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The assessment of African penguin (*Spheniscus demersus* (Linnaeus, 1758)) management performances at the Underwater World Langkawi, Malaysia

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A Malaysian Aquaria, the Underwater World Langkawi (UWL), has brought in 14 African penguins (*Spheniscus demersus*) for their *ex-situ* conservation. Following The Penguin Husbandry Manual produced by the American Zoo Aquarium Association (AZA), the UWL has adopted the population as their management regime and, as a result, has successfully bred the population from a total of 14 individuals to 40 individuals. This study aims to evaluate the captive management of penguins at the UWL and increase the efficiency of the management regime at the UWL. Environmental data were collected in this study, including the size of the Enclosure 13, temperature, lighting, seawater quality, and feeding data. The results showed that the showcase areas fulfilled the minimum requirements of the penguin, and no significant difference was found between morning and the evening temperatures. However, it differed significantly from the six lighting spots, and the pool's water was within the comfort zones. The diet provided for the African penguins at UWL follows their requirements. However, the amount of food supplied to each penguin at UWL is low compared to the food intake of the same individual penguin in the wild. Overall, the management of UWL is excellent practice. However, some weaknesses need further improvement.

[**Keywords**: Aquaria, Captive penguin, Diet, Environmental data, *Ex-situ*, Husbandry manual, Water quality]

Introduction

The African penguin (*Spheniscus demersus*), formerly known as the Black-footed penguin, is endemic to the Southern Africa. It breeds in 29 different locations, ranging from central Namibia to the Algoa Bay on South Africaan southern coast[1]. The population can grow up to a maximum height of 61 to 71 cm with an average weight of 3 kg(ref. 1).

The African penguin is initially listed as "vulnerable" due to a decline in population[2]. During the 20th century, it was reported that there was a significant decline in penguin numbers in South Africa, declining from an estimated 141,000 pairs in 1956 to approximately 21,000 breeding pairs in 2011. Therefore, on October 29th, 2010, the status of the African penguin was changed to "endangered species" under the U.S. Endangered Species Act and the International Union for Conservation of Nature (IUCN) Red List of Threatened Species[3].

Ex-situ conservation is also being done by zoos and aquariums around the world in order to save and study this species. The North American zoo community has already implemented its management based on the Penguin Husbandry Manual Advances. The manual has improved the ability of North American zoos to contribute to penguin conservation through captive breeding, population management, and education[4]. However, despite the success of the North American zoo community, this programme has been limited to activity in the North American zoo community but not in other zoos located elsewhere in the world.

Malaysia's Underwater World Langkawi (UWL) brought in 14 African penguins on May 27th, 2005. Therefore, Malaysia must have a similar stride to the success of the North American zoo community. Assessing captive penguins kept at UWL should be considered necessary as this aquaria is a pioneer in showcasing penguins in this country. Hence, the primary goal of this study is to evaluate the performance of captive penguin management at UWL according to the Penguin Husbandry Manual developed by the American Zoo Aquarium Association (AZA). The collectible data from this study may be used to improve the management and facilities at UWL, directly improving the welfare

issues of the population. The success of the UWL in managing the penguins in captivity would be translated into the success of a breeding programme in Malaysia. Other interested parties and zoos will be able to use the effective practises as a management model and standard operating procedures.

Material and Methods

Study site

The UWL, located in Pantai Chenang, Langkawi Island, Malaysia (6°17'15.46" N and 99°43'43.54" E) (Fig. 1), began its operations on August 26th, 1995. Since then, UWL has evolved into one of the largest marine and freshwater aquarium in the Southeast Asia[5]. The concept and theme of UWL are geared towards knowledge, education, and entertainment[5]. Giant tunnel along the 15 meters is the unique feature of UWL[5]. In 2011, UWL successfully increased the penguin population from 14 to 40 individuals through its breeding programme[6-8]. The penguins were kept and maintained in Enclosure 13 (Fig. 2) with built-in pool, land space, quarantine and isolation area[9].

