MANAGEMENT OF PENGUIN POPULATIONS IN NORTH AMERICAN ZOOS AND AQUARIUMS

E.N. DIEBOLD[1], S. BRANCH[2] & L. HENRY[3]

[1]*Riverbanks Zoological Park and Botanical Garden, PO Box 1060, Columbia, South Carolina 29202-1060, USA (ediebold@riverbanks.org)*
[2]*Sea World of Florida, 7007 Sea World Drive, Orlando, Florida 32821-8097, USA*
[3]*Sea World of California, 1720 South Shores Drive, San Diego, California 92109-7995, USA*

SUMMARY

DIEBOLD, E.N., BRANCH, S. & HENRY, L. 1999. Management of penguin populations in North American zoos and aquariums. *Marine Ornithology* 27: 171–176.

The North American zoo community has made great strides towards collaborating in the management of captive penguins on the subcontinent. Organized captive management programmes such as that of the American Zoo and Aquarium Association Species Survival Plan (SSP) and Penguin Taxonomic Advisory Group (TAG) have enhanced the zoo community's ability to contribute to penguin conservation through captive breeding, population management and education. These advances are summarized, including improvements in captive husbandry, development of a penguin husbandry manual, enhanced space utilization for captive penguin management, and development of a Penguin Regional Collection Plan.

INTRODUCTION

North American zoological gardens and aquariums (hereafter referred to as zoos) have undergone incredible change in the last 15 years. The primary impetus for this change came in 1980 when the Board of Directors of the American Zoo and Aquarium Association (AZA), formerly the American Association of Zoological Parks and Aquariums, or AAZPA, designated conservation as its first priority. Previously, animal managers concentrated on individual animals in their own institutions but it had become clear that cooperation between zoos was essential if long-term wildlife conservation was to benefit.

The AZA Species Survival Plan (SSP) concept was developed in 1981 to correlate species level management and was the cornerstone on which AZA's conservation ethic was built (AZA Conservation and Science Office 1995a). Initially SSPs concentrated on maintaining healthy, self-sustaining groups of selected species in genetically diverse and demographically stable captive populations. SSPs also grew rapidly to include public education, research, collaboration with the academic community, re-introduction, technology transfer and field conservation.

Prior to 1980, decisions concerning what species to maintain in North American zoos were based on personal preference, competition with other zoos and availability (Diebold & Hutchins 1991). The adoption of SSPs markedly changed the amount of inter-zoo co-operation in respect particularly of targeted species. This cooperative spirit infiltrated captive management on all levels. Recent appraisals of the space available for long-term captive management plans has focused zoos on the urgent need for cohesive planning of collections. To this end the Taxon Advisory Group (TAG) concept was proposed in 1990.

TAGs are essentially committees of experts in specific taxonomic groups of animals, usually at the ordinal or family level. Through regional collection planning TAGs carry out a systematic analysis of captive holding space for the group(s) under study and recommend new AZA studbooks, SSPs and other zoo programmes (AZA Conservation and Science Office 1995b). The above 'region' refers to the zoos of North America, and other regions (Europe, Australasia, etc.) do the same. TAGs establish priorities for management and research and appoint individuals to these assignments. A detailed perspective on the evolution of these processes locally and internationally, is given by Hutchins *et al.* (1995).

AZA PENGUIN TAXON ADVISORY GROUP

The AZA Penguin TAG was established in August 1992, and set the following goals and objectives:

1. Penguin husbandry manual: publishing, distributing and updating;
2. Space utilization: locating additional captive space and setting priorities for utilization of current space;
3. Regional Collection Plan (RCP): developing and implementing a Regional Collection Plan for penguins in North America to best serve AZA's conservation mission; and
4. Communication liaison: to liaise between zoo biologists and captive collection managers, the academic community and the field research community.

Penguin husbandry manual and advances in captive husbandry

According to the International Species Information Systems (ISIS BIRD ABSTRACT 1995) there are currently over 50 North American zoos which maintain one or more species of penguins. However, their ability to maintain these populations cannot be taken for granted. Early attempts to keep penguins in captivity were often unsuccessful (Simpson 1976, Austin 1978). In those early years a poor understanding of environmental requirements led to excessive morbidity and mortality, with only sporadic reproductive success (Simpson 1976, Gailey-Phipps 1978).

The pioneering efforts of institutions such as the Edinburgh Zoo in the United Kingdom, the New York Zoological Society and the Sea World Organization (Todd 1983) have improved penguin husbandry techniques enormously. Over the years individual zoos had accumulated a great mass of information on various aspects of penguin management but until recently no attempt had been made to combine this into one document.

