In this Issue

The British and Irish Humboldt Studbook, 1990 1
Planning for the Future of North American Humboldts 1
Hand-rearing Humboldts at Sea World, San Diego 2
Building Better Nesting Sites for *Spheniscus* Penguins 8
A Survey of *Spheniscus* Field Studies 10
A Selected Bibliography of *Spheniscus* Penguins 16
This issue of SPN:

The major articles in this issue, with the exception of "Nesting Sites for Spheniscus Penguins," are from papers presented at the Spheniscus Workshop held at the AAZPA Regional Conference in Sacramento, California, in March 1990. Other papers presented at that workshop were included in the November, 1990 SPN, and it was intended to include all remaining papers in this issue. Unfortunate realities of printing costs, however, forced a change in plan (see below for information on contributing toward production costs of this publication). Papers remaining, for our next issue, are: "Avian Malaria," "Incubation Behavior Patterns in Adelies," "Molt Patterns of Black-footed Penguins," and "Diet, Feeding Regimen, and Growth Rates in Hand-reared Magellanic Chicks." Thanks to the authors and to the American Association of Zoological Parks and Aquariums, for permission to reprint these papers.

Publication information:

SPN Spheniscus Penguin Newsletter
ISSN # 1045-0076
Indexed in Wildlife Review

SPN is published twice annually, with financial support from the Portland Chapter of the American Association of Zoo Keepers, and the Metro Washington Park Zoo. Subscription is free, to those with a serious interest in Spheniscus penguins. Contributions toward printing and postage costs are welcome (and tax-deductible in the US); please make checks payable to "Portland Chapter, AAZK," and send to the Editor at the address below.

Articles submitted for publication should be typed. For articles which include graphs (such as line or bar graphs) please include a separate sheet giving the data used to generate the graph. Authors who work on a Macintosh computer can help our layout process by sending their work on disk (accompanied by a paper copy just in case).

The drawing which serves as our cover logo is reproduced by kind permission of the artist, Ann Munson.

Thanks to Kathy Ivanov for help with word processing for this issue.

Please address all correspondence to: Cynthia Cheney, Editor
Spheniscus Penguin Newsletter
Washington Park Zoo
4001 SW Canyon Rd.
Portland, Oregon 97221 USA
Telephone: (503) 226-1561
FAX: (503) 226-6836
SPN

1990 British and Irish Regional Humboldt Studbook

Simon Blackwell, Regional Studbook Keeper, has published the 1990 edition of the British and Irish Humboldt Penguin Studbook, with data complete through the end of 1990. The 1989 Studbook showed a total of 842 individuals of which 464 were living, 319 in the United Kingdom (the other 141 living individuals were hatched there but had been sent to other countries). The latest figures show 356 living Humboldt penguins in the UK.

Breeding during 199Burford, Great BritainBurford, Great Britain produced 71 chicks of which 61 survived the first year. Mr. Blackwell points out, however, that only 11 of 32 institutions produced chicks, and 53 of the hatchings were at only 3 establishments.

In his introduction to the 1989 Studbook, Mr. Blackwell identified as the first priority for this population, sexing and individually identifying as many individuals as possible in the various collections, since 214 of the Humboldts in the UK were not sexed as of 1989, and some are not tagged or otherwise identified. Both sexing and individual identification are fundamental to captive management. In their absence, reliable records of parentage cannot be kept, inbreeding may occur, optimal sex ratios may not be maintained in colonies, and wild-caught birds, potential founders, may die without leaving offspring. These considerations apply to any captive population, but much more urgently to one such as S. humboldti, which is unlikely to receive additional individuals from the wild anytime soon.

Next in priority is the establishment of guidelines for management—from maintenance, breeding and rearing to record keeping and veterinary treatment, especially postmortem data—and collecting data on egg laying and viability.

North American Humboldts: SSP Report

The position of studbook keeper for the Regional Humboldt Penguin Studbook was transferred to Gail Perkins at Brookfield Zoo, as of March 1990. The former studbook keeper was Steve McCusker. Since the transfer, effort has been dedicated to completing and correcting all existing data, as well as updating the studbook. The 1989 studbook update is now ready for publication.

Unlike the population dealt with in the North American Humboldt Penguin Studbook, the UK population has produced a substantial number of captive-bred birds which have been exported from the region, to other European countries as well as to Japan and Israel. The British and Irish Studbook identifies and lists these individuals, and identifies the zoos to which they were sent. It is to be hoped that these zoos will identify and track the UK imports, and that other regional studbooks will be developed in the near future.

[Correspondence to Mr. Blackwell should be addressed to: Simon Blackwell, Assistant Curator; Cotswold Wildlife Park, Burford, Oxford, OX8 4JW, Great Britain.]

Penguin Symposium Held

Representatives of British and Irish zoological institutions gathered at Cotswold Wildlife Park for the Symposium on Penguin Management in September, 1989. Of 43 institutions housing penguins in the United Kingdom, 30 were represented, and it is hoped that this day of "penguins with no interruptions" will provide a base upon which future cooperative endeavors can be built. Participants discussed the possibility of forming a management group to standardize identification techniques, centralize information, and minimize potential inbreeding.

Nine papers were presented, including one on penguin conservation in the Falkland Islands, by J.R. Wilson, Secretary of the Falkland Island Foundation, and others covering a variety of topics relating to captive

Patty McGill, Ph.D., Species Coordinator Chicago Zoological Society
Reprinted from: AAZPA Communique

please turn to page 7
Hand-rearing Guidelines for the Humboldt

Over the past several years Sea World has gained extensive experience hand-rearing various species of penguins. Knowledge gathered from the incubation and hand-rearing of eggs from our Sea World colonies combined with more recent experience through our extensive Penguin Quarantine Projects has yielded an extensive data base. From this we have developed a specific set of guidelines which we now use to hand-rear our penguin chicks.

Though the protocol provided is useful for rearing a variety of penguin species (i.e., pygoscelids, eudyptids and spheniscids), the emphasis here will be on the rearing of spheniscids, specifically Humboldt penguins.

**GENERALIZED HAND-REARING PROTOCOL**

The following is meant as a guideline only, and not a strict regimen. Listen to the chick’s needs. Each individual chick will have individual needs at varying stages and may reach transition periods at a different rate.

**EGGS**

Incubated at 96.5°F (35.8°C) dry bulb, 82-85°F (27.8-29.4°C) wet bulb.

**CHICKS**

1. **Brooding**

   Chicks are allowed to dry in the incubator hatchette. Once dry, they are moved to a well ventilated brooder which should be constructed of an easily cleaned material (e.g., glass, plexiglass, fiberglass, etc.) and supplied with a heat source (e.g., a 250-watt infra-red heat lamp.) Temperature should be maintained at 80-90°F (26.6-32.2°C) for the first week or two. Temperature requirements will change depending on the chick’s age, weight and thermoregulatory needs. As the chick matures, the temperature in the brooder should be reduced and the heat lamp eventually removed.

2. **Formula**

   Formula = Sea World Fish Milkshake (recipe follows). Unheated formula will remain fresh for 24 hours and should be refrigerated until use. Formula is prepared for feeding by heating in a double boiler to 90°F (32.2°C). Formula must be stirred frequently during heating to prevent overheating and curdling. Do not boil. The unused portions of heated formula should be discarded immediately.

3. **Early feeding (1-5 days)**

   - Five (5) feedings per day, every three (3) hours; e.g., 0600, 0900, 1200, 1500, 1800.
   - For the chick’s first feeding, it is recommended to feed water only.
   - Day 1 here is defined as the first day of feeding; this may differ from the chick’s age where day 1 = day of hatch.
   - About weighing: a chick’s total intake per feeding is determined by the gram difference in weight before and after feeding. As a chick matures toward a weight of 1,000 grams or more, weighing can be discontinued for all except the first morning weight.