Penguin Husbandry Manual

Although UWL is the first aquaria to showcase penguins in Malaysia, research on specific management programmes is limited. Therefore, it has never been investigated how the management of African penguins will affect the survival of this species. Thus, UWL referred to the Penguin Husbandry Manual published by the American Zoo Aquarium Association (AZA) in order to get the best management plans for African penguins. This manual contains a large variety of information about various aspects of the penguins, which are combined into one document[10]. Based on this manual, UWL has drafted these management plans, namely i) captive environment management, which includes enclosure size, temperature, lighting, and pool water quality in an enclosure; and ii) husbandry, which includes feeding and routing health and sanitation management programmes.

Data collection

During the study, 40 individuals of African penguins (*Spheniscus demersus*) were placed inside Enclosure 13. Data was gathered in two ways: through direct observation (*e.g.*, feeding routine, working culture, hygiene, and conservation efforts) and through secondary data collection from the UWL database. Both data have been used to comprehend captive management, including food and feeding (or nutritional management), enclosure facilities management[10], and breeding management (breeding history). All the collected information was directly used to analyse and assess the strengths and weaknesses of *ex-situ* management at UWL.

Environmental data

The environmental data collected includes the size of Enclosure 13, temperature, lighting, and seawater quality. The measurements have been carried out in

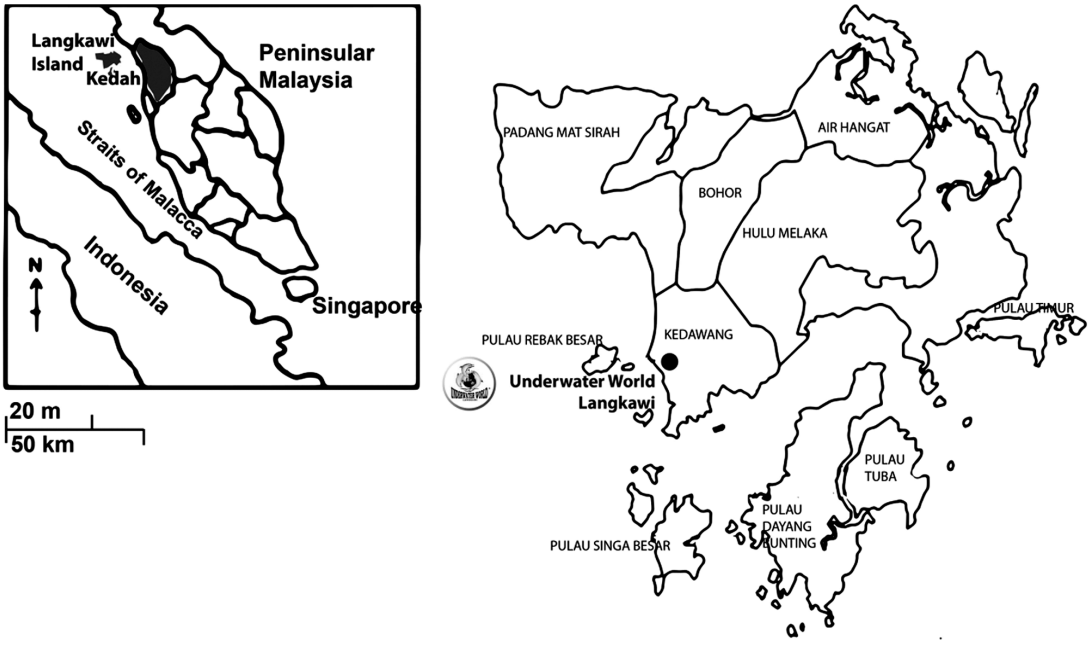

Fig. 1 — Study site (Underwater World Langkawi) located at Langkawi Island, Malaysia

