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COMMON CUTTLEFISH (*SEPIA OFFICINALIS*) MORTALITY AT THE NATIONAL ZOOLOGICAL PARK: IMPLICATIONS FOR CLINICAL MANAGEMENT

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Abstract: Six out of seven cuttlefish acquired by the Smithsonian National Zoological Park in July 1998 died before 1 November 1998. Postmortem examinations showed mantle ulcers, secondary bacterial infections, inanition, and cuttlebone fractures. The surviving cuttlefish developed a progressive focal mantle ulcer, was treated with oral chloramphenicol intermittently for 9 wk, and maintained a normal appetite and growth rate until death at 7 mo of age. The National Zoological Park pathology database showed signalments, histories, and causes of mortality of 186 common cuttlefish, each 1–14 mo old, that received gross and histologic examinations; for example, the largest group of cuttlefish of known sex, age, and body weight at postmortem were 7–9 mo old and weighed an average of 376.2 g (males, n = 18) and 299.0 g (females, n = 15). Many cuttlefish had multiple pathologic diagnoses. Significant diseases included inflammation and secondary bacterial infections, especially gastrointestinal, cardiovascular, respiratory, reproductive, and ophthalmic, and septicemia due to *Vibrio* spp. or other gram-negative bacteria. Mantle lesions, including ulceration/dermatitis, abscess/granuloma, necrosis/fibrosis/cellulitis, and laceration/abrasion/erosion, were also identified, along with inanition, cuttlebone lesions, and trauma. Mantle lesions were associated with secondary bacterial infections and death. On the basis of this information, if captive cuttlefish behavior creates risk for development of mantle lesions, administration of antibiotics effective against gram-negative bacteria may delay or halt disease progression. Cuttlefish exhibits require proper design, husbandry, economic resources, and staffing to minimize disease syndromes and mortality.

Key words: Sepia officinalis, common cuttlefish, pathology, clinical management, mantle ulcers, gram-negative bacteria.

INTRODUCTION

Common cuttlefish (*Sepia officinalis*) and such cephalopod molluscs as squid, octopus, and the nautilus are frequently bred in captivity. Their basic biology and husbandry are reported in the aquaculture literature,[1,3,12–15,18,22,26] and their complex sensory systems and semiparous life cycles create challenges for culture.[3,14,15,23] They spawn shortly after reaching sexual maturity, then usually die within 60 days.[26] Infectious and parasitic[19] diseases (protozoal,[37] viral[35]) of cephalopods have been reported.[3,12,13,16,17,33] Literature addressing medical management of cuttlefish is limited in quantity, and reports on mortality of this species in zoos and aquaria are scarce.[6,19,26,29]

Captive cephalopods are susceptible to disease and major health problems[17,18,20,33,34] due to their marine-adapted immune system and their thin, delicate, microvillar epidermal structure.[17,20,24,26–28,31] All cephalopods possess one type of blood cell, or hemocyte, which functions in basic cellular immunity but is not phagocytic.[26,28] Humoral immunity involves lectin-like proteins, not antibodies, that hemagglutinate foreign antigens.[9,26,27,31] Visible clumping of cephalopod hemocytes has been associated with septicemia.[27,31] Although well adapted to natural environments, cephalopod immune systems may be compromised by stress related to captivity, leading to disease.

Cuttlefish physiology and behavior affect their management.[11,12,18,26] The apparent curiosity of cuttlefish makes them interesting to observe but difficult to manage in a small display tank. They may be aggressive and highly territorial[3,26] and therefore require a large tank. Intermale aggression marks the transition between juvenile and adult status.[26] Aquaculture and laboratory facilities maintain cuttlefish groups in sizable tanks for propagation or research,[18,26] but zoos typically keep no more than a dozen cuttlefish in smaller display tanks[21] and may have different husbandry techniques and economic resources as well. Small-scale captive environments present some disadvantages for cuttlefish health and longevity.