   **Day 1:** 50-50 water: formula; not to exceed 2-4 grams or 10% of the morning weight (AM wt.) total intake per feeding.
   **Day 2:** 25:75 water: formula; not to exceed 2-4 grams or 10% of the AM weight, total intake per feeding.
   **Day 3:** Straight formula—not to exceed 4-7 grams or 10% of the AM wt„ total intake per feeding.
   **Day 4:** Try 10% of the AM wt. total intake per feeding (do not exceed).
   **Day 5:** Use 10% of the AM wt. as a guide for total intake per feeding.

   Watch hydration carefully throughout chick’s development and particularly as the chick begins to eat fish. The morning is a critical time to check for signs of dehydration. Use three-point system of skin-tent test, moist eyes and plump feet. Monitor weight loss between feedings.
Penguin (*Spheniscus humboldti*)

with special emphasis on common hand-rearing concerns

LINDA M. HENRY AND FRANK TWOHY

4. The next stage begins when the chick reaches 200–300 grams first morning weight. Begin solid fish supplementation at 200–300 grams first morning weight. Introduce fish using herring filets cut into 1–1.5 inch (2.5–3.8 cm) x 0.25 inch (0.6 cm) pieces. As the chick matures, whole small herring, capelin and smelt may be used when the chick is able to swallow whole fish of these varying sizes.

*200-300 grams first AM wt.*: Introduce fish.

First day on fish: 3-5 grams of fish maximum given twice during the first day. Fish given in proportion to formula and water, not to exceed 10% AM wt. total intake per feeding.

Second day on fish: 3-5 grams of fish given every other feeding in proportion with formula and water as stated above. Fish is continued on an every-other-feeding schedule until chick reaches 300–400 grams first AM wt.

*300–400 grams first AM wt.*: Gradually increase fish.

10 grams fish every feeding maximum in proportion with formula and water as previously outlined.

*400–500 grams first AM wt.*: continue to increase fish.

10-15 grams fish every feeding maximum in proportion with formula and water as stated.

*500–600 grams first AM wt.*: continue to increase fish.

Continue to give fish in proportion to formula and water. Fish now equals approximately 50% of the total intake per feeding, e.g., a 500 gram bird might receive 20 grams formula, 5 grams water and 25 grams fish per feeding (water might be given every other feeding or only twice per day depending on the individual chick’s needs.)

5. 600 grams or greater first morning weight

Temperature should be lowered in brooders as chicks approach 500 grams first morning weight. Overheated chicks will display behavior such as panting, flippers and feet extended, decreased appetite, etc. Watch for dehydration.

Decrease the number of feedings per day to four (4), e.g., 0600, 1000, 1400, 1800. Continue using 10% of the first morning weight as a guideline to total intake per feeding. Begin vitamin supplementation outlined below.

After the chick reaches 700 grams or greater and has been doing well on the 50:50 fish:formula and water regimen, then the feeding schedule may be altered to further increase the proportion of fish in the diet, i.e., 20 grams formula, 10 grams water (30 grams total fluids) and an amount of fish equal to 10% AM weight total intake per feeding. For a 778 gram bird this would equal 20 grams formula, 10 grams water (it turns out that 1 gram is approximately equal to 1 cc for measuring the formula and water), and 47 grams of fish.

6. 1000 grams or greater first morning weight

Transition to a fish-only diet begins. Fish alone is given for two feedings and fish in combination with formula and water is given for two feedings. For example, the first and third feedings of the day for a chick might consist of fish and vitamins only. The second and fourth feedings might consist of 35 grams formula, 15 grams water and fish to achieve total allotted intake. If indicated, feedings may be reduced to three per day in which case only one feeding might include formula and water. However, chicks generally do well on four feedings per day until they approach fledging.

At the time of fledging the chicks may have access to a pool and the formula and water can be discontinued. Fledglings then receive feedings according to the feeding protocol for adults.

7. Vitamin Supplementation

Chicks begin vitamin supplementation at 500 grams first morning weight, when they receive 50 mg. vitamin B₁ (thiamine) twice per day. This continues as the sole supplementation until the chick reaches 1,000 grams first morning weight when the chick receives the following supplements: 1 Calcium Plus tablet and 100 mg. B₃ twice per day; 1/2-lb. Sea World Marine vitamin (formulation for animals weighing 1/2 pound) and 100 I.U. vitamin E once per day.

please turn to page 4

SPN August 1991 page 3
Hand-rearing Guidelines for the Humboldt Penguin

continued from page 3

HAND-REARING CONCERNS

We have found through our own experience and from the types of questions we have received from other institutions that rearing problems center around a few specific areas.

One of these areas is the pip to hatch interval. We have found that our chicks take between 36 to 48 hours to go from initial pip to hatch. Many times our chicks have required assistance in hatching because they have become malpositioned for hatching. This is either a result of pipping towards the small end of the egg, or because the chick has gotten its head stuck under theflipper in the process of rotating around the egg, stalling further pip progress. This seems to be a common occurrence based on the phone inquiries we have received. These situations can be remedied by carefully enlarging the pip and exposing the chick's head.

Once hatched, the chicks are allowed to dry in the hatcher for several hours. They are then identified using colored embroidery floss on one flipper and moved to the brooder. At this time, the initial introduction to formula may provide another area of concern. We are careful to always give water for the chick's first feeding. This allows us to determine the chick's initial vitality, as well as introducing the chick to feeding from the tube and syringe.

After the first introduction of formula, the chicks are fed every three hours five times per day. They will generally do very well if a few simple procedures are followed:

1. All instruments, dishes and work areas are sprayed with disinfectant and carefully rinsed before and after each use. Feeding syringes and tubes are soaked in disinfectant between uses and rinsed thoroughly just prior to use. We use dilute Nolvasan for soaking syringes, thermometers and dishes used for heating formula.

2. No one but the person or persons directly involved with rearing the chicks may handle the chicks.

3. The chicks are kept somewhat isolated. We keep them separate from other penguins as well as other species of birds. Disturbance in the immediate center around a few specific areas.

4. Chicks are introduced to formula gradually over 4-5 days. They are never fed more than an amount equal to a calculated 10% of their first morning's weight.

5. Weight loss between feedings is noted to be sure that the chick is processing the formula, and later fish, adequately. If a low weight loss between feedings is recorded for consecutive feedings, this may be an early indication of problems. Water only is given at a feeding session until an adequate weight loss is observed between feedings. Usually, a chick will show a 2-4 gram weight loss a few hours following a water-only feeding. Noting the weight loss between feedings in this way is of primary concern in the first two weeks of life and becomes less significant as the chick matures.

6. A skin tent test is taken at each feeding and hydration is noted. The chick's abdomen is palpated softly to check for bloating, an early sign of enteritis. The chick's stools are also evaluated and noted. A black, grainy stool is cause for serious concern.

As the chicks approach 25 to 30 days of age, they may begin to show a sudden drop in appetite. Though this behavior may result from many causes, it is most often manifested in association with over-feeding or heat stress. One way to differentiate a chick suffering from heat stress from one

brooder area is kept to a minimum. As the chicks approach fledging and go through their shy, aggressive stage, they are visually isolated as well to prevent undue stress.

As the chicks approach 25 to 30 days of age, they may begin to show a sudden drop in appetite, most often in association with over-feeding or heat stress.