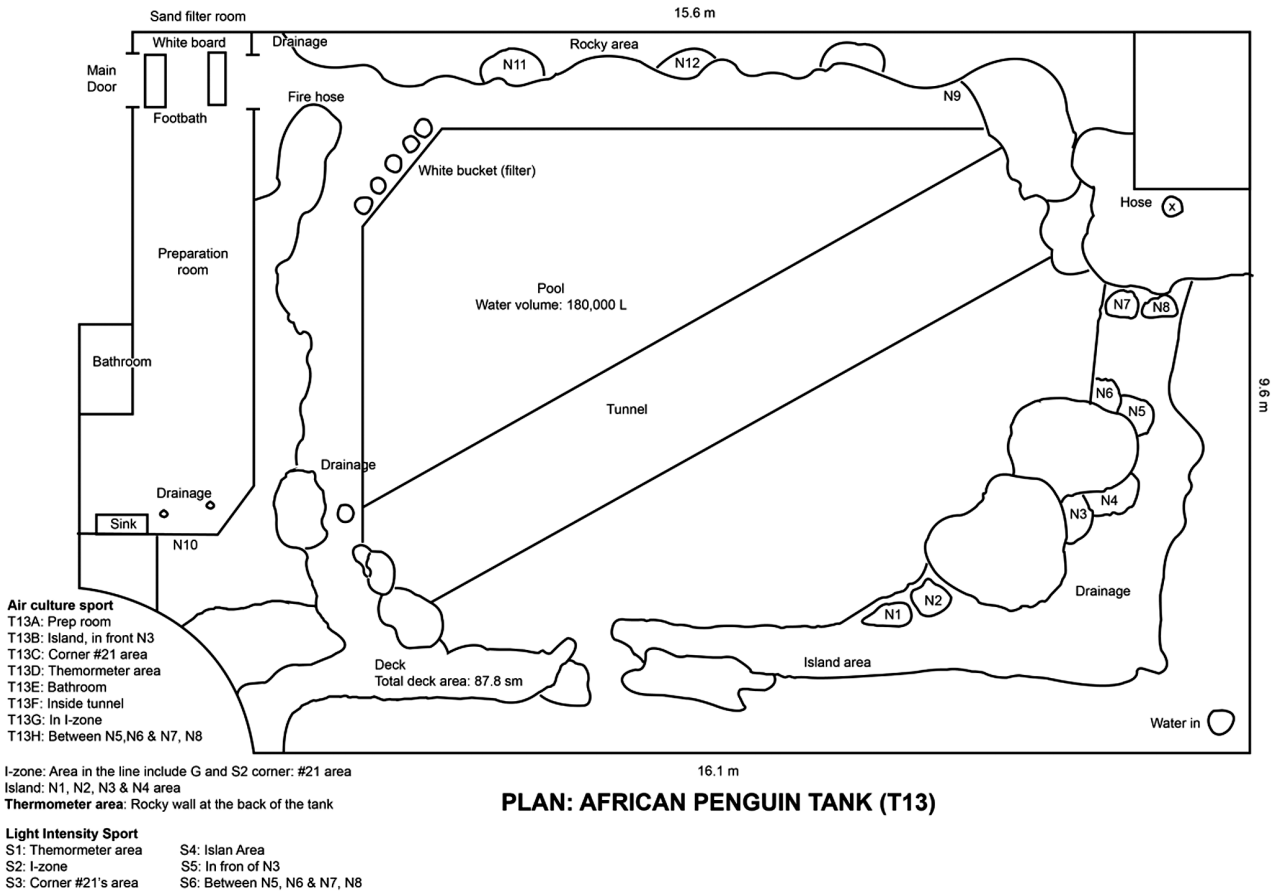

Fig. 2 — Floor plan of Enclosure 13

Enclosure 13 using the measurement tape, including height, width, length, area of land or deck, and the depth of the pool. Daily temperature readings (*e.g.*, room and water temperature) were recorded by using a thermometer every morning (9:00 a.m.) and evening (6:00 p.m.) at local time. In addition, the temperature has been recorded after the cage cleaning. The light intensity was measured using a Lux illumination metre (Konica Minolta, Japan). Each spot (light bulb) of six had its own Lux metre and was recorded every two weeks. Despite that, only data in 2011 was used in the analysis. Additionally, the water's physical characteristics, dissolved chemical contents (*i.e.*, ammonia, nitrate, nitrite), pH, and acidity or alkalinity of the pool were tested using the Water Test Kit. At the same time, the salinity concentration of the seawater was measured using a hydrometer.