Life spans of 186 common cuttlefish in the Invertebrate Department at the Smithsonian National Zoological Park (NZP) from 1986 to 1998 were 1–14 mo. Most of these cuttlefish developed abnormal

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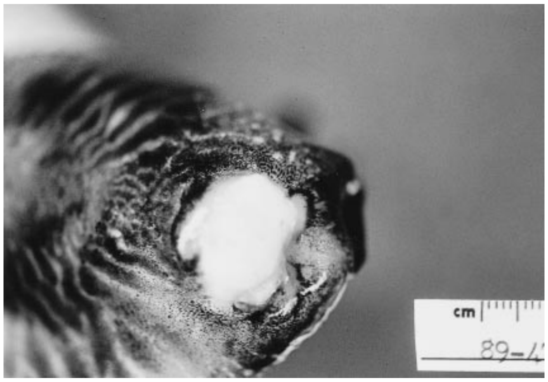

Figure 1. Close-up view of the distal mantle tip of a common cuttlefish (*Sepia officinalis*) depicting a severe mantle ulceration (white, irregular tissue). Edges of the ulcer are rolled and edematous. Mantle lesions are typically preceded by agitated swimming behavior and commonly lead to secondary bacterial infections and rapid death.

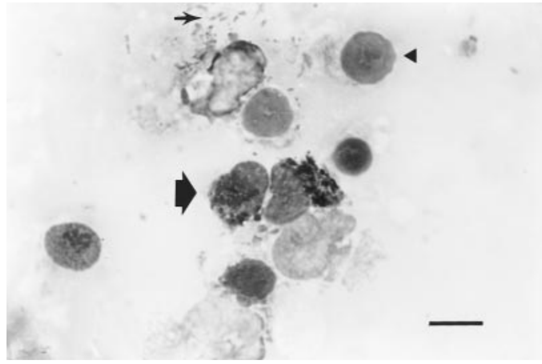

Figure 2. Hemolymph (blood) from a common cuttlefish (*Sepia officinalis*) that died after developing a mantle ulceration. Large blood cells or hemocytes with (large arrow) and without (arrowhead) prominent, eosinophilic cytoplasmic granules are present, admixed with a few gram-negative bacilli (small arrow). The diagnosis was hemocytic inflammation with intralesional bacilli, compatible with bacterial septicemia. Wright stain, ×320. Bar = 9.76 μm.

behavior suggestive of infection or sepsis, including anorexia, lethargy, dark coloration, hiding, frequent inking, or erratic swimming patterns, prior to death. When a new group of juvenile cuttlefish arrived at NZP in July 1998, several strategies were implemented to prevent disease and improve longevity.

This report summarizes case histories of seven captive-born, hatchling cuttlefish (*Sepia officinalis*) acquired by NZP in July 1998 and postmortem records for 186 juvenile and adult cuttlefish necropsied at NZP from 1986 to 1998 and provides medical management recommendations for captive cuttlefish in zoological parks and aquaria.

CASE REPORTS

Seven captive-born hatchling cuttlefish, approximately 1 mo of age, were acquired in early July 1998 from the National Resource Center for Cephalopods of the Marine Biomedical Institute (NRCC/MBI), Galveston, Texas 77555, USA. They were housed in a 0.765-m^3 polyvinylchloride and plastic mesh bin within a 22,680-L round fiberglass tank with under-gravel and ultraviolet filtration. They ate and developed normally for 4 wk and were then released into the larger tank. For the first 3 wk, they were fed grass shrimp gut-loaded with fish flake food (Tetra-Min®, Tetra Sales USA, Blacksburg, Virginia 24060, USA) and vitamins (Vita-fish®, Marine Enterprises International, Baltimore, Maryland 21221, USA) and brine shrimp presoaked in an aquarium food supplement (Selcon®, American Marine, Inc., Ridgefield, Connecticut 06877, USA). After 3 wk, thawed shrimp, crayfish, and live guppies were added to the diet. Water quality was checked weekly with a standard commercial test kit (Hach, Loveland, Colorado 80539, USA). Tested parameters were within acceptable cephalopod limits (pH = 8.2–8.4, ammonia = 0 mg/L, nitrates = 0–10 mg/L, temperature = 22–26°C).[3,11,12,26] Water changes of 30–50%, with artificial seawater formulated from dechlorinated, deionized tap water, were performed approximately every 10 days and after any animal death.

Four of the cuttlefish in the large tank died within 2 wk. Focal mantle lesions and behavioral changes (anorexia, surfacing, acute color changes, aggressive posturing, bumping into tank walls, inking) were noted prior to death. Husbandry techniques were then changed, including increased water circulation, provision of hiding places and visual barriers, addition of a dark-screened tank cover, and reduced local activity and overall noise levels. Nevertheless, anorexia and abnormal behavior persisted in the remaining juveniles, and their mantle ulcers worsened. The ulcers were dark gray and white edematous erosions (up to 2 cm in diameter) at the distal tip of the mantle (Fig. 1). Impression-smear cytology (Wright and Gram stains) of ulcerated mantle tissue from the most severely affected animal revealed colonies of gram-negative rods and inflammatory cells (Fig. 2).

Ulcer-induced bacterial septicemia was suspected. Mantle erosions and ulcers were attributed to trauma from collision with tank walls and abrasion of distal mantle tips in the gravel substrate. *Vibrio* spp. and other gram-negative rods were cultured at postmortem from hemolymph of the first two dead cuttlefish. Samples were cultured at 25°C for 1–3 days in tryptic soy broth (Difco Laboratory, Detroit, Michigan 48232, USA) with 3% NaCl added, as well as on 5% sheep blood trypticase soy agar (Becton-Dickinson Microbiology, Cockeysville, Maryland 21030, USA) and MacConkey agar (Difco). Microbiologic identification for gram-negative bacteria was performed with the API 20E system (bioMérieux Vitek, Inc., Hazelwood, Missouri 63042-2320, USA). Antibiotic sensitivity assays were not performed.

On the basis of these findings, the three remaining cuttlefish with no discernible mantle lesions were treated prophylactically with food bits injected with chloramphenicol sodium succinate (Chloromycetin®, Parke-Davis, Morris Plains, New Jersey 07950, USA; 40 mg/kg p.o. s.i.d. for 10 days). Individual treatment doses were based on an estimated body weight of 30 g. All three cuttlefish ate well and grew larger. Over the following 3 wk, however, one cuttlefish exhibited severe unilateral corneal opacity and periocular swelling. Another developed a fluctuant vesicle approximately 2 cm wide along the distal mantle, and cytology (Wright and Gram stains) of a fine-needle aspirate of the vesicle revealed hemocytic inflammation with abundant gram-negative rods. Both cuttlefish were again treated with oral chloramphenicol at the previous dosage but each subsequently died. Gross examination, histopathology, and postmortem bacterial cultures revealed dorsal herniation of the stomach and cecum, a fractured cuttlebone, and unilateral hypopion (*Vibrio* sp.) in the cuttlefish with antemortem ocular lesions. The cuttlefish with the distal mantle vesicle had severe mantle erosions, a fractured cuttlebone, and a supraosseous abscess (*Vibrio* sp.) diagnosed at postmortem.

The surviving cuttlefish remained clinically normal until 3 mo after arrival, when it was moved to a 1.8- × 0.61- × 0.61-m, 680.4-L, rectangular glass display tank, maintained at 18–20°C with undergravel and ultraviolet filtration, containing a stable population of four adult chambered nautilus (*Nautilus pompilius*). Four days after relocation, the cuttlefish intermittently bumped into the sides of the tank. It developed a focal, grayish-white, nonulcerative, edematous lesion approximately 1 cm in diameter on the distal tip of the dorsal mantle, and oral chloramphenicol (40 mg/kg s.i.d.) was initiated to prevent secondary infection. The cuttlefish grew normally for 3 wk, then developed a 2- × 1-cm fluctuant swelling at the previous site of mantle discoloration. This swelling slowly decreased in size but ruptured 4 days later, exposing a triangular (2 × 1 × 1 cm) section of white, striated subcutaneous tissue with rolled, edematous edges. Although the prognosis was guarded, treatment with oral chloramphenicol continued. The cuttlefish continued to eat and grow over the next 2 mo, and the ulcer regressed and flattened (Fig. 3), but at the age of 7 mo, 9 wk after the initial mantle ulceration, a focal, yellow-tan, raised, proliferative area, 3–4 mm in diameter, developed in the center of the lesion. The cuttlefish became highly agitated, as indicated by frequent inking and rubbing of the irregular distal mantle tissue against the sides of the glass aquarium. After refusing food for 36 hr, the cuttlefish died.