To rectify this, the AZA Penguin TAG in 1993 set out to gather these data from the institutions managing penguins and to organize them into one inclusive reference document. A comprehensive Penguin Taxon Advisory Group Survey (PTS) was distributed to all AZA institutions holding penguins. As a result of the new spirit of cooperation many penguin management protocols, developed by individual zoos over many years, were compiled. From these protocols and their own research, penguin experts in each area distilled standards, recommendations, and protocols and published them as the AZA Penguin Husbandry Manual (Ellis & Branch 1994). Most of the organizational work was done during an intensive three-day workshop funded by the AZA Conservation Endowment Fund (CEF). The Penguin Husbandry Manual has six chapters:

1. Housing and enclosure requirements;
2. Management;
3. Behaviour and social organization;
4. Reproduction;
5. Nutrition; and
6. Health.

For the penguin manager it provides a compendium of state-of-the-art knowledge in penguin husbandry. Copies of the manual are available from Tom Schneider, Penguin TAG Co-chair, Curator of Birds, Detroit Zoological Park, 8450 West Ten Mile Road, Royal Oak, Michigan 49068-0039, USA.

Studies of the natural needs of penguins have led to great improvement in zoo exhibits. Indoor displays now have excellent ventilation, water quality controls and reliable thermostability. Artificial light replicates conditions in the wild. Artificial rocks and snow are produced as needed. Sea World of California led the way with the opening of their Penguin Encounter (Todd 1983), and subsequently has built three more penguin habitats. Other zoos have followed and surfaces, nesting areas and water quality are now reliably excellent.

Common diseases such as aspergillosis, bumblefoot (pododermatitis) and avian malaria are now better understood. Aspergillosis is considered to be secondary to stress resulting from inadequate exhibit/nest environments, shipping, moult and other underlying diseases (Stoskopf & Beall 1980). However, high risk situations are now better understood and can be avoided (Harrison & Harrison 1986). A number of strategic changes includes moving birds at night and in cooler weather, providing companionship during quarantine, and administration of antifungal medications pre- and post-transfer. Early detection is important, and attempts are being made to develop ELISA or similar diagnostic tests (Brown & Redig 1994, Redig 1994, Redig *et. al*. 1997). Standard blood counts and blood chemistry are also helpful, yet aspergillosis remains difficult to control (Reidarson & McBain 1992).

Bumblefoot is now much less common due to better exhibit surfaces and easy, frequent cleaning; special track materials and horizontal self-draining surfaces have been important advances. Monitoring remains important and when an outbreak does occur, better treatment, combining surgery with systemic and topical treatment and better protection of the affected area, has reduced morbidity. Sea World of California has designed a protective shoe (called an 'iceflo') constructed from Neoprene, which protects the foot during healing and reduces the formation of scar tissue (Burch & Reidarson unpubl. ms).

The treatment of avian malaria may see the most exciting of these advances. Current protocols require constant vigilance for signs of infection (e.g. lethargy, loss of appetite, pale mucous membranes and separation from the group). Baltimore Zoo has been researching this problem for three decades in African Penguins *Spheniscus demersus*. Working together with Johns Hopkins University and the National Institutes of Health, the Baltimore Zoo is close to producing a vaccine to protect the penguins from malaria. Human health researchers are working in the same field, and the applications may be interlinked (S. Sarro pers. comm.).

Proper nutrition is essential for good health. Dietary guidelines are based on studies of feeding ecology, known nutrient needs, food preferences and food availability to zoos (Ellis & Branch 1994). Many facilities now use a wide variety of fish and vitamin supplements (PTS 1993). An unpublished study (Mellen & Cheney unpubl. ms) and work by Wallace *et al*. (1995, 1996) have added to our knowledge of the food requirements of captive penguins.

Food shortages loom as a threat to both captive and wild penguins. Diminished commercial fish catches have made it difficult for zoos to obtain appropriate food fish for their penguins. In anticipation of future shortages, Sea World and Mazuri (a subsidiary of Purina Mills) started discussions in late 1995 with a view to developing an artificial fish with predictable and uniform food values. They undertook palatability studies on Gentoo *Pygoscelis papua*, Rockhopper *Eudyptes chrysocome* and King *Aptenodytes patagonicus* Penguins. As a result a semi-firm gelatin-based 'fish' *c.* 18–20-cm long, tapering at both ends and flattened on the sides was developed.