Husbandry data

Raw foods such as mackerel fish, sardine fish, squid, shrimp, and white sardines were included in the penguins' daily diet. These diets were either purchased from the wholesale food supplies or in bulk which were stored in the refrigerator. The food was weighed before the feeding process, and feeding was conducted twice a day at 11:00 a.m. and 2:45 p.m. local time. Generally, meals were given consistently between 6.0 kg to 11.5 kg per day for each session. Feeding methods were customised to individual aptitudes, including casts from the pool, throwing on the deck and hand-rearing. The amount consumed was obtained by calculating the total weight minus the weight of food leftovers (that were not taken). The diet was recorded and reported by the keeper on duty.

Data analysis

The *t*-test statistical analysis was used in order to determine the differences between day and night for temperatures between room and water. The significant value at $p < 0.05$ was used to show their differences. In addition, one-way Analysis of Variance (ANOVA)[11] was used to analyse the lighting data to test the light illumination intensity differences between the six spots of light. All statistical analyses were conducted

using the IBM Statistical Package for Social Sciences (Version 20.0)[12].

Results

Environmental data

At the beginning of the study, which was in 2006, only 14 African penguins were introduced as a pioneer population at UWL. However, they were bred to a total of 40 penguins until 2011. This colony in 2011 consisted of 15 males, 11 females, and 14 unidentified sex penguins in the aquarium. All these penguins were placed in the Enclosure 13, with a total deck size of 74.16 m² and a pool surface of 74.16 m². The length, width, and height of the enclosure were 15.6 m, 9.6 m, and 3.14 m, respectively, while the depth of the pool was 2.56 m (Table 1).

To maintain a conducive environment for the penguins, the room temperature of the enclosure was maintained at an average of 19.13±0.38 °C and 19.62±0.54 °C for the morning and evening, respectively. Meanwhile, the average water temperature was kept at 20.88±0.69 °C in the morning and 20.69±0.3 °C in the evening (Table 2).

The lighting was also maintained in Enclosure 13 with six spot locations. The highest illumination intensity is at spot-5 with 497.41±64.24 lx, and the lowest intensity was recorded at spot-2 with 58.86±9.72 lx (Table 3).

The physical and chemical characteristics of the pool water in the enclosure are shown in Table 4. The pool water has an average water salinity of 1.0135±0.0018 ppt and an average pH of 7.4011±0.0060. As for nutrient composition, the concentration for ammonia, nitrite (NO^{2-}) and nitrate (NO^{3-}) were 0.0008±0.0010 mg/l, 0.0021±0.0146 mg/l, and 7.7191±14.7042 mg/l, respectively.

Husbandry data

The UWL has designed a time-specific feeding program for the African penguin, which started at 11:00 a.m. and 2:45 p.m. local time. Their diets consisted of various types of seafood, namely mackerel fish, sardine, squid and shrimp (Table 5). Among the different kinds of fish provided, mackerel was the most consumed by African penguins, 182,820 g. In contrast, only 10 g of shrimp was taken in 2011. The second highest food consumed by *S. demersus* in

Table 1 — The physical characteristics of the Enclosure 13

Length (m)	Width (m)	Height (m)	Pool depth (m)	Pool surface area (m²)	Land surface area (m²)
15.6	9.6	3.14	2.56	74.16	75.6

Table 2 — Air and water temperature in Enclosure 13 recorded during morning and evening

Room		Water	
AM (°C)	PM (°C)	AM (°C)	PM (°C)
19.13±0.38	19.62±0.54	20.88±0.69	20.69±0.31