Figure 3. Photograph of a 7-mo-old common cuttlefish (*Sepia officinalis*) in a display tank. The mantle ulceration (white triangular tissue at the distal mantle tip, white arrow) developed after the rupture of a large vesicle, diagnosed as a supraosseous abscess at postmortem.

At postmortem gross examination, this adult male cuttlefish weighed 371.4 g and had a focal granuloma associated with a circular, 3–4 cm-diameter, distal mantle ulcer and a nondisplaced, partial thickness cuttlebone fracture.

Necropsy database review

The pathology records of 186 common cuttlefish presented to the Department of Pathology at NZP from 1986 through 1998, and the records of six of the seven cuttlefish acquired in July 1998, were reviewed. Complete necropsies consisted of gross and microscopic examination of all organs and tissues, as well as cytology or bacteriology in selected cases. Pertinent data for 186 common cuttlefish were collected from necropsy reports for each cuttlefish and included signalment, body weight, clinical history, gross and histologic descriptions (except in cases of severe autolysis or missing car-

Table 1. Signalment, body weight ranges, and average body weight (in grams) determined at postmortem for common cuttlefish of known age (to the nearest month) necropsied at the National Zoological Park between 1986 and 1998 (n = 99). Individual cuttlefish with either no recorded age (n = 49) or unreported body weight (n = 38) were excluded.

Age (mo)	Sex[a]	Total in group	Weight range (g)	Average weight (g)
1–3	M	5	16.2–68.4	39.8
(n = 14)	F	6	2.0–92.0	34.8
	NR	3	4.5–36.3	23.7
4–6	M	8	28.7–193.7	130.8
(n = 25)	F	12	18.9–439.0	141.9
	NR	5	49.8–312.0	118.4
7–9	M	18	44.4–1,135.4	376.2
(n = 34)	F	15	84.7–565.0	299.0
	NR	1	102.8	102.8
10–12	M	12	243.0–1,641.0	819.4
(n = 21)	F	9	231.6–1,140.0	677.0
13–14	M	4	632.2–1,418.4	1,137.7
(n = 5)	F	1	1,414.7	1,414.7

[a] M = male, F = female, NR = sex not recorded (n = 9).

cass), special test results (e.g., bacterial cultures or cytologies), final diagnoses, and cause of death.

Data are presented in Tables 1 and 2. Between 1986 and 1998, 186 common cuttlefish died at NZP and 166 (89.2%) received complete necropsies. Six carcasses were not retrieved and 14 were markedly autolyzed (10.8%). Average body weight for 99 cuttlefish of known sex and age was calculated from body weight obtained at necropsy (Table 1). Age analyses to the nearest month at death were based on keeper records and/or postmortem assessment. The ages of 49 cuttlefish and weights of 48 were unknown.

Most cuttlefish received multiple postmortem disease diagnoses (Table 2). Anorexia, mantle lesions, and ocular lesions were cited most frequently in historical descriptions (60, 41, and 26 times, respectively), and other recurrent antemortem clinical signs included depression, dark coloration, lethargy, agitation, hiding, self trauma, and slow growth or failure to thrive. Postmortem findings correlated with antemortem histories and clinical signs; many cuttlefish had mantle lesions, secondary bacterial infections, and/or no body stores of fat.

On microscopic examination, inflammatory lesions and infections of multiple body systems were documented most frequently (n = 320; Table 2). Typically, an individual cuttlefish had multiple tissues affected. In selected cases, pure and mixed bacteria were cultured postmortem from hemo-

Table 2. Frequency (in decreasing order) of significant disease syndromes occurring in common cuttlefish before (clinical signs) and after death (postmortem diagnosis), based on a review of the National Zoological Park necropsy database from 1986 to 1998 (n = 186). For most individuals, multiple clinical signs and postmortem diagnoses were recorded; however, not all necropsy reports included a detailed clinical history.