In March 1996 testing started on five King Penguin chicks, all approximately 60 days old. Three birds were fed artificial fish and the other two acted as controls. Initially all birds were given a diet of real fish consisting of 75% herring *Clupea harengus* and 25% capelin *Mallotus villosus*, approximating their normal captive diet. At weekly intervals the test birds were given part of their diet in artificial form, in increments of 25% per week so that at the end of five weeks they were eating only artificial 'fish'. Blood samples were taken from all penguins on days 0, 30, 60 and 90. The test birds readily accepted the new diet. Growth was satisfactory and comparable in all birds. Thirty-day blood samples showed no significant differences in blood values between the two groups.

However at 60 days uric acid levels in the test birds were high. This and other indications suggested dehydration. Several days of extra fluids, per tube and subcutaneously, restored the birds and their blood values. The manufacturers established that there was some water loss during the freezing process (from an expected 75%w/v to about 68–70%). This was corrected and fat content was increased from 7 to 9%. Blood samples at 90 days were within normal limits.

In April 1996, five King, five Rockhopper and five Gentoo Penguins (all adults) were started on a six-month maintenance diet study, using two birds in each group as controls. The

'second generation' artificial food with a higher water and fat content is softer than the original trial 'fish' and all birds readily converted to it. The food is kept frozen and allowed to air thaw for 24 hours then briefly water thawed on the day of use to remove remaining ice crystals and to ensure complete thawing. To date, all birds (both study and control) have gained mass, with the exception of one King Penguin which was a little overweight at the commencement of the trial. Results of digestibility trials commenced in July 1996 are not yet available.

Improvements in husbandry skills have led to great success in maintaining captive penguins in North American zoos, which in turn has led to a much lower reliance on capturing penguins in the wild. The increase in the percentage of captive versus wild hatched birds in North American zoos is illustrated in ISIS data for the last four years (Table 1). The data reflect an 81% decrease in zoo reliance upon wild-hatched penguins.

Space utilization

Because of differences in biology and in environmental needs, existing captive spaces are not interchangeable between all penguin taxa, but should be divided into two groups: 1. for *Spheniscus* spp.; and 2. for all other taxa. The AZA Penguin TAG immediately recognized the difficulty with allotting space for *Spheniscus*. They are the most numerous and widely distributed among North American zoos. Three of the four *Spheniscus* penguin species are currently held in captivity, namely African, Humboldt *S. humboldti* and Magellanic *S. magellanicus.*

When the TAG was formed in 1992 the Humboldt Penguin had already been designated as an SSP species and 252 birds were held in captivity (Perkins 1992). To meet desired genetic and demographic goals, the SSP had suggested 350 as the target population size. It also recommended expanding the numbers rapidly to meet that target. At that time the African Penguin had a North American Regional Studbook, but no associated genetic or demographic management plan. The captive population numbered 590 and was expanding rapidly (Sarro 1992). The Magellanic Penguin population was stable at about 150 birds but was not being monitored by a studbook.

Based on a wild population estimate of well over one million birds with relatively stable numbers and apparently limited threats to their future, the TAG initially recommended eliminating captive Magellanic Penguins by attrition in favour of expansion for the more threatened Humboldt and African members of the genus. It had also become apparent that the space available for Humboldt Penguins in North America was saturated, forcing the SSP to call a halt to breeding, with the only exception of genetically valuable birds (e.g., wild-caught with no living offspring). However, this was clearly contrary to the goal of increasing the population size to 350.

In order to address the shortage of space for *Spheniscus* penguins the TAG recommended the African Penguin be upgraded to an SSP species. The resultant genetic and demographic analysis of the existing population led to a decision to limit breeding in this species as well (except for genetically valuable birds). At the same time AZA institutions were asked to create more space for Humboldt Penguins.

Support of the TAG-recommended breeding moratoriums gave the TAG time to assess and reallocate *Spheniscus* space. With the creation of additional Humboldt Penguin spaces, the Humboldt Penguin SSP has been able to allow breeding to recommence. The African Penguin SSP has also been able to start limited breeding again. Finally, as a result of all these studies, the Magellanic Penguin is no longer doomed to disappear from captive sites. It will be maintained at a stable number slightly lower than at present.

Prior to the era of broad-based strategic planning produced by the activities of TAGs, this type of management would not have been possible. Available penguin holding space would not have been so well used and the prospects for future collaborative management would not have been so great.