Table 3 — Light intensity (lx) according to locations in Enclosure 13

Month	Spot 1	Spot 2	Spot 3	Spot 4	Spot 5	Spot 6
January	74	61	359	425	415	79
February	76	59	381	451	409	76
March	79	28	298	318	543	51
April	76	49	346	398	456	69
May	78	39	322	358	499	60
June	77	44	334	378	478	64
July	77	41	328	368	488	62
August	77	43	331	373	483	63
September	79	54	502	356	546	114
October	78	48	416	364	514	89
November	79	51	459	360	530	101
December	78	50	438	362	522	95
Overall	88.54±13.21	58.86±9.72	482.36±79.22	448.77±89.32	497.41±64.24	101.90±18.47

Table 4 — The physical and chemical characteristics of pool water

Tank	Salinity (ppt)	pH	Ammonia (mg/l)	Nitrite (NO^{2-}) (mg/l)	Nitrate (NO^{3-}) (mg/l)
T13	1.0134±0.0020	7.4011±0.0060	0.0008±0.0010	0.0021±0.0146	7.7191±14.7042

Table 5 — The amount of seafood (diets) taken by all 40 African penguins according to a month in 2011

Diet (g)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Mackerel	4160	12440	11310	17840	19230	19440	18600	14300	17800	14300	15500	17900	182820
Sardine	7410	1310	2800	0	0	0	0	3200	20	3300	2900	0	20940
Squid	60	0	0	0	10	0	0	0	23	20	0	0	113
Shrimp	0	0	0	0	0	0	0	0	0	10	0	0	10
White Sardine	100	0	0	0	10	0	0	0	0	180	100	0	390
Total	11730	13750	14110	17840	19250	19440	18600	17500	17843	17810	18500	17900	204273

Fig. 3 — The Mazuri fish eater food tablets that were inserted into the fish gill

UWL was sardine, with 20,940 g. For the same year, UWL provided an average of 17,022.75 g of food per month, with the highest amount recorded in June (*i.e.*, 19,440 g) and the lowest amount recorded in January (*i.e.*, 11,730 g).

The *S. demersus* residing in UWL is not only grown up with food but also nourished with supplemental foods known as the Mazuri Fish Eater tablets (Fig. 3). This supplement was provided in accordance with its early morning feed at 8.00 a.m. local time by mixing with the foods that the tablet was slipped inside the fish's gill.

Discussion

Environmental data

The number of African penguins introduced to UWL is considered manageable, and appropriate as Alcantar *et al.*[13] has recommended keeping penguins in a group that is not less than six birds, in the same area and at the same time. Furthermore, Ellis *et al.*[10] noted that the minimum pool and land surface areas should be 0.74 sq m per bird for the first six birds, and the addition of each bird should be associated with an accumulation of 0.37 sq m area. Therefore, the calculated minimum area required to accommodate a total of 40 individual of penguins is 17.02 sq m. However, the land surface area in Enclosure 13 is about 74.16 sq m, *i.e.* three times greater than the minimum size required. Meanwhile, the pool depth in Enclosure 13 is 2.56 m and thus exceeds the recommended depth of 0.16 m[10].

According to Ellis *et al.*[10], the optimal air temperature range recommended for the indoor exhibit is between 3 to 22 °C and the acceptable water temperature range for *Spheniscus* sp. is about 0 – 290 °C (equivalent to 32 – 850 °F). While Fowler & Cubas[14] noted that penguins forage and live in waters with temperatures ranging from -2 °C to 23 °C, each species could be limited or favourable to only a subset of this temperature range. Generally, the room and water temperature provided in the UWL's enclosure seemed suitable for the African penguin.

Although penguins have reproduced under a simple turn on/turn off lighting system, some breeding success in the zoo was reported to be influenced by the length of days and light intensity[21]. The length of daylight in the Enclosure 13 was set up for 11 hours 30 minutes, while the night length was 12 hours and 30 minutes. In the wild, such as in South Africa and Galapagos Island, their day and night length is about 12 hours; thus, it is slightly different from the lighting systems applied at UWL. However, several zoos and aquariums use lighting schedules that approximate the latitudes in which the species are exhibited and found[10,21].