Parameter	Frequency
Clinical signs	
Anorexia	60
Mantle lesions	41
Ocular lesions	26
Depression, lethargy	16
Agitation, hiding	15
Reduced growth (runts)	13
Trauma (self)	10
Tentacle lesions	6
Trauma (others, cannibalism)	5
Cuttlebone lesions	4
Postmortem diagnosis[a]	
Inflammation and/or infections	
Septicemia	43
Other bacteria	30
Vibrio spp.	13
Gastrointestinal	64
Cardiovascular	53
Respiratory	52
Reproductive	44
Ophthalmic	37
Renal	14
Locomotor	8
Neurologic	5
Total inflammation and/or infections	320
Mantle lesions	
Ulceration, dermatitis	72
Abscess, granuloma	15
Cellulitis	6
Laceration, abrasion, erosion	5
Necrosis, fibrosis	4
Total mantle lesions	102
Inanition	39
Cuttlebone lesions	
Erosion, necrosis	11
Fracture	10
Supraosseous abscess	7
Deformity	3
Total cuttlebone lesions	31
Trauma	
Self	8
Others, cannibalism	11
Total trauma	19
Reduced growth	3
Maladaptation	3

[a] No postmortem was possible in cases of advanced autolysis (n = 16) or unretrieved carcass (n = 4).

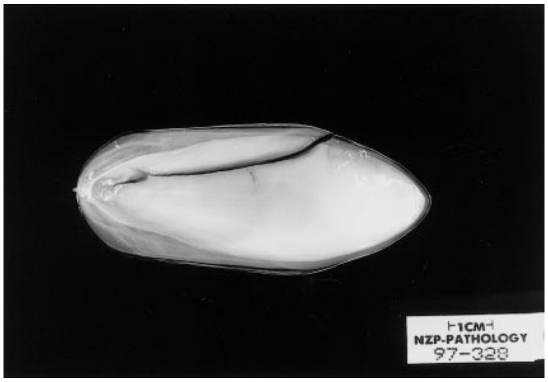

Figure 4. Postmortem appearance of a severely fractured cuttlebone. Common cuttlefish (*Sepia officinalis*) at the National Zoological Park have been diagnosed with cuttlebone fractures, erosions, necrosis, and infections frequently associated with deep, ulcerative mantle lesions.

lymph, mantle ulcers, abscesses, and ocular fluid. Mantle lesions were associated with septicemia, granulomas, and osteomyelitis with or without pathologic fractures of the cuttlebone. Septicemia (in which case bacteria were cultured postmortem from hemolymph) was present in 43 cases and involved primarily gram-negative bacteria, *Vibrio* spp. (n = 13), *Aeromonas hydrophila, Citrobacter freundii*, and others. Lesions of the mantle, defined as ulceration, dermatitis, granuloma, laceration, abscess, abrasion, erosion, fibrosis, cellulitis, or necrosis, appeared as a final diagnosis 102 times. Lack of body fat detected during gross necropsy, classified as inanition, occurred in 39 individuals. Cuttlebone lesions (n = 31) included deformity, erosion, necrosis, supraosseous abscess, and fracture (Fig. 4). Several cases of fractured cuttlebones directly correlated with a history of observed self-trauma.

On the basis of information collected at NZP, review of the literature, and consults with experts in cuttlefish husbandry, preferred water quality parameters and a formulary for captive cuttlefish are presented as Table 3, and some recommendations for the medical management of captive cuttlefish in small-scale environments are summarized.

DISCUSSION

Similar inflammatory lesions and secondary bacterial infections of multiple organ systems,

Table 3. Specific recommendations for optimal water quality parameters and a formulary for the medical management of captive common cuttlefish.

Water quality parameters	Range	References
Temperature (°C)	20–24	11, 12
Salinity (parts per thousand)	27–38	3, 11, 12
pH	7.7–8.2	11, 12
Ammonia, nitrites (mg/L)	<0.1	3, 11, 12, 26
Nitrates (mg/L)	<20.0	3, 11, 12, 26
Formulary	**Dosage/route/frequency**	**References**
Treatment options	oral, parenteral	13, 17, 26
	bath, tank immersion	10, 13, 15, 17, 26
Antibiotics		12, 13, 17, 26
Chloramphenicol	40 mg/kg p.o. or i.m. s.i.d.	26
	75–100 mg/kg p.o. or i.m. s.i.d.	12, 13
Gentamicin	20 mg/kg i.m. s.i.d.	26
Nitrofurazone	2 mg/L for 72 hr	10, 26
Tetracycline	10 mg/kg p.o. s.i.d.	29
Antiprotozoals		13, 37
Metronidazole	100 mg/L for 16 hr	13
Anesthesia	dose to desired effect	2, 12, 25, 26, 32
Ethanol	2% (diluted 1:1 with seawater)	12, 25, 26, 32
Magnesium chloride	7.5% (diluted 1:1 with seawater)	25, 32
	2.5% (diluted 1:1 with seawater)	12
Euthanasia		26, 30
Ethanol	10%, in seawater	26
Magnesium chloride	10%, in seawater	26

