JZAR www.jzar.org JOURNAL OF ZOO AND AQUARIUM RESEARCH

JZAR Evidence-based practice

OPEN ACCESS

Evidence-based practice

Incidence rate of *Erysipelothrix rhusiopathae* clinical disease in cetaceans is reduced following water treatment changes in a closed artificial seawater system

William Van Bonn[1] and Mary Anne Rogers[2]

[1]*A. Watson Armour III Center for Animal Health and Welfare, John G. Shedd Aquarium, 1200 South Lake Shore Drive, Chicago, IL 60605.*
[2]*Registrar's Office, John G. Shedd Aquarium, 1200 South Lake Shore Drive, Chicago, IL, 60605.*

Correspondence: William Van Bonn, email: bvanbonn@sheddaquarium.org

Keywords: artificial seawater, cetaceans, *Erysipelothrix rhusiopathae*, vaccine

Article history:
Received: 27 Sep 2019
Accepted: 21 Apr 2020
Published online: 31 Jul 2020

Abstract

Cetaceans have been housed at John G. Shedd Aquarium, Chicago, Illinois, in an approximately 3 million-gallon, closed, recirculating, artificial saltwater system since March 1991. From then through September 2008 there were five clinical cases of disease caused by *Erysipelothrix rhusiopathae* with a case fatality rate of 40%. The incidence rate for that period was 5/173.9 (2.88%) animal-years. In September 2008, the system was entirely drained, and recommissioned in April 2009. From 2009 through 2019, there was one case of erysipelothricosis, which was not fatal: an incidence rate of 1/118.1 (0.85%) animal-years for that period. Thus, cetaceans housed in this system after the management changes were 3.39 times less likely to contract clinical disease due to *E. rhusiopathae* infection compared with those prior to the change. Simultaneously with the maintenance of the system and habitat, a change was made to system water sourcing and treatment. Pre-maintenance source water was entirely municipal water. Post-maintenance, source water includes approximately 30,000 gallons of water per week moved from systems housing other animals including teleost and elasmobranch fishes. The salt mixes added to the municipal water also changed and post-maintenance water temperature cycling was initiated. Diversity of the microbial communities of the water increased following the change and may in part explain the reduced erysipelothricosis incidence rate.

Background

Clinical disease caused by infection of the bacteria *Erysipelothrix rhusiopathiae* has long been recognised as a threat to aquarium-housed cetaceans and continues to be so (LaCave 2019; Seibold and Neal 1956; Thurman et al. 1983). Although the disease has been reported in free-ranging wildlife, many reports of this disease in cetaceans are from aquarium-housed animals (Geraci et al. 1966; Kinsel et al. 1997; Seibold and Neal 1956; Simpson et al. 1958; Thurman et al. 1983). This raises the question whether some aspects of management influence disease incidence rate. Some institutions have adopted vaccination programmes using commercially available swine bacterins (ER Bac Plus®, Zoetis US; Eurovac Ery®, Eurovet Animal Health) to stimulate a specific immune response against *E. rhusiopathiae* in individual animals. Several studies provide evidence that the incidence rate of this disease in aquariums managed by those institutions have decreased (Lacave et al. 2019; Nollens et al. 2016; Stitt et al. 2010). Vaccination is not without risk, particularly vaccination with products developed for different species. A moderate correlation between the number of vaccinations given and an adverse reaction has been noted when using the swine bacterin in bottlenose dolphins *Tursiops truncatus* (Nollens et al. 2016). This study documents a markedly reduced incidence rate of this disease

Table 1. Retrospective *Erysipelothrix rhusiopathiae* case data from a 3 million-gallon artificial saltwater indoor habitat housing cetaceans pre- and post-water management changes. Vaccinated animals were excluded from calculation of incidence rate.

Time period	Animals in system	Animal years	Clinical cases	Case fatality rate	Incidence rate %	Number vaccinated
Pre-change	22	175.9	5	40%	2.88	1
Post-change	25	126.6	1	0%	0.85	2

that coincides with management changes, specifically changes in water treatment, and not due to vaccination.