AZA Penguin TAG Regional Collection Plan

In January of 1996 the TAG convened to create a first draft of a Regional Collection Plan (RCP) for penguins. The TAG decided that each species of penguin to be managed in North America zoos will be assigned to one of following Management Categories, as described below.

Species Survival Plan

A Species Survival Plan (SSP) species is intensively managed. A studbook will be maintained and a Species Coordinator and Management Group will be established. A genetically viable and demographically stable population will be maintained for long-term conservation purposes. A Masterplan will be generated and implemented for each SSP species. SSPs require a signed Memorandum of Participation (MOP) from each institution taking part in the programme.

Population Management Plan

A Population Management Plan (PMP) species is the subject of a studbook and is a species that requires genetic and demographic analysis and management (but not as intensively as an SSP species). Species in this category may be upgraded to SSP

TABLE 1

Summary of ISIS data for all penguin species maintained in North American zoos between 1992 and 1995

Year	Captive hatched (%)	Wild hatched (%)	Hatched last 12 months	Deaths at <30 days
1992	76	19	417	130 (31%)
1993	78	18	371	93 (25%)
1994	79	17	368	75 (20%)
1995	81	15	511	111 (22%)

status at a future date, or downgraded to the Stable Population category (see below) once the desired population levels are attained.

Stable population

A species designated as a having a stable population will require some management, although not as intensively as a PMP species. No studbook is required. Growth of the population will be controlled and in some cases population size reduced.

Model species

A Model species is usually held by only a few institutions and is used for husbandry, reproductive, nutritional or other research. These species are maintained as needed to continue research, but not supplied to other institutions, unless needed for additional studies.

Phase-out species

Species currently in AZA collections but designated to be phased out in order to provide priority taxa with needed space.

Phase-in species

Species not currently held in AZA collections but that may be acquired in the future. Prior to efforts to acquire such species, a comprehensive management plan will be developed. For a summary of species recommendations made by the Penguin TAG Regional Collection Plan, see Table 2.

General penguin TAG recommendations

- Send a TAG representative to EEP Penguin meeting in Europe.
- Develop education programmes for North American institutions (Penguin Conservation Education Resource Manual).
- Develop action network.
- Create opportunities to interact with penguin field biologists. Invite penguin field biologists to TAG meetings to discuss areas of common interest.
- Recommend that the TAG be used as resource for institutions planning new penguin exhibits and acquiring new birds.
- Recommend that any additional birds removed from the wild should be done so only with TAG endorsement and in accordance with goals and objectives of the Penguin RCP.
- Recommend that new penguin exhibits be as flexible as possible in terms of species composition.
- Promote *in-situ* penguin conservation.

Penguin TAG five-year action plan projects

Each AZA conservation committee, including SSPs, TAGs, Fauna Interest Groups (FIGs), and Scientific Advisory Groups (SAGs) is charged with developing a Five-Year Action Plan intended to stimulate the development of on-the-ground conservation initiatives. These Five-Year Action Plans are to outline five to six projects, at least one of which is to be an *in-situ* conservation initiative and at least one other to focus upon conservation education. Projects identified in the various Five-Year Action Plans are given priority for funding from the AZA Conservation Endowment Fund (CEF). A preliminary list of Penguin TAG Five-Year Action Plan projects is given below.

Development of educational Humboldt Penguin posters to be distributed along the coast of Chile and Peru. The posters are to tell the story of the importance of preserving the Humboldt Penguin and its rich marine environment, the Humboldt Current.

Artificial nest sites for Humboldt Penguins nesting at Algarrobo, Chile. Many nests are destroyed due to heavy rains. These artificial nest sites would be designed to withstand heavy rains.

Chinstrap Penguin moult research. The Chinstrap Penguin in captivity is plagued by an abnormal moulting syndrome resulting in disheveled plumage. This research is aimed at resolving this problem.

Spheniscus hybridization study. There is concern that there may be some hybrid *Spheniscus* in North American zoo collections. This research will use molecular techniques to discern the presence of hybrid birds so they may be removed from the captive populations.

Communication liaison

The AZA Penguin TAG is committed to increasing communication and cooperation between the penguin captive breeding community and the academic and field research community. Discussions held at the Third International Penguin Conference in Cape Town, South Africa in September 1996 and the subsequent Penguin Conservation Assessment and Management Plan (CAMP) Workshop (Ellis *et al.* 1998) helped to elucidate issues of common interest/concern to both communities (e.g. management strategies for small, fragmented populations, development of new band designs, reintroduction techniques, questions of taxonomy, telemetry and tracking, etc.). The TAG offers its combined expertise and resources to supporting efforts that contribute to a better understanding of penguins and their conservation in captivity and in the wild.