bacterial septicemia, mantle lesions, and inanition have been reported in squid,[10,20] octopi,[15] and cuttlefish[12,18,21,26,33,34] at propagation facilities. A captive environment can contribute to the progression of disease in cuttlefish for a variety of reasons, many of which are husbandry related.[12,17,20,26,33]

The invertebrate immune system, adapted to prevent disease in natural or optimal marine environments, may be overwhelmed by suboptimal conditions in captive environments with, for example, ubiquitous microflora, elevated ammonia levels, overcrowding, or improper tank design.[26] Cuttlefish, though adaptable and capable of thriving in captivity,[26] are highly sensitive to environmental disturbances.[29] Agitated cuttlefish will briskly bump into or against the sides of the tank when reacting to environmental stressors, such as tankmate aggression or poor water quality.[34] The resulting damage to the distal tip of their mantle compromises their thin, microvillar integument and provides a route for bacterial invasion.[13,26,34]

In many NZP cuttlefish, bacterial infections of cardiovascular, respiratory, digestive, reproductive, and renal tissues were probably secondary to mantle lesions. Cephalopods have an extensive vascular system connecting gills to branchial and systemic hearts and to the peripheral vasculature.[4] Hematogenous spread of bacteria has been cited as the most likely etiology of septicemia in one group of captive cuttlefish, with possible entry routes via mantle ulceration or the anatomically exposed respiratory and reproductive systems.[29] In several NZP cuttlefish, trauma, particularly self-induced, resulted in mantle erosions and ulcerations with rapid bacterial invasion and subsequent death due to septicemia.

Bacteria on the normal and ulcerated mantle surface of captive squid may exceed in number those found on free-living squid.[10] Trauma, and not primary bacterial colonization, has been implicated as the initiating cause of mantle compromise.[10] Bacteria (usually gram-negative rods), along with edema and necrosis, have been observed in the subepidermal layer of squid mantles within a few hours of trauma-induced epidermal loss.[20]

Ubiquitous aquatic flora, including *Aeromonas* sp., *Vibrio* sp., and *Pseudomonas* sp., have been isolated from both normal and ulcerated mantles of squid (*Lolliguncula brevis*), and both prophylactic and therapeutic antibiotics have been suggested for treatment of any squid susceptible to mantle compromise or damage.[10] Cephalopod skin lesions may contain *Aeromonas, Vibrio,* and *Pseudomonas* spp., usually simultaneously.[17] *Vibrio* sp. was isolated postmortem from hemolymph, abdominal fluid, and eyes of four captive cuttlefish with myocarditis.[29]

Unless a pure culture of one organism is obtained, however, the significance of mixed bacterial cultures is unclear in any aquatic specimen that is not examined immediately after death because of the likelihood of rapid postmortem bacterial overgrowth.[4,26,29,30]

Cuttlebone fractures were seen in 10 cuttlefish, including two from the July 1998 group. At postmortem, cuttlebones have been characterized as brittle and, in three cases, were malformed. Possible explanations for abnormal cuttlebone development include suboptimal nutritional and/or water quality parameters (J. Scimeca, pers. comm.). For example, nutritional deficiencies, water temperatures outside of normal ranges, or stress induced by excessive nitrogenous waste compounds can adversely affect cuttlebone mineral deposition and growth rate.[11,22,24] According to NZP case histories, self-induced trauma is the most likely cause of mantle ulceration. Self-trauma can affect the cuttlebone by either spread of infection or fracture at impact with tank walls.[34] Skin damage at the mantle tip can result in chronic, localized infections, as in several cuttlefish at NZP, or the infection can spread to adjacent tissues and the cuttlebone, leading to death.[17]

The NRCC/MBI, a major source of squid and cuttlefish for scientific investigators and for NZP, has produced a review[26] of specific environmental and nutritional parameters that have contributed to successful year-round propagation of large numbers of cephalopods. Their protocols may apply to cuttlefish exhibits in zoos and aquaria. The NRCC/MBI has treated mantle ulcerations with antibiotics successfully.[26,33,34] Another formulary, developed through clinical trials, outlines methods for antibiotic treatment of cephalopods in large propagation tanks.[13]

The individual NZP cuttlefish receiving oral chloramphenicol therapy for almost 10 wk continued eating and growing during treatment. The dose of oral chloramphenicol administered intermittently may not have increased with increased animal size, however, resulting in subtherapeutic tissue levels. Although antibiotic treatment may have extended life span by delaying bacterial infections and septicemia, an inflammatory response eventually developed in the central portion of the healing mantle ulcer. We hypothesize that the anorexia and agitated behavior observed in this cuttlefish 48 hr prior to death was due to discomfort and stress induced by the acute inflammatory response, leading to compromised physiologic and immune functions, septicemia, and death. Ideally, body weight would have been obtained or more accurately estimated in this individual for proper dosage adjustments. Keepers have successfully weighed juvenile cuttlefish and chambered nautilus after minimally stressful underwater transfer into a smooth plexiglass container filled with tank water of known weight, but weight can be reasonably estimated on the basis of age group.

The use of oral, parenteral, or tank/bath immersion prophylactic antibiotics in captive cuttlefish subjected to physiologic stress is reasonable and may delay disease progression and improve longevity. Oral administration by injecting drug solution into pieces of food is preferable and less stressful than parenteral administration. Bath treatments are prepared with tank water to avoid acute water quality changes, especially temperature.

Preventive management of captive cuttlefish depends on careful husbandry, frequent clinical assessment, and the appropriate use of antibiotics. Case histories of NZP cuttlefish illustrate the need to prevent mantle lesions or to treat them early and aggressively if they do occur. Alternative therapies for cuttlefish are needed. The roles of housing and environment on the health of captive cuttlefish are significant and must be considered.[3,29] Such stressful factors as lack of hiding places, excessive human activity near the tank, overcrowding, and poor water quality should be avoided.[3,12,18,26,29] Strategies for preventing mantle ulcers include strict attention to tank design, substrate, water quality and temperature, nutrition, and population density.[3,12,17,20,26,29,33,34]

Training cuttlefish (and other cephalopods) to accept routine gentle handling, including in-water transfers, and medical assessments is possible.[3,12,18,26] To reduce stress, tanks should be darkened and/or covered for 2–3 hr after procedures. If necessary, cuttlefish can be anesthetized for brief procedures with ethanol or magnesium chloride solutions made with tank water,[12,25,26,32] with efforts made to eliminate self-trauma. Smooth-sided covered containers with adequate oxygenation and a separate recovery container with fresh tank water should be employed.

There are several different successful types of tanks and filtration schemes.[3,12,15,17,18,20,33,36] A round tank with a cover and boundaries that are visually obvious at all times is preferable.[3,18,20] Boundaries can be achieved by painting stripes along interior walls and/or by placing plant décor along swimming paths. Suggested minimum water depths are $\geq$5 cm for hatchlings and $\geq$30–40 cm for adults.[11] A maximum water volume for tank size is ideal, and erratic currents or uneven water flow should be avoided.[3,15] Intakes can be covered with plastic mesh. Filtration methods should include a combination of mechanical, biologic, and adsorptive filters, as well as ultraviolet light sterilization.[3,12,36] Ink material, released by excited or stressed cuttlefish, should be promptly removed via activated carbon or protein skimmer, primarily to prevent fouling of gill tissue.[11,26]

The rapid growth rate, metabolic rate, and concentrated protein diet of cuttlefish result in the excretion of two to three times more ammonia waste product per kilogram than other aquarium species.[3,12,18,26] Toxic ammonia levels accumulate more rapidly in aquaria housing cuttlefish than in comparable ones containing teleost fish, especially in closed systems.[3,22] Water quality limits stocking densities.[3,12] With the July 1998 group of NZP cuttlefish, weekly tests of water quality may not have detected spikes in ammonia or nitrite levels, leading to subclinical stress and disease progression. Temperature, salinity, ammonia, nitrites, nitrates, pH, and dissolved oxygen should be tested at least twice weekly and immediately after any deaths to ensure acceptable levels.[3,12,15,18,26,36]

Any substrate should be fine and smooth to prevent mantle trauma. Tank décor or furniture should provide places for cuttlefish to hide, establish territories, and escape aggression. Octopi may become depressed and anorexic if denied adequate hiding places.[15] Sudden change in light intensity may cause panic and injury.[3,11] One-way glass for display sections of tanks limits startling of cuttlefish on exhibit.

Clinical histories from NZP records describe frequent male sparring and female stress during mating, with trauma to eyes, tentacles and mantles. Although cuttlefish are sensitive to crowding, recommended optimal population density varies.[3,11,12,15,18,26] In display aquaria or exhibits, no more than two adults/m^2, and only one male, should be housed in the same tank[26] (J. Scimeca, pers. comm.). At NZP, trauma was common and included attack and cannibalism by tank mates, predation by other invertebrates, and accidental access to intake valves.

Studies of the dietary habits and requirements of, and nutritional recommendations for, captive and wild cephalopods are available.[3,5,7,8,11,12,18,22,26] Cuttlefish can survive for several months at only 10% of normal growth rate.[3] Given that inanition, based on absence of intracoelomic fat, was a common postmortem finding at NZP, either NZP cuttlefish were not always fed adequate amounts or variety of diet or they were failing to consume offered foods because of health-related reasons. Increased diet variety and feeding rates may stimulate appetite in partially anorexic cuttlefish. Buoyancy problems and the appearance of a longitudinal dark stripe along the dorsal mantle due to chromatophore concentration in contracted skin have been observed in starving *Sepia* spp.[3] Similar clinical signs were occasionally recorded in histories of NZP cuttlefish.

Cuttlefish grow rapidly, with a life span in captivity that rarely exceeds 1 yr.[11,12,26] Proper growth depends on nutrition, water quality (especially temperature), and behavior.[7,8,22,26] Captive life spans may be shorter at temperatures above 20°C.[11] Mariculture of cuttlefish at temperatures of 20–24°C has resulted in growth rates of 3–4% body weight per day.[11] Other reported growth rates in juvenile and adult cuttlefish range between 2.5 and 5%[8,18,26] and 3 and 10% per day.[18,22] Typical laboratory-reared cuttlefish weigh 139–441 g as juveniles,[11,26] 500–1,400 g at 10 mo of age,[12,18] and 1–2 kg as adults.[11,26] According to NZP necropsy records, the most common age group at death was 7–9 mo, and average body weights were 376.2 and 299.0 g for males and females, respectively. For reasons that remain unclear, perhaps related to husbandry techniques, NZP data reflect reduced longevity and growth rates when compared with NRCC/MBI data.[26]

Monitoring cuttlefish sizes and rates of growth can be helpful in evaluating their overall health and nutritional status.[8,22,26] A common method of assessing body size and growth rate of cuttlefish and squid is the measurement of maximum mantle length.[3,12,22] Mantle lengths within a wild cuttlefish population ranged from 1.5 to 24 cm in one survey[5] and between 16 and 17 cm (16 mo of age) and 24 and 25 cm (21–22 mo of age) in another study.[6] Unfortunately, mantle lengths were not routinely recorded either before or after death in NZP cuttlefish. Postmortem weight and mantle length, in combination with disease syndromes, may help identify factors affecting cuttlefish growth and might be a better means of classification of juvenile or adult age status versus months of age and/or weight at death only (J. Scimeca, pers. comm.).[3,12]

Early detection of illness plays an essential role in cuttlefish management. Once anorexia develops, successful medical intervention is unlikely. Many of the cuttlefish that died at NZP became anorectic just prior to death, refusing food completely or partially for a period of 1–21 days. Death without premonitory anorexia also occurred in NZP cuttlefish and has been described at other facilities.[26,29]

CONCLUSIONS

The most significant disease syndrome observed in NZP cuttlefish during a 12-yr period was mantle ulceration leading to secondary bacterial infections and inflammatory lesions. Preventive measures are paramount to the longevity of this species in captivity. If cuttlefish are exhibiting behaviors that put them at risk for development of mantle lesions, prophylactic long-term antibiotic therapy effective against gram-negative aquatic bacteria may delay or halt disease progression. The successful display of these unique aquatic invertebrates requires proper exhibit design, husbandry, and medical care.

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