We spray Betadine on chopping boards, for the blender, knives, etc. used in preparing the formula. The brooder is cleaned twice daily (usually concurrent with a feeding to prevent excessive handling of the chicks) and sprayed with Betadine. Great care is used to disinfect everything thoroughly between groups when rearing more than one group or species simultaneously.

As the chicks approach 25 to 30 days of age, they may begin to show a sudden drop in appetite. Though this behavior may result from many causes, it is most often manifested in association with over-feeding or heat stress. One way to differentiate a chick suffering from heat stress from one
Sea World's Penguin Milkshake Formula

SEA WORLD'S PENGUIN MILKSHAKE FORMULA

440 grams herring filets
440 grams krill
16 ounces (473 mls) water
16 ounces (473 mls) half and half cream
6 Sea World Marine Vitamins (2-lb*) for chicks under 7 days
3 Sea World Marine Vitamins (2-lb*) for chicks over 7 days
30 Calcium plus tablets
8 Brewer's Yeast tablets
500 mg. B1 (Thiamine)
2,000 IU vitamin E
1 Lactinex tablet
1.5 cc Pre-digested protein (Citramino pre-digested liquid protein)

Blend ingredients thoroughly. Mixture may be strained for ease of feeding. Refrigerate and use within 24 hours.

*The Sea World Marine Vitamins come in several formulations; here, use tablets formulated for animals weighing two pounds.

Heat stress is most commonly observed in older chicks that have developed a second coat of thicker down. Therefore, as the chick grows, the need for a cooler brooder, along with adequate air circulation becomes imperative. The chicks will often exhibit heat stress by lying on their stomach, with their flippers and feet out-stretched. In severe cases, the breathing will appear labored. In mild cases, no visible signs of overheating may be apparent, but the chick will show sudden low vitality, refusing to respond to a feeding stimulus. This can be remedied by providing a more open area for brooding the chick equipped with air conditioning or a fan for added circulation.

Another common cause for a finicky chick is the onset of fledging. Chicks may begin to show the first signs of fledging as early as 50-55 days of age. Fledging is usually concurrent with the onset of the shy, fearful stage. We have found that our chicks are fully fledged by about 75-80 days. Their fledging weight may vary greatly, anywhere from 3 - 4 kilograms average and as much as 5 kilograms in larger chicks.

Fledglings are introduced to the colony gradually over a period of several days. Supervised swimming lessons may be given to the chicks at this time. When it is felt the chicks are ready, they are released permanently into the colony. We have had little trouble integrating individuals into the colony. Our hand-reared chicks have gone on to produce chicks of their own, often within 2-3 years of fledging. In this way we hope to increase our breeding group for years to come.

A video tape depicting a general overview of Sea World's penguin hand rearing techniques accompanied the presentation of this paper at the Spheniscid Penguin Workshop. The script from this video is included here for completeness.

VIDEO SCRIPT

Sea World of California's relationship with penguins began in the late 60's with the introduction of the first Humboldt penguins. Since then, we have developed successful management and propagation techniques for Humboldt penguins as well as many other penguin species.

This is Sea World's Humboldt penguin habitat. The colony is housed in an off-exhibit breeding facility adjacent to Mission Bay in San Diego. With land area measuring approximately 40 to 45 feet by 75 to 80 feet, the exhibit offers access to natural substrate and tidal action.

The colony consists of 43 individuals, 20 of which were hatched at Sea World. Of these, 18 have been hand-reared. This year we added 6 more juveniles, birds hatched during last winter's breeding season.

Since 1986, we have had increasing success breeding Humboldt penguins. Due to the off-exhibit locale, the habitat is quiet, and relatively disturbance-free. Aviculturists visit the exhibit twice daily.

Nesting burrows are provided for the birds which consist of a combination of artificial and natural construction. A plywood box with an open bottom and "burrow hole" is installed over a shallow hollow in the ground. Once a pair establishes residence, they usually excavate the burrow further on their own; sometimes to great depth. Nesting material is available from two pampas grass plants growing within the exhibit. At the start of breeding season, keepers cut additional grass and place it throughout the exhibit for easy collection by the birds.

After the eggs are laid and incubation begins, the parents' behavior is closely monitored. Usually, the birds are allowed to incubate their eggs until 10 days prior to predicted hatch.
Hand-rearing Guidelines for the Humboldt Penguin

At this time, the eggs are candled and a determination is made, based on the past rearing success of the pair, whether to leave one egg and pull one egg; or to pull both the eggs for artificial incubation and hand rearing.

After the eggs are transferred from the parents to the incubator, they are maintained at 96.5°F dry bulb and 85°F wet bulb. The eggs are candled every few days until pipping begins. Pipped eggs are moved to the hatchette where they are misted frequently until the chick hatches, usually within about two days.

The newly hatched chick is moved to a brooder consisting of a modified isolette incubator. The primary criterion for the brooder is that it be warm (between 80 - 90°F) and dry with adequate air circulation. The brooder is lined with toweling which is liberally sprayed with Betadine. The heat source, a 250-watt infrared heat, should be at least 18 inches from the chick. The newly hatched chick is moved to a brooder consisting of a modified isolette incubator. The primary criterion for the brooder is that it be warm (between 80 - 90°F) and dry with adequate air circulation. The brooder is lined with toweling which is liberally sprayed with Betadine. The heat source, a 250-watt infrared heat, should be at least 18 inches from the chick.

The newly hatched chick is moved to a brooder consisting of a modified isolette incubator. The primary criterion for the brooder is that it be warm (between 80 - 90°F) and dry with adequate air circulation. The brooder is lined with toweling which is liberally sprayed with Betadine. The heat source, a 250-watt infrared heat, should be at least 18 inches from the chick.

The newly hatched chick is moved to a brooder consisting of a modified isolette incubator. The primary criterion for the brooder is that it be warm (between 80 - 90°F) and dry with adequate air circulation. The brooder is lined with toweling which is liberally sprayed with Betadine. The heat source, a 250-watt infrared heat, should be at least 18 inches from the chick.

The newly hatched chick is moved to a brooder consisting of a modified isolette incubator. The primary criterion for the brooder is that it be warm (between 80 - 90°F) and dry with adequate air circulation. The brooder is lined with toweling which is liberally sprayed with Betadine. The heat source, a 250-watt infrared heat, should be at least 18 inches from the chick.

The newly hatched chick is moved to a brooder consisting of a modified isolette incubator. The primary criterion for the brooder is that it be warm (between 80 - 90°F) and dry with adequate air circulation. The brooder is lined with toweling which is liberally sprayed with Betadine. The heat source, a 250-watt infrared heat, should be at least 18 inches from the chick.

The newly hatched chick is moved to a brooder consisting of a modified isolette incubator. The primary criterion for the brooder is that it be warm (between 80 - 90°F) and dry with adequate air circulation. The brooder is lined with toweling which is liberally sprayed with Betadine. The heat source, a 250-watt infrared heat, should be at least 18 inches from the chick.

The newly hatched chick is moved to a brooder consisting of a modified isolette incubator. The primary criterion for the brooder is that it be warm (between 80 - 90°F) and dry with adequate air circulation. The brooder is lined with toweling which is liberally sprayed with Betadine. The heat source, a 250-watt infrared heat, should be at least 18 inches from the chick.

The newly hatched chick is moved to a brooder consisting of a modified isolette incubator. The primary criterion for the brooder is that it be warm (between 80 - 90°F) and dry with adequate air circulation. The brooder is lined with toweling which is liberally sprayed with Betadine. The heat source, a 250-watt infrared heat, should be at least 18 inches from the chick.

The newly hatched chick is moved to a brooder consisting of a modified isolette incubator. The primary criterion for the brooder is that it be warm (between 80 - 90°F) and dry with adequate air circulation. The brooder is lined with toweling which is liberally sprayed with Betadine. The heat source, a 250-watt infrared heat, should be at least 18 inches from the chick.

The newly hatched chick is moved to a brooder consisting of a modified isolette incubator. The primary criterion for the brooder is that it be warm (between 80 - 90°F) and dry with adequate air circulation. The brooder is lined with toweling which is liberally sprayed with Betadine. The heat source, a 250-watt infrared heat, should be at least 18 inches from the chick.

The newly hatched chick is moved to a brooder consisting of a modified isolette incubator. The primary criterion for the brooder is that it be warm (between 80 - 90°F) and dry with adequate air circulation. The brooder is lined with toweling which is liberally sprayed with Betadine. The heat source, a 250-watt infrared heat, should be at least 18 inches from the chick.
North American Humboldts: SSP Report

continued from page 1

The population is 56 birds, with a total founder population (actual plus potential) of 102. The theoretical retention of wild genetic diversity is still very high. Although a few founders are well represented, none are yet so highly represented as to warrant preventing breeding. To date, there has been extremely little inbreeding. However, the population is in poorer condition demographically. Overall, the population is declining slightly, with successful reproduction not keeping pace with deaths. The age distribution indicates a sizable fraction of the population more than 10 years of age, with a particular cluster at 15-20 years. At the present time, this cohort is not replacing itself, although it appears to be the period of peak reproduction. Maximum life span appears to be about 28-30 years. Thus, the population has a significant fraction entering years of declining reproduction and increasing mortality.

In consideration of the above, the goals for the population were established as retaining 90% of the genetic diversity over 200 years, thus, requiring 250-300 birds in the population. The specific immediate objectives include increasing reproductive success, decreasing early chick mortality and decreasing mortality post-shipment. Particular emphasis should be given to breeding under-represented founders. It is strongly recommended that institutions pull eggs and hand-raise chicks from pairs that show inadequate parental behavior. In addition, pulling eggs to increase double clutching is encouraged for founders that have no or low representation. However, caution should be exercised to avoid encouraging more than three clutches of eggs per female, per season.

Protocols for hand-raising are well established; a survey of hand-raising techniques is being distributed. Protocols and guidelines are being developed for transfers to reduce post-shipment losses. Finally, attention should be given to determining the sex of as many birds as possible, particularly all birds greater than one year of age.

Penguin Symposium and Proceedings

continued from page 1

penguin management, such as hand-rearing, sexing, population management, and new exhibit design. D.G. Edgington of Cotswold Wildlife Park presented results of a survey of institutions exhibiting penguins in the United Kingdom, including population information and management data, with particular emphasis on means taken to sex individuals and avoid inbreeding. A summary of data is given, covering seven different species kept at 43 institutions.

To order the Proceedings

The published Proceedings, entitled Penguin Management, may be ordered from the editor:

Simon Blackwell
Assistant Curator
Cotswold Wildlife Park
Burford
Oxford OX8 4JW
Great Britain

Price: £3 per copy plus postage (40p UK and 80p overseas)
(Published by Cotswold Wildlife Park, with support from The Association of British Wild Animal Keepers; all profits to be donated to the Falkland Island Foundation.)
Nesting Sites for *Spheniscus* Penguins

*Spheniscus* penguins are known to nest in the open, under live and dead bushes, in natural crevices, lava tubes, amongst boulders and in burrows that they dig. In captivity, the range of choices for breeding sites is restricted. Gunitite, the cement mixture that forms the rocks in most penguin exhibits, is about as easy to dig as fresh lava thus, substrate within exhibits can severely limit breeding sites. Good nesting sites are obviously important for breeding but how can zoos provide suitable sites? This paper examines breeding sites for penguins in the wild to gain insights into what makes a nesting site attractive. Using nature as a guide, zoos may be able to provide penguins with better quality artificial sites.

There is reason to believe that zoos can improve upon nature or at least do as well in providing good quality nesting sites. Nesting boxes and burrows were readily accepted by Magellanic penguins at Punta Tombo, Argentina. There is even evidence showing that nesting boxes sometimes are preferred to natural sites. The Little Blue penguin normally nests in natural crevices in boulders. Chris Challis provided about 100 wood nesting boxes which he dug into cliffs outside of Christchurch, New Zealand. He found that Little Blue penguins moved from the natural crevices to his boxes suggesting that humans can improve, in a penguin's eye, on nature.

At Punta Tombo, where several thousand Magellanic penguins breed, a little less than half nest under bushes and a little more than half nest in burrows. Only about 1% nest in scrapes in the open. These data, as well as experiments which we have conducted in the field, indicate that Magellanic penguins, when given a choice, prefer nests with more coverage rather than less. In many of the areas at Punta Tombo where Magellanic penguins nest mostly under bushes, the soil is too thin for them to construct burrows. Similarly, Humboldt and Galapagos penguins frequently nest in sea caves but this is often because suitable burrow substrate does not exist.

What type of nests should zoos provide? It may be difficult to provide high quality bush nest sites in zoos but the burrow sites are so attractive to *Spheniscus* penguins can be easily constructed out of wood. The most common dimensions of Magellanic penguin burrow nests should be suitable for Black-footed and Humboldt penguins which are about the same size and also nest in burrows.

A typical burrow has a relatively wide entrance which narrows to a short neck and then widens slightly into a chamber where the eggs are laid (Fig 1). Burrows at Punta Tombo range from a little more than open scrapes to sizable tunnels over a meter in length. In 15 burrows where chicks fledged the length was 59 cm (s.d. = 19); width at entrance = 56 cm (s.d. = 11); width at the neck was 37 cm (s.d. = 5) and height was 21 cm (s.d. = 4). For 130 nests where success was not known mean burrow length was 63 cm (s.d. = 23) and mean entrance width was 40 cm (s.d. = 11). In 50 other burrows height at the burrow opening ranged between 14 and 41 cm with of mean 24 cm (s.d. = 6) and burrow width ranged between 66 and 27 cm with a mean of 40 (s.d. = 9).

Compared to the "dog house" nest boxes provided by many zoos, natural burrows are generally much longer and wider but not as tall. This difference in dimensions may have a bearing on the humidity within the nest box as well as upon the penguins' likelihood of defecating within the nest. All the *Spheniscus* penguins nest in very dry climates even though they nest close to the sea. In part of Peru where the Humboldt penguin nests it hasn't rained in 300 years. In Argentina, it rains occasionally but normally the climate is so dry that the soil is like concrete and the vegetation is that of a temperate desert. The Galapagos penguin and the Black-footed penguin also nest where the ocean water is cold and the land is often dry for long intervals.

Contrast these natural environments with zoos where the humidity is high in comparison with the natural habitat. The frequent hosing of zoo exhibits adds to the humidity penguins experience. Moreover, there is little wind. Penguins often arrive dripping wet at their zoo nest site while in the wild they are usually completely dry when they arrive. Nest boxes in zoo exhibits have high relative humidity, which can foster growth of Aspergillosis and other unwanted diseases. Humidity in big nesting boxes will often be higher than in smaller ones. In larger boxes the air within the nest box will stay cooler and more moist and in addition penguins may defecate in the box. Increased air flow into nest boxes through ventilation holes or slots on the upper part of the walls or fans can be used to increase water evaporation and help keep the burrows dry. Nest box floors can be lined with artificial, non-absorbent matting that is spongy, with a
few air circulation holes drilled in the floor itself, so that water brought in by the birds can be easily drained and kept away from the bird. By just making the burrow much smaller and more similar to nest sites in the wild nest humidity and defecation problems can be avoided. In natural burrows, penguins rarely defecate in the nest site probably because the quarters are cramped. Generally they like to go outside, look around, defecate, and walk back into the nest. Zoos may increase nesting success and decrease mortality by adopting nest site size that is more comparable to what birds select in the wild.

Zoos must also consider the placement of nest boxes and the number of nest sites to be provided. In the wild, pairs are often not nest site limited, although quality nest sites are often in short supply. Penguins fight over high quality nest sites and on occasion, birds are mortally wounded. Birds often switch mates and pairs may change sites, thus, in captivity it may be prudent to provide more nest sites than can be used. This will help reduce the value of each site, thereby reducing the intensity of fighting. It will also allow males and females to switch sites and hence change pairings. Nest sites should be separated so that penguins do not have to cross too close to another nest. In general, penguins appear to prefer nests that look out on a rock or a hill of dirt. Nests with a view appear less attractive. Perhaps in the wild, visual seclusion from other penguins translates into less aggressive encounters with other penguins and more protection from predators.

As exhibits attempt to become more like pieces of nature where the wildlife can survive and procreate, consideration should be given to the aquatic environment that penguins inhabit. Small fish and structural complexity are desirable additions both to entertain the public and the penguins. Exhibits with fish must have areas of high structural complexity so that the fish can avoid capture by the penguins. Even then, fish are likely to eventually be captured so that fish will have to be periodically added to the exhibit. If the exhibit is cleaned by completely emptying the pool it will be more difficult to keep penguins and fish in some kind of semi-stable relationship.

Of the Spheniscus penguins, the Humboldt is in the most need of help. Captive breeding programs should do all they can to increase the number of spaces allocated to this species until minimum population size for the Species Survival Plan has been reached. There are still wild caught Humboldt penguins (founders) that have not successfully bred. These birds are in their teens. The Magellanic and Blackfoot penguins are doing better both in the wild and in zoos than the Humboldt penguin. Zoos must concentrate on breeding Humboldt penguins as rapidly as possible. Providing nest sites that are similar to what Spheniscus penguins prefer in the wild is one step that is relatively easy for zoos to take and one that may improve their reproduction.
Field Studies of *Spheniscus* Penguins

**DAVID CAMERON DUFFY**

The popular image of penguins is one of ice. However, penguins of the genus *Spheniscus* rarely if ever see ice and instead inhabit areas more tropical than polar. This has been both boon and bane. The *Spheniscus* penguins have taken the brunt of human exploitation, while until recently being more or less ignored as research subjects compared to polar penguins. Human exploitation and research neglect have now diminished, although much remains to be done concerning both conservation and research.

What follows is a selective overview, but the papers cited will provide access to the rest of the literature on each species. I would like to note that most of what we know is mostly the result of work by a very few people: Boersma on Galapagos Penguins; Scolaro on Magellanic Penguins; Araya and Hays on Humboldt Penguins; and Cooper, Rand, Randall, and Wilson on African Penguins, presently the best known of the species.

**Taxonomy**

There are currently believed to be four species of *Spheniscus* penguin: the Humboldt *Spheniscus humboldti*, Galapagos *Spheniscus mendiculus*, Magellanic *Spheniscus magellanicus*, and the African, Black-footed, or Jackass *Spheniscus demersus*, all with a very similar morphology (Livezey, 1989). I prefer African as the common name for the last species, as Jackass is also used for Magellanics and Humboldts, and Black-footed is singularly uninformative. The other three have geographic names, so why not the African Penguin? George Gaylord Simpson (1976), the godfather of penguinology, made the same plea.

Given the propensity of the various species to interbreed in captivity, a few words on their evolutionary relationships are in order. Genetically, there is at present only one study, by Grant et al. (in press), on the Humboldt, Magellanic and African taxa, using electrophoretic analysis of gene frequencies. The three species are very closely related, suggesting that if they are species, rather than subspecies, they are very recent ones. The Galapagos Penguin probably evolved from a stray colonization of the islands by 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.

**Distribution**

The *Spheniscus* penguins range to the Equator in the Pacific and stray almost to the Equator in the Atlantic (Gabon: Shelton et al. 1984), but they are cool-water specialists, associating with upwelling marine ecosystems (Murphy, 1936).

The Galapagos Penguin has an extremely restricted range, nesting only on the west side of Isla Isabela and on Isla Fernandina in the western Galapagos Islands (Harris, 1974). The Humboldt Penguin is confined to the upwelling of the Humboldt Current of the west coast of South America, nesting from northern Peru to Chiloe Island, Chile (Araya, 1983; Hays, 1983). The Magellanic Penguin nests on the Pacific coast, from central Chile, south around Cape Horn, and north on the Atlantic, to central Argentina, as well as on the Falklands and on several of Chile's offshore islands (Murphy, 1936; Araya and Millie, 1986). The African Penguin nests from central Namibia south around the Cape of Good Hope and along the south coast of South Africa (Rand, 1960; Shelton et al. 1984).

Only the Magellanic and Humboldt overlap in breeding range, over approximately 1750km of Chilean coast (Duffy, 1987a; Duffy et al., in prep. a). Mixed pairs have been observed but not studied. We haven't a clue as to how the species differ in their courtship and mating behavior to prevent interbreeding in the wild.

**Colony Size And Distribution**

The *Spheniscus* penguins don't nest in colonies so much as they nest where suitable access to the sea and suitable nesting sites occur, with nesting ranging from solitary Galapagos Penguins to immense colonies of Magellanic and African penguins. The reasons for these differences need further study. The Galapagos Penguin nests in small, scattered groups (Boersma, 1977; Harcourt, 1980; Valle, 1986). Much of its range appears too cliff-bound for birds to get ashore.
Field Studies of *Spheniscus* Penguins

(Boersma, 1977), a problem faced by the other species. The Humboldt Penguin in Peru nests mostly in small colonies in sea-caves on islands and the coast or in burrows on islands where it is slightly safer from intense poaching pressure (Hays, 1983, Duffy et al., 1984a), whereas in Chile, where human disturbance is much reduced, it nests in much larger colonies on islands (Araya, 1983). The Magellanic and African Penguins nest or nested in colonies of 10,000 to 100,000+ (Scolaro and Arias de Reyna, 1984; Scolaro et al., 1980a, 1984; Shelton et al., 1984; Capurro et al., 1988). Except for several small colonies which may suffer periodic bouts of catastrophic disturbance from humans and at least once from a leopard (*Panthera pardus*) (pers. observ.), African Penguins nest on islands (Shelton et al., 1984). Magellanic nests on both islands and the mainland, and it remains a mystery to me why terrestrial predators have not exterminated whole colonies. Scolaro (1985) suggests that humans have reduced local populations of terrestrial predators.

**Numbers**

**Counting Penguins**

Not the least of problems involved in studying penguins is counting them. The Galapagos and Humboldt are frequently counted from boats, pitching just beyond the surf, as observers try to see birds in caves or under rocks, (Boersma, 1977; Hays, 1984). As both species are partially nocturnal on land or feed at sea during the day (Boersma, 1977; Duffy et al., in prep a), day counts are underestimates. Counts at colonies also have problems, as many nest sites are unoccupied, depending on time of day (Frost et al., 1976a; Hays, 1984; Capurro et al., 1988) and one pair may visit several sites (Capurro et al., 1988). Even worse, with the exception of the Magellanic Penguin, the *Spheniscus* species can be found breeding throughout the year (Koepcke, 1970; Boersma, 1978; Cooper, 1980) so that single counts, even at peak breeding, miss many pairs that breed at other times of year Randall et al. (1986a) developed a method of counting moulting birds throughout the year at a frequency similar to the duration of moult, so that each moulting bird was counted only once. Assuming that birds do not move to other islands to moult (Randall et al., 1987), this would give a 'true' count of the population.