CONCLUSIONS

Advances in penguin husbandry expertise and collaborative and strategic collection planning methods have enhanced the North American zoo community's ability to contribute to penguin conservation through captive breeding, population management and education. Although it will always be the goal of penguin managers in this region to provide the highest standards of care for captive populations, the AZA Penguin TAG seeks ways to expand its role in terms of collaborations aimed at creating a better understanding of penguins and their conservation in their natural habitats in the wild.

Zoos reach enormous numbers of people each year. The combined attendance at AZA zoos alone stands at around 120 million people annually. This places zoos in a unique position to reach people with their conservation message. The development of strong links between *ex-situ* penguin management and *in-situ* conservation efforts will enhance this conservation message, thus strengthening the role of zoos in penguin conservation.

Although the scope of this paper has been limited to activities in the North American zoo community, similar strides are being made in other zoo regions of the world. International cooperation and collaboration amongst zoo regions is becoming commonplace. The Conservation Breeding Specialist Group

TABLE 2

Summary of species recommendations made by the Penguin Taxon Advisory Group Regional Collection Plan

Species	Captive status[1]		Management category	Justification
Emperor Penguin *Aptenodytes forsteri*	26.25.4 (55)[2]		Stable population	Reproduction, husbandry and basic research. Education; flagship species
King Penguin *A. patagonicus*	42.53.81 (176)	Target: 150	PMP	Large captive population breeds well and needs management. Charismatic, flagship species
Adélie Penguin *Pygoscelis adeliae*	33.37.109 (179)		Stable population	Visitor appeal, education, and conduct opportunitic research
Chinstrap Penguin *P. antarctica*	162	Target: 200	Model population; possible PMP	Research abnormal moulting syndrome. Make contacts re: survey at South Sandwich Islands
Gentoo Penguin *P. papua*	46.53.150 (259)	Target: 250	Stable population	Visitor appeal, education. Investigate taxonomy
Southern Rockhopper Penguin *Eudyptes c. chrysocome*	23.24.164 (211)	Target: 300	PMP	Surrogate species for vulnerable crested species, husbandry expertise
Northern Rockhopper Penguin *E. c. moseleyi*	13.15.15 (43)	Target: 0	Phase-out species	Maintain only one subspecies of Rockhopper Penguin
Macaroni Penguin *E. chrysolophus*	33.35.70 (13)	Target: 200	PMP	Exhibit diversity of crested species, surrogate for vulnerable forms
Magellanic Penguin *Spheniscus magellanicus*	53.54.57 (164)	Target: 125	Stable population	Reduce population size to make room for more vulnerable forms
African Penguin *S. demersus*	171.179.307 (657)	Target: 500	SSP	Wild populations at risk, provides a forum for contact with field biologists
Humboldt Penguin *S. humboldti*	93.93.41 (227)	Target: 350	SSP	Vulnerable in the wild, education; flagship species
Little Penguin *Eudyptula minor*	5.5.1 (11)	Target: 50	Proposed phase-in species	Taxonomic uniqueness, smallest, husbandry research. Possible model for Yellow-eyed
Yellow-eyed Penguin *Megadyptes antipodes*	0		N/A	Explore fieldwork – chick rearing
Galapagos Penguin *S. mendiculus*	0		N/A	Determine current wild status and conservation needs

1. Expressed in order: males; females; unknown sex (total).
2. 26.25.4 (55) = 26 males, 25 females, 4 unknown sex (total 55 birds)

(CBSG) of the World Conservation Union's Species Survival Commission provides the forum for international coordination of zoo collection planning in the form of its Global Captive Action Recommendation (GCAR) process. The GCAR provides a mechanism for zoo collection planning between a number of major zoo regions. The regional collection plans of the various regions are thus forged into a coherent global plan. The GCAR process can also serve as the basis for providing guidance and support for zoo regions seeking help in developing conservation strategies.

REFERENCES

AUSTIN, W.A. 1978. Penguin management at the Detroit Zoo. *Internat. Zoo Ybk* 18: 66–70.

AZA CONSERVATION AND SCIENCE OFFICE 1995a. AZA fact sheet, Species Survival Plan. Bethesda: American Zoo and Aquarium Association.

AZA CONSERVATION AND SCIENCE OFFICE 1995b. AZA fact sheet, Taxon Advisory Group. Bethesda: American Zoo and Aquarium Association.

BOYD, L. (Ed.) 1996–1997. AZA directory of zoological parks and aquariums. Wheeling: American Zoo and Aquarium Association. pp. 13–41.

BROWN, P.A. & REDIG, P.T. 1994. Aspergillus ELISA: a tool for detection and management. Proceedings, Association of Avian Veterinarians Annual Conference. Orlando. pp. 295–300.

BURCH, L. & REIDARSON, T.H. 1993. A new approach to bumblefoot treatment. Unpublished ms.

DIEBOLD, E. & HUTCHINS, M. 1991. Zoo bird collection planning: a challenge for the 1990s. Proceedings American Association of Zoological Parks and Aquariums Regional Conferences. Wheeling: American Association of Zoological Parks and Aquariums. pp. 244–252.

ELLIS, S. & BRANCH, S. (Eds). 1994. Penguin husbandry manual. First edition. Bethesda: American Zoo and Aquarium Association.

ELLIS, S., CROXALL, J.P. & COOPER, J. (Eds). 1998. Penguin Conservation and Management Plan. Report. Apple Valley: INCN/SSC Conservation Breeding Specialist Group.

GAILEY-PHIPPS, J. 1978. Management of penguins in captivity. Proceedings First International Birds in Captivity Symposium. Avian Medicine and Surgery. pp. 80–92.

HARRISON, G.J. & HARRISON, L.R. 1986. Clinical avian medicine and surgery. Philadelphia: W.B. Saunders. pp. 464–466.

HUTCHINS, M., WILLIS, K. & WIESE, R.J. 1995. Strategic collection planning: theory and practice. *Zoo Biol.* 14: 5–25.

ISIS BIRD ABSTRACT 1995. Apple Valley: International Species Information Systems.

MELLEN, J.D. & CHENEY, C.A. Effects of vitamin supplementation regime on chick survivorship and circulating levels of a-Tocopherol and Retinol on captive Humboldt Penguins (*Spheniscus humboldti).* Unpublished ms.

PERKINS, G. 1992. Regional Studbook for the Humboldt Penguin (*Spheniscus humboldti*). Chicago: Chicago Zoological Society.

PTS 1993. Penguin Taxon Advisory Group survey. Unpublished.

QUINN, H. & QUINN, H. 1993. Estimated number of snake species that can be managed by Species Survival Plans in North America. *Zoo Biol.* 12: 243–255.

REDIG, P.T. 1994. Diagnosis of avian aspergillosis. Proceedings, Association of Avian Veterinarians Annual Conference. Orlando. pp. 355–357.

REDIG, P.T., OROSZ, S. & CRAY, C. 1997. The ELISA as a management guide for aspergillosis in raptors. Proceedings, Association of Avian Veterinarians Annual Conference and Expo. Orlando pp. 99–101.

REIDARSON, T.H. & McBAIN, J.F. 1992. Diagnosis and treatment of aspergillosis in temperate penguins. *Vehr. Ber. Erkrg. Zootiere* 34: 155–158.

SARRO, S. 1992. Regional Studbook for the African Penguin (*Spheniscus demersus*). Baltimore: Maryland Zoological Society.

SHEPPARD, C. 1995. Propagation of endangered birds in US institutions: how much space is there? *Zoo Biol.* 14: 197–210.

SIMPSON, G.G. 1976. Penguins: past and present, here and there. Binghampton: Yale University Press.

STOSKOPF, M.K. & BEALL, F.B. 1980. The husbandry and medicine of captive penguins. AAZV Annual Proceedings. Lawrence: Allen Press. pp. 81–97.

TODD, F.S. The Penguin Encounter: from dream to reality. *Zoonooz* 56(4): 8–15.

WALLACE, R.S., TEARE, J.A., DIEBOLD, E.N., MICHAELS, M. & WILLIS, M.J. 1995. Hematology and plasma chemistry values in free-ranging Humboldt Penguins (*Spheniscus humboldti*) in Chile. *Zoo Biol.* 14: 311–316.

WALLACE, R.S., TEARE, J.A., DIEBOLD, E.N., MICHAELS, M. & WILLIS, M.J. 1996. Plasma Tocopherol, Retinol, and carotenoid levels in free-ranging Humboldt Penguins (*Spheniscus humboldti*) in Chile. *Zoo Biol.* 15: 127–134.