Pacific white-sided dolphins *Lagenhorynchus obliquidens* and beluga whales *Delphinapterus leucas* have been continuously housed at the John G. Shedd Aquarium since March 1991 except for an 8-month period between September 2008 and April 2009. During that period, the entire approximately 3 million-gallon artificial saltwater habitat and associated life support system was drained for maintenance. Prior to this maintenance period, all water introduced into the habitat was sourced from Chicago municipal water. An in-house salt mix was added to this water to approximate the sodium, chloride, magnesium, calcium and potassium concentrations found in natural seawater. The system was disinfected by parallel mixed media sand filters and ozonation. Total coliform counts were maintained below the USDA AWA standard of 1000 per 100 ml of water. The temperature of the system was maintained at a constant 13°C (±1°C).

Action

As part of an aquarium-wide sustainability and energy conservation initiative, several management changes were made to this habitat and system when re-commissioned in April 2009. When refilled following the maintenance period, the salts added to the same municipal source water were switched to a commercial product (Instant Ocean®, Spectrum Brands, 3001 Commerce Street, Blacksburg, VA 24060-6671). This product provided the same major ions, resulting in approximately the same concentrations, but also included 17 trace elements and seven nutrients in µmol kg-1 amounts.

Additionally, as a water-saving measure, approximately 1% of the total system volume each week was added by moving water from systems housing teleost fishes and elasmobranchs to the cetacean system during backwash procedures of the fish systems rather than sending that water to the sewers. Water moved from fish systems to the marine mammal system was passed through an ozone contact chamber prior to introduction into the marine mammal system.

Two additional management changes were made after the maintenance period. In September 2013, water temperature cycling in the system began, to provide temperatures between 13 and 17°C (±1°C), a peak temperature in August and a low in January, to encourage dynamic microbial community structure. Finally, as of January 2017, variable frequency drives (VFD) were liberally used on all of the system recirculation pumps reducing energy use during peak demand periods. This effectively slowed the rate of changeover of the water in the system from approximately once every 2.5 hours in a static fashion to up to once every 12.5 hours in a dynamic fashion.

Other management practices, including ration sourcing, preparation and feeding, remained unchanged prior to and following the period when the system was empty. The same commercial vendors were used to source fish, the same species of fish and invertebrates were included in rations and the same kitchen facility was used to prepare them. There were no changes in thawing, bucketing or feeding methods.

Consequences

To evaluate the influence of the management changes on the system, and specifically the incidence of clinical *E. rhusiopathiae* infection, a retrospective search was conducted of all medical records for the system from initial commissioning through to present (Table 1). Over the entire period, 37 dolphins and whales have lived in the system for a total of 302.5 'animal-years'. During the time prior to closure for maintenance, 22 animals lived in the system for a total of 175.9 animal-years. Following re-commissioning, 25 animals lived in the system for a total of 126.6 animal-years. For animals that moved to other habitats, only the time in the subject habitat was used to calculate animal-year values. Of the total 37 animals, 11 (7 whales and 4 dolphins) spent time in the habitat both prior to and following the maintenance period. Eleven animals only lived in the habitat prior to the maintenance period and 15 only lived in the system since maintenance. Three animals (2 dolphins and 1 whale), that had been vaccinated against *E. rhusiopathiae* elsewhere, were housed in the system. One vaccinated male dolphin was housed in the system for 2.03 years prior to the maintenance action. One vaccinated female dolphin lived in the system for 3.72 years following maintenance and one vaccinated male beluga lived in the system for 4.78 years following maintenance. The vaccinated female dolphin had never been pregnant or suckled offspring. To avoid any potential influence of these vaccinated animals on the incidence rates, they were excluded from the calculation. Five confirmed cases of *E. rhusiopathiae* were documented during the pre-maintenance period; two were fatal with a case fatality rate of 40%. Following maintenance, only one case has been confirmed. This case was in an aquarium-born male dolphin, born after maintenance and the animal fully recovered.

https://doi.org/10.19227/jzar.v813.501

The proportion of incidence for the years prior to maintenance was 5/173.9 (2.88%) animal-years. Following the changes, incidence was 1/118.1 (0.85%) animal-years. Therefore, animals living in the system after the maintenance period were 3.39 times less likely to develop the disease than animals living in the system prior to the changes. The case fatality rate also dropped from 40% to 0%, although with only one case post-changes it is difficult to ascertain significance.