**Population Fluctuations and Trends**

With the possible exception of the Magellanic Penguin, the *Spheniscus* penguins have suffered either short-term or historical population decreases. The Galapagos Penguin, apparently otherwise stable at between 3,000 and 15,000 birds (Brosset, 1963; Harris, 1977; Boersma, 1977), lost 77% of its counted population during the strong El Niño oceanographic event in 1982-1983 and subsequently experienced poor reproduction through 1984 (Valle and Coulter, 1987). More recent data have not been published.

Humboldt Penguins in Peru have been in decline since the 19th century, perhaps in part because of the removal of the guano substrate they used for their burrow nests (Murphy, 1936). I suspect, however, that human exploitation for food has been and continues to be a serious, if not the principal problem (Duffy et al., 1984a). The Peruvian and Chilean combined population was estimated to be approximately 20,000 (Hays, 1983,1984) before the 1982-1983 El Niño which reduced numbers by 65% in Peru to 2,000-3,000 (Hays, 1986). Similar reductions occurred in Chile (Araya, 1984 ms; Araya and Todd, 1988). More recent data are not available.

The Magellanic Penguin, with a population on the order of a million birds or more, is increasing in Argentina, perhaps because of changes in food availability or reduction of predators (Scolaro, 1985; Boersma et al., 1990). The status of its population in Chile is unknown, although the species is common (Schlatter, 1984). The African Penguin has suffered a population crash since the turn of the century (Burger and Cooper, 1984; Shelton et al., 1984) Between 1956 and 1978, the population decreased from 230,000 to 100,000 (Burger and Cooper, 1984), but its recent dynamics have been complex, decreasing in the center of its range and increasing or remaining stable to the north and east (Frost et al., 1976a; Siegfried and Crawford, 1978; Shelton et al., 1984). These changes have been linked to changes in fish stock (Crawford and Shelton, 1978, 1981; Burger and Cooper, 1984; Crawford et al., 1985) and overfishing (Crawford and Shelton, 1978, 1981), but the mechanisms for overfishing are unclear, as penguins and fishermen don't fish in the same areas (Broni, 1986; Wilson et al., 1988) and fishery landings bear no relation to penguin diet or growth (Duffy et al., 1987a). Breeding success for penguins at one island studied near fishing grounds was the same as that on a control island in an unfished area (La Cock et al., 1987). At present, we believe that penguins and fishermen compete during the pelagic first-year life of the African penguin, when juveniles from decreasing colonies disperse to areas of intense fishing and have low survival rates, whereas those from stable or increasing colonies disperse to unvisited areas and survive better (La Cock et al., 1987; Duffy and Cooper, 1990).

please turn to page 12

SPN August 1991 page 11
Field Studies of *Spheniscus* Penguins

Natural and Unnatural Mortality

Accounts of the natural predators of *Spheniscus* penguins are numerous (e.g. Galapagos Penguin: Boersma, 1977; Humboldt Penguin: Hays, 1984, 1986; Araya and Duffy, 1987; Magellanic Penguin: Boswall, 1972; Rodriguez, 1983; Scolaro, 1985, African Penguin: Cooper, 1974; Brooke and Wallett, 1976; Frost et al., 1976a; I.Randall et al., 1988). Parasites may also be important (e.g. Boersma, 1977; Randall and Bray, 1983; Duffy and Daturi, 1987), but we have almost no idea of the impact of either parasites or predators on penguins at the population level. Such studies are urgently needed.

Human exploitation ranges from poaching (Duffy et al., 1984a; Hays, 1984; Schlatter 1984) to indigenous clothing (Avery, 1985) and industrial glove production (Scolaro, 1986) to zoo exports (Hays, 1984). Exploitation of eggs (up to 500,000/year and 13 million in 30 years: Siegfried and Crawford, 1978) in South Africa caused population decreases on at least some of the islands (Frost et al., 1976a). Oiling has been especially noticeable off South Africa, on the route of much of the world’s tanker traffic (Westphal and Rowan, 1971; Morant et al., 1981), but there is some disagreement over its impact. Frost et al. (1976a) estimated the oiling rate to be only 0.7-0.9%/year, but Randall et al. (1980) working farther to the east considered oiling the main cause of adult mortality. A major public effort, the South African National Foundation for the Conservation of Coastal Birds, operates a permanent rescue and cleaning operation that has been highly effective in returning birds to the wild and in educating the public about oil contamination (Randall et al., 1980; Morant et al., 1981). Oiling rates in Galapagos and Peru are apparently low, but there is considerable concern about oiling rates and resulting mortality of Magellanic Penguins in Argentina (Jehl, 1975; Perkins, 1983; Boersma et al., 1990).

Natural disasters, ranging from local heavy rains (Crawford et al., 1986; Randall et al., 1986b; Duffy et al., 1988) and anomalous cold-water events (Schumann et al., 1989) to species-wide El Niño-caused mortality (Vogt, 1942; Boersma, 1978; Boersma, 1987; Duffy et al., 1984a,b, 1988; Hays, 1986; La Cock, 1986; Valle and Coulter, 1987; Araya and Todd, 1988; Duffy, 1990), have been well documented, but again the population effects have been difficult to document because, with the exception of the Galapagos (Valle and Coulter, 1987) and locally with the African (La Cock et al., 1987; La Cock and Hanel, 1987) and Magellanic (Boersma et al., 1990) penguins, long-term population or breeding data are not available. Computer models of penguin populations (e.g. Jackson et al., 1976; Scolaro, 1987b; Scolaro et al., 1981) may help assess the possible impact of natural, and unnatural, disasters, long before we have direct data (Duffy, 1990).

Nesting Biology

Breeding Seasons

Humboldt (Koepcke 1970; Castro and Ishiyama, 1985–1986) and African Penguins nest throughout most of the year, (Cooper, 1980; Randall and Randall, 1981, La Cock et al., 1987) but show strong seasonal which have been linked to differences in food availability (Wilson, 1985c) and nesting success (Wilson, 1985c; La Cock et al., 1987). Boersma (1977, 1978) showed that nesting by Galapagos Penguins can occur throughout the year, in response to appropriate oceanographic and food conditions. In contrast, Magellanic Penguin nesting is strongly seasonal (Scolaro, 1984a; Scolaro et al. 1980a; Boersma et al., 1990), perhaps because the southern distribution leaves too few daylight hours for foraging during the winter (Duffy et al., in prep a).

Nest site

The biggest problem for nesting *Spheniscus* penguins is the sun (Drent and Stonehouse, 1971; Frost et al., 1976b). They avoid it by nesting in burrows and sea caves or under vegetation (Murphy, 1936; Scolaro and Arias de Reyna, 1984b), or, if surface-nesting, doing so during the winter (La Cock, 1988) or when there is a strong windchill. When penguins nest on the surface, they tend to nest densely, to protect their eggs and young against aerial predators (Siegfried, 1977). Burrow nests appear more successful than surface nests (Frost et al., 1976a) which may be used when covered sites are occupied or substrates are unsuitable for burrowing because of texture or susceptibility to flooding (Scolaro, 1984; La Cock, 1988). Nest sites must also be accessible to the sea and, for surface nesters, essentially level, as penguins build only rudimentary nests (Duffy and La Cock, 1985). These habitat requirements combine to produce complex mosaics of nesting colony distributions and nest densities (e.g. Bodano et al., 1982; Scolaro and Arias de Reyna, 1984a,b; Scolaro, 1984; Scolaro et al., 1979, 1984, 1985; Duffy and La Cock, 1985; Capurro et al., 1988). These in turn complicate estimates of colony size (discussed above).

Breeding Behavior and Ecology

Breeding of the *Spheniscus* penguins appears relatively similar across species, although we lack details for the Humboldt Penguin in the wild. Boersma (1977); Scolaro (1978, 1980, 1983,1984a,b,d), Scolaro et al. (1980a); Cooper (1980), Hockey and Hallinan (1981), Randall (1983), Williams and
Cooper (1984), and Wilson (1985c) provide details of various aspects of the breeding of Galapagos, Magellanic and African penguins, respectively. For the African Penguin, the normal clutch is two eggs, laid about three days apart, with an incubation period of 88 days, and both young are usually raised in about 80 days, except during poor food conditions, when the younger of the pair dies (Cooper, 1980; Williams and Cooper, 1984). For the Magellanic Penguin, the incubation period for the two-egg clutch is 38-42 days, with a two to four day period between eggs and an extremely variable growth of young to fledging (Boersma et al., 1990). The Galapagos Penguin also lays two eggs, three or four days apart, has an incubation period of approximately 38 days and young reach adult size at thirty days, "although some chicks remained in the nest until after 50 days of age" (Boersma, 1977), which is a very short fledging period compared to the other two species.

Growth

Growth of young in the field has been extensively studied in African Penguins (Cooper, 1977; Williams and Cooper, 1984; Duffy et al., 1987a). Heath and Randall (1985) examined growth of African penguins fed different diets. Boersma (1977) provided the only growth data for the Galapagos Penguin, and Scolaro (1984d) and Boersma et al. (1990) for Magellaneics. No published data exist for Humboldt Penguins.

Moult

Moult takes approximately 20 days in Humboldt Penguins, 10-15 days in Galapagos Penguins, and 18 days in African Penguins, during which time the birds fast and usually do not enter the water (Boersma, 1977; Cooper, 1978). For Magellaneic Penguins, moult occurs during a relatively short, fixed time of year, after breeding and prior to dispersal from the colony (Scolaro, 1984d). This fixed pattern appears to be a response to the strongly seasonal and consistent pattern of climate and food availability, not found in the environments of the other species. African and Galapagos Penguins can be found moulting throughout the year, but African Penguins exhibit a strong seasonal peak in October-November (Randall and Randall, 1981). Moult is a pre-breeding activity in Galapagos Penguins (Boersma, 1977). It occurs, although not in the same birds, both immediately before and after breeding in African Penguins (Cooper, 1978), but appears to be predominantly post-breeding (Randall and Randall, 1981). Galapagos Penguins moult twice a year (Boersma, 1977), perhaps as a response to damage to plumage by the equatorial sun. If this is the case, a similar frequency of moult should occur in Humboldt Penguins. Moult in African Penguins and Magellaneics appears to be annual (Randall and Randall, 1981; Scolaro, 1984).

Moult appears to be extremely stressful, and birds may be forced to return to the water to forage before completion (Boersma, 1977), even though they lack thermal protection against the cold (Erasmus et al., 1981) and may be too slow to catch their normal prey (Wilson, 1985b).

Foraging Biology

Diet

Early diet work involved killing birds. The development of an effective stomach pump (Wilson, 1984) removed all necessity to slaughter penguins for diet studies. Problems remain, however, as diet analyses can be biased by a variety of factors, including methods of analysis, and comparisons of data can be hindered by differing methods of presentation (Duffy and Jackson, 1986). Another complication is differential digestion of prey species, which has led to studies of penguin digestive rates (Furness and Laugksch, 1983; Duffy et al., 1985a; Wilson et al., 1985; Laugksch and Duffy, 1986; Wilson et al., 1989b).

Diet reviews which summarize previous work include: African Penguin: Rand (1960); Randall and Randall (1986); Duffy et al. (1985a, 1987a,b); Humboldt: Wilson et al. (1989a); Duffy et al. (in prep. a); Galapagos: Boersma (1977) and Magellanic: Gosztonyi (1984); Scolaro and Bodano (1985). Basically, Spheniscus penguins eat a wide variety of species and sizes of prey, from 10 to 310 mm (Wilson and Wilson, 1990) but specialize on small, schooling fish, such as anchovy Engraulis spp. and sardines Sardinops.

Distribution at Sea

Measurement of distribution at sea is extremely difficult, as penguins ride low in the water and travel underwater, reducing the chance of seeing them. The two traditional ways of studying them have been to measure the duration of foraging trips and to run transects at sea. In the first case, the departure and return times of penguins, especially those with small young, are measured (Boersma, 1977; Wilson, 1985a). By assuming a certain traveling speed and time spent actually foraging, a maximum range can be calculated (Wilson, 1985a,b; Duffy et al., 1987a; Wilson et al., 1988). These measurements are necessarily rather crude.

In the second case, direct observation, penguins are counted on transects from moving vessels. Observations
Field Studies of *Spheniscus* Penguins

include distance from shore, group size, social behavior, and attendance in foraging groups (e.g. Rand, 1960; Siegfried et al., 1975; Duffy, 1983, 1989; Broni, 1986; Wilson et al., 1986b, 1988). Unfortunately, transects require strong stomachs, are extremely expensive to run, and are frequently interrupted by bad weather. The presence of a vessel may also influence penguin behavior.

More recently, methods have been developed to measure *Spheniscus* penguin foraging at sea, through remote sensing. Small measurement packages are placed on the bird (e.g. Heath, 1987; Wilson and Wilson, 1989) and either store data until recovered or transmit them by radio. Speed, depth and distance meters store data on x-ray film, using small counters to store counts of propeller turns (Wilson and Achleiter, 1985). When combined with diet data from birds returning colonies, the devices allow estimates of foraging effort versus food ingested (e.g. Nagy et al., 1984).

Radio-transmitters provide continuous signals while birds are on the surface (Heath and Randall, 1989). Interruption of the signal is caused by submergence, so the device can be used to measure dive frequency and duration. Range of signal can be a problem, as penguins ride so low in the water that waves intercept signals. Also, triangulation of radio-signals and pursuit of animals with airplanes or boats is necessary for locating the birds at sea. Nevertheless, radio-transmitters can provide an abundance of detailed data which can be combined with direct, simultaneous observations of foraging situations and prey. Where telemetry is not possible, a new dead-reckoning device may provide similar data, although it requires recovery of the bird with the device (Wilson and Wilson, 1988).

A potentially serious problem with devices and methods of attaching them is the increased drag or water-resistance they can create when the penguins are diving. Drag may hamper foraging or cause birds to desert their nests (Wilson et al., 1986a), so recent devices have tended to be as small as possible. In addition, either the devices or their attachments may annoy the birds sufficiently to generate aberrant behavior. Wilson and Wilson (1989b) developed a device to count the number of pecks directed at devices, as a measure of disturbance. Finally, the disturbance caused by capturing the bird to install and remove devices may be a serious problem, especially perhaps for birds such as Humboldt Penguins in Peru, that appear much more shy than other *Spheniscus* populations (pers. observ.). Automatic injection of sedatives by remote control may reduce trauma (e.g. Wilson and Wilson, 1989c).

During the breeding season, penguins return to shore. Frequently, especially when feeding young, so they tend to be distributed at sea near their colonies. During their first year of life and, while non-breeding, penguins may be pelagic for extended periods of time (Wilson et al., 1988; Duffy and Cooper, 1990).

Foraging Behavior

Wilson and Wilson (1990) have recently reviewed *Spheniscus* foraging. They report that *Spheniscus* penguins travel at 6.8 – 7.4 kph underwater and at 12.3 kph while porpoising. Dives can last as long as 146 sec and reach mean maximum depths of 60+ m, although most dives are shallower. They may travel as much as 72 km per day while providing food for young.

