Journal of Wildlife and Conservation Medicine
p-ISSN: 3090-5656; e-ISSN: 3109-8436
https://journal.ipb.ac.id/index.php/jwcm

Domiciano *et al.*
Vol 2 No 1, June 2026, Pp 20–31
DOI: 10.29244/jwcm.2.1.20

Case study **OPEN ACCESS**

Integrated approach to treatment of a multidrug-resistant bacterial infection in Geoffroy's side-necked turtle (*Phrynops geoffroanus*)

Nicole de Jesus Domiciano[1]*, Rafael de Carvalho Cabalero[2], Raphael Libório Ribeiro Melo[2], Lara Carvalho Alves de Sousa[2], Estela Larissa Silva dos Santos[3], Marta Vasconcelos Bittencourt[3], Ludmila Rodrigues Moroz[3], Paulo Roberto Bahiano Ferreira[4]

[1] Department of Physiology, Institute of Biosciences, University of São Paulo, Butantã, 05508-900, São Paulo, São Paulo, Brazil
[2] Médico(a) veterinário(a) autônomo(a) (Independent Veterinarian), Salvador, Bahia, Brasil
[3] School of Veterinary Medicine and Zootechny, Federal University of Bahia, Salvador, Bahia, Brazil
[4] State Wildlife Triage Center, Fauna Management Coordination, Directorate of Sustainability and Conservation, Institute of Environment and Water Resources (Inema), Barreiras, Bahia, Brazil

Abstract

Background Opportunistic bