy, D.C., Wilson, M.P. and Araya, B. 1995 Aspects of the ecology of species replacement in Humboldt and Magellanic penguins in Chile. *Gerfaut* 85: 49-61

Wilson, Ryan and Wilson. 1989b. Sharing food in the stomachs of seabirds between adults and chicks-a case for delayed gastric emptying. *Comparative Biochemistry and Physiology* 94A:461466.

Wilson, R.P., M.P. Wilson, D.C. Duffy, M.B. Araya, and N. Klages. 1989. Diving behaviour and prey of the Humboldt Penguin (Spheniscus humboldti). *Journal fur Ornithologie* 130:75-79

Yamazaki, Y. et al. Sex determination of Humboldt penguins using an original designed restraint. In: *Penguin Conservation* Vol.7, nr.3 1994 p.7-9,11

Yorio, P and P.D.Boersma. 1994 Consequences of nest desertion and inattendance for Magellanic Penguin hatching success. *Auk*, 111 (1994): 215-218

Yorio, P. and P.D.Boersma. Causes of nest desertion during incubation in the Magellanic penguin (Spheniscus magellanicus) Condor 96: 1076-1083

Yorio, P. and P.D.Boersma. 1992 The effects of human disturbance on Magellanic penguin behaviour and breeding success. *Bird Conser.International* 2: 161-173

Zavalaga, C.B. and R.Paredes. 1997 Humboldt penguins at Punta San Juan, Peru. *Penguin Conservation.* 10(1): 6-8

Zavalaga, C.B. and R.Paredes 1997 Sex determination of adult Humboldt penguins using morphometric characters. *The Journal of field ornithology*. 68(1): 102-112