Unfortunately, we know relatively little about actual foraging behavior, as events take place tens of meters below the sea-surface, at high speeds in murky waters. Most of our inferences come from indirect observations or devices measuring depth, speed, and duration of dive, size of foraging group, stomach samples, and fish behavior.

Being flightless, *Spheniscus* penguins must encounter frequent, inshore food sources, as the birds must swim, not fly, to their foraging grounds and underwater searching visibilities are short (Frost et al., 1986a). Penguins seem to travel directly, often in groups (e.g. Siegfried et al., 1975; Boersma, 1977; Broni, 1986) to a certain area, then begin searching (e.g. Wilson and Wilson, 1988; Heath and Randall, 1989). 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. Locating the school at a fishing area may be done by an individual bird, or it may be attracted to calls by other penguins (Broni, 1986) or by foraging by other species (Duffy, 1983, 1989).

Most dives are relatively shallow (Wilson, 1985b), suggesting feeding on fish schools near the surface. Most penguin prey form schools and, while this may facilitate locating fish, penguins may find it difficult to target a single fish, amongst tens or hundreds of thousands of similarly-sized, similarly behaving fish. Based on bite marks on fish, penguins attack from below, perhaps silhouetting the fish against the surface (Wilson and Duffy, 1986; Wilson et al., 1989a) and using their dark dorsal plumage as camouflage (Cairns, 1986). They may also use the alternation of black and white of the breast band as an aggressive display, herding the fish in a school closer and closer, until the minimum distance between fish breaks down and the school structure collapses (Wilson et al., 1987). Penguins may also use group fishing to break up school structure (Sumner,
1934; Boersma, 1977; Boswall and Maclvor, 1975; Wilson et al., 1987) or may join with other predators that effectively serve the same role (Boersma, 1977; Broni, 1986), although Wilson (1985b) suggests that African Penguins forage on smaller schools of fish than do other birds. Finally, penguins may drive fish to the surface for other, more shallowly-diving birds (Broni, 1986).

Contributions From Captive Studies

Those who have an opportunity to study the Spheniscus Penguins in captivity have much to contribute to our basic knowledge and research that will aid in penguin conservation. Such research can range from the intensive, such as behavioral studies, to low-key, such as consistent measurements of mass and body measurement of individual penguins over time.

Careful measurements of several generations of penguins, raised under constant conditions, will give us a much-needed idea of heritability of body size. If we can measure the relative contributions of environmental and genetic factors, we can perhaps use changes in body size to monitor population dynamics of Spheniscus penguins (Duffy, 1987b). This will be invaluable in examining the possible effects of competition with commercial fisheries and of climate change. Measurement of known genetic lineages can also give us some idea of the genetic basis for partial and complete double breast banding in African and Humboldt penguins and can be compared with molecular genetic studies.

We know something about the courtship and mating behavior of two of the species (e.g. Boersma, 1977; Eggleton and Siegfried, 1979), but we have little information about Humboldt or Magellanicus (Jouventin, 1982). It would be extremely useful to have basic ethograms of the four species, to allow comparison of their species-specific and sex-specific behaviors in captivity (e.g. Merritt and King, 1987; Scholten, 1989). Adding or removing breast bands would be an interesting experiment to test the importance of such coloration between species (cf. Ryan et al., 1987). It would also be interesting, without allowing actual reproduction, to study the behavior of mixed-species pairs in captivity.

Work on aging and sexing penguins is extremely important and useful (e.g. Cooper, 1972; Bulfon et al., 1986; Boersma and Davies, 1987; Scolaro, 1987a; Scolaro et al., 1983). Measurements of captive birds, under constant conditions, over time will greatly aid field studies (e.g. Edgington, 1989). Determination of the growth of young (Cooper, 1977), energetics (Erasmus and Smith, 1974), and of age of first-breeding under controlled, captive conditions would also be very useful for comparison with similar measurements made in the more variable natural conditions.

Birds, such as those kept at Sea World, Inc. in Mission Bay, San Diego, may potentially play an important role in our understanding of how penguins detect El Niño. Linda Henry and I have been examining data that seem to show that the Humboldt Penguins at Sea World stopped breeding during the severe 1983 El Niño. These birds were fed ad libitum, so food shortage was not responsible. What clues caused them to stop (cf. Merritt and King, 1987)?

Finally, the development of inexpensive, safe artificial burrows and their testing in captivity would provide a useful management tool for penguin managers in the field. For example, lack of sites on small islets may force penguins in Africa and Galapagos to nest on the mainland or on larger islands where they are vulnerable to terrestrial predators. Artificial burrows could raise the 'carrying capacity' of such sites.

Conclusion

This is a highly condensed review of the literature on field studies of Spheniscus penguins. It does not, for lack of space, do justice to many fine studies and to the physical environments in which the birds nest and forage or to the ecology of prey species. We know a great deal about Spheniscus penguins, especially their nesting ecologies and diets, but, even with the development of increasingly sophisticated means of studying penguins at sea, we are really only beginning to understand the marine part of their existence. Unfortunately, field researchers can be criticized, with a few bright exceptions, for not applying our knowledge to the management and conservation of Spheniscus penguins. The managers of captive penguins with their direct management experience, albeit at a very small scale, can play an important role in applying the insights of field work to the management of wild, as well as captive populations.

References are included in the bibliography which follows.
A Selected Bibliography of the *Spheniscus* Penguins

DAVID CAMERON DUFFY

I have attempted to make this bibliography as complete as possible and it probably contains most of the more important *Spheniscus* ecology papers published before 1987. Historical, local colony counts and more recent papers, especially those in regional journals, may have been omitted. I would appreciate references or reprints of missing recent papers.


A Selected Bibliography of the *Spheniscus* Penguins


please turn to page 18


Duffy, Wilson, Wilson, Araya and Klages. (in prep. a). The ecology of Humboldt and Magellanic penguins in Chile ms.


please turn to page 20
A Selected Bibliography of the *Spheniscus* Penguins

continued from page 19


Company Contributes to Humboldt Conservation

The Stride Rite Corporation, a U.S. manufacturer of children's shoes, has made Humboldt penguins the focus of donations and promotional events this year.

With a very generous donation of $25,000 to the American Association of Zoological Parks and Aquariums, the Stride Rite Penguin Trust Fund was begun, to assist the Humboldt Species Survival Plan and other activities related to Humboldt penguin conservation.

Various zoos with colonies of S. humboldti have also received donations, and in some areas the company encouraged zoo attendance by distributing coupons good for discounts on admission.

At the Metro Washington Park Zoo in Portland, Oregon, Stride Rite recently became "Zoo Parent" of the entire Humboldt colony. David S. Fuhrman, Corporate Manager–Public Relations, and Paul Dwoskin, of Stride Rite's Seattle office, presented zoo officials with a check for $4000 and received the Zoo Parent Certificate and photos of some of their "adoptees." Penguin keeper Mary Jo Andersen led a tour of the Penguinarium, including a brief visit with some of the chicks being hand-reared.

Nutritional Analyses of Commonly Used Fish


Contains laboratory analyses of whole fish for these two nutrients (Vitamin A and Vitamin E), and recommendations based upon the levels found and what is known about marine animals' needs or tolerances.

The fish species analyzed include: butterfish, capelin, herring, mackerel, salmon, sardines, smelt, and others.

Reprints may be requested from:

Dr. Ellen S. Dierenfeld
Animal Health Center
New York Zoological Society
185th St. and Southern Blvd.
Bronx, NY 10460