The global average seawater pH is 8.1, but it could sometimes fluctuate to as low as 7.4. When the pH of the water is 7.9, it can cause sufficient damage and impact resulting in up to a 30 % decline in marine life species[15]. For ammonia levels[16], the free ammonia level should be maintained below 0.02 mg/l in freshwater and 0.01 mg/l in seawater. This is supported by Glodek[17] and Alcantar *et al.*[18], which stated that the ammonia level above 0.02 mg/l is considered to cause harm to aquatic life. Furthermore, a safe nitrate level is below 20 mg/l, and an average maximum level is 50 mg/l[14]. High nitrate

concentration harms marine life by inhibiting growth, impairing the immune system and damaging young internal organs. Even at low concentrations such as 0.5 mg/l, over extended periods causes long term damage and affects the immune system's ability[20]. Referring to Armstrong & Hilton[11], nitrite concentration should not exceed 0.2 mg/l in freshwater and 0.125 mg/l in seawater. Overall, water quality[22] plays an essential role in penguins' survival, and the pH, ammonia, nitrate and nitrite levels in Enclosure 13 of UWL were suitable for penguin life/survival.

Husbandry data

It was found that early endeavours to conserve penguin species in captivity were frequently reported to be unsuccessful[23]. These are the results of a poor understanding of the biological and environmental requirements of the penguin itself that was ultimately resulted in excessive mortality and morbidity[24]. Over the years, many institutions such as Edinburgh Zoo and Sea World Organization[22] have intensively studied the critical elements to improve the penguin husbandry management technique. The American Zoo Aquarium Association (AZA) in 1993 has taken an enormous initiative to produce a practical manual for penguin husbandry by combining the mass information and research from various institutions that remained highly fragmented at the time. The manual will be exploited as guidelines and comparisons for the management of penguins at UWL[25].

In South Africa, two species have been reported to be the primary prey of *S. demersus*, namely anchovy (*Engraulis encrasicolus*) and sardine (*Sardinops sagax*), which make up to 50 – 90 % of their diets[26,27]. In addition, wild fishes, including shoaling fish, Sardine, Mackerel, and Horse Round Herring, are part of the penguin population's daily diet[27]. These are parallel with the types of food provided by UWL to the African penguins. An individual African penguin can consume up to 540 grams of food per day[27]. However, the extent of feeding may increase (*e.g*. more than one kilogram) when the chicks get older[28]. Based on the UWL records in 2011, the average monthly food consumed by African penguins was about 17022.75 kg; thus, it can be concluded that the diet provided for African penguins at UWL follows their requirements. These criteria are the primary key to determining the survivability of the African penguin. Decreasing food availability will affect the stability of the populations[29,30], thus reducing the survivability and viability of *S. demersus*.

Therefore, proper nutrition is crucial for the well-maintained captive population's health. UWL has taken a step ahead in ensuring the population's survivability by administering the Mazuri Fish Eater tablets. The supplements given to the penguins in UWL were Vitamins, Maltodextrin, Yeast, Silicam Stearic Acid, Magnesium Stearate, and Cellulose. Feeding dead or frozen fish or fish with removed internal organs is associated with lower nutrient levels (for example, Vitamin B1 'Thiamine' is destroyed by Thiaminase activity). Also, it contains fewer essential vitamins and minerals required for this population[10,25].

Apart from ensuring the survival of the *S. demersus*, UWL is also committed to conducting a conducive and efficient reproductive management regime for the African penguins during the peak breeding season. The reproductive management regime includes nest management programs, eggs management programs, and chick management programs (Fig. 4a). During the breeding season, all materials required for nesting are provided within the enclosure for the population. The new-laid eggs were inspected, weighed and candled every seven days after being laid. If the parent rejects the egg, the eggs were artificially incubated with the period being the same as parental incubation. In the chick management program, the body was weighed, and a physical examination was conducted by a veterinarian once a week starting from the first day of hatching. The chick's flipper, foot and beak were also measured[5,31].

Besides that, the management programs organised by UWL for nests, eggs, and chicks of African penguins are also crucial. Since the birds were raised in Enclosure 13, they were unable to make their nests alike in the wild. There are various natural nests for the penguin species: burrows, crevices, and surface nests; the *Spheniscus* sp. are burrow nesters[25,32,34]. The burrow-nest includes self-excavated holes in captivity, which are artificially covered with natural human-made caves[10,25]. An artificial nest has been proven to increase the breeding success of Little penguins *Eudyptes minor*[33]. Still, a similar nest failed to do the same in Australia for the same species due to high ambient temperatures inside the nest[33]. The success of the artificial nests is site-and-design dependent[34]. Thus, UWL should pay attention to this matter to enhance the breeding performance of *S. demersus*.

The activities of penguins' eggs management by the UWL include marking eggs, record keeping, and candling. Typically, African penguins lay two eggs[9].

Fig. 4 — Photographs showing (a) Chick, and (b) Nest

So, it is essential to differentiate between the eggs. Candling an egg is a method that can help us get a glimpse of the egg by shining a concentrated light beam through the egg[7,8]. It is beneficial to observe embryo development around seven days before candling can be started. The embryo is appeared as a dark spot surrounded by a faint outline of blood vessels, and it becomes more prominent as incubation progresses[35]. As the eggs develop, the air cell (located at the fat end of the egg) is enlarged and eventually tilts. The air cell can be observed upon candling[36]. By drawing the edges of the air cell on the outside shell, the staff can predict their hatching time. The chick draws its first breath of air into its lungs in this air cell, known as the internal pip. After 12 hours, they begin to externally pip (*i.e.* break through the eggshell). Records are kept for each time the eggs are candled, especially for the internal and external pip, to hatch intervals[5,37,38]. Writing on the eggs, record keeping and candling are essential management tools for chick survival[39]. The mean incubation periods for the eggs by the parent are 38 days with a pip-to-hatch range of 24 – 48 hours[7,8,40]. If the parents reject the eggs, they will be artificially incubated within the same natural incubation processes[7-9].

Future research plan and recommendation

In UWL, there was some potential inbreeding depression occurs several years ago. In order to address this problem, further study and investigation are needed. It is highly recommended for UWL to change, acquire or introduce a new feeding program in UWL. Serving fresh food high in calcium is necessary to avoid cracked eggs and low hatchability problems. It was also noticed that the nest appeared to be very limited and required a long struggle to establish. Therefore, the UWL is needed to increase the number of nests (Fig. 4b) in line with the theme of "one pair, one nest." Besides, multi-substrate materials should be provided for the penguins to form their nests all the time because this species is typically bred all year round. The substrate helps to avoid the continuous widespread cracking of eggs. The process of nest formation shall be recorded as the data would be useful in future research and development.

Most importantly, it is recommended for UWL to send specially trained staff(s) to conduct training programs for the penguins, such as a penguin show to attract more visitors, which can accommodate penguin management costs in the long term. Besides, it is also advisable for the management at UWL to provide attractive electronic or standard information panels filled with precise information to increase public awareness of the importance of species and environmental conservation. Also, it is recommended to issue management modules and husbandry for penguins here as a reference and to ease the update of appropriate management methods and changes over time.

Conclusion

The African penguins require serious conservation attention as their population declines due to several factors discussed. The needs of efficient *ex-situ*

conservation are necessary for the species' survival. The UWL has practised a successful management regime for the population. As suggested, some management sections need further improvements. However, the UWL has successfully prevented disease outbreaks, starvation, and torture. Therefore, the recommendation in this study should be considered by UWL to sustain the efficiency of management and indirectly boost the breeding performance of the population.

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Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

NMS: Conceptualization, validation, resources, writing - review and editing, visualization, supervision, project administration, and funding acquisition; and SMHM: Methodology, investigation, data curation, writing - original draft preparation, visualization. Both authors have read and agreed to the published version of the manuscript.

Ethical Statement

The animal study permission and protocol were approved by the management and veterinary of Underwater World Langkawi.

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