This observation is interesting as it is in contrast to the findings of a previous report, which stated that the incidence rate of this clinical disease was reduced in a population by vaccination without any management change (Stitt et al. 2010). Incidence rates were not reported in that paper, so it is not possible to make a direct comparison. However, this study reports a substantial reduction in incidence rate without a vaccination programme but with several management changes. It is possible that the management changes enhanced the non-specific immune competency of the resident animals. Other studies conducted simultaneously in the same system confirmed that the microbial community structure of the water in the system increased in both richness and evenness following the changes (Cardona et al. 2018). Work to further understand the influence of microbial communities, both host-associated and environment-associated, on the immunocompetence of resident animals, is ongoing in the laboratory.

Studies using animal models have documented differences in host fitness and disease resistance between wild type and laboratory-reared mice (Devalapalli et al. 2006; Rosshart et al. 2017). The present observations suggest a similar influence of environmental factors, particularly microbial communities, in highly managed aquatic systems on resident animal immune competency. It is suggested that this concept be further explored to improve understanding and capability of optimising habitat conditions provided to animals in zoos and aquariums.

References

Cardona C., Lax S., Larsen P., Stephens B., Hampton-Marcell J., Edwardson CF, Henry C., Van Bonn B, Gilbert J.A. (2018) Environmental Sources of Bacteria Differentially Influence Host-Associated Microbial Dynamics. *mSystems* 3: 1–18.

Devalapalli A.P., Lesher A., Shieh K., Solow J.S., Everett M.L., Edala A.S., Whitt P., Long R.R., Newton N., Parker W. (2006) Increased Levels of IgE and Autoreactive, Polyreactive IgG in Wild Rodents: Implications for the Hygiene Hypothesis. *Scandinavian Journal of Immunology* 64: 125–136.

Geraci J.R., Sauer R.M., Medway W. (1966) Erysipelas in Dolphins. American *Journal of Veterinary Research* 27: 597–606.

Kinsel M.J., Boehm J.R., Harris B., Murnane R.D. (1997) Fatal Erysipelas rhusiopathiae septicemia in a captive pacific white-sided dolphin. *Journal of Zoo and Wildlife Medicine* 28: 494–497.

Lacave G., Cui Y., Salbany A., Flanagan C., Grande F., Cox E. (2019) Erysipelas vaccination protocols in dolphins *Tursiops trucatus* evaluated by antibody responses over twenty continuous years. *Diseases of Aquatic Organisms* 134: 237–255.

Nollens H.H., Giménez-Lirola L.G., Robeck T.R., Schmitt T.L., DiRocco S., Opriessnig T. (2106) Evaluation of anti-*Erysipelothrix rhusiopathiae* IgG response in bottlenose dolphins *Tursiops truncatus* to a commercial pig vaccine. *Diseases of Aquatic Organisms* 121: 249–256.

Rosshart S.P., Vassallo B.G., Anegletti D., Pardo-Manuel de Villena F., Yewdell J.W., Rehermann B. (2017) Wild Mouse Gut Microbiota Promotes Host Fitness and Improves Disease Resistance. *Cell* 171: 1015–1028.

Simpson C.F., Wood F.G., Young F. (1957) Cutaneous Lesions on a Porpoise with Erysipelas. *Journal of the American Veterinary Medical Association* 133: 558–560.

Seibold H.R., Neal J.E. (1956) Erysipleothrix Septicemia in the Porpoise. *Journal of the American Veterinary Medical Association* 128: 537–538.

Stitt T., Bowen L., Blanchard M.T., Gershwin L.J., Byrne B.A., Dold C., McBain J., Stott J.L. (2010) Cellular immune responses in cetaceans immunized with a porcine erysipelas vaccine. *Veterinary Immunology and Immunopathology* 137: 181–189.

Thurman G.D., Downes S.J.T., Fothergill M.B., Goodwin N.M., Hegarty M.M. (1983) Diagnosis and Successful Treatment of Subacute Erysipelas in a Captive Dolphin. *Journal of the South African Veterinary Association* 54: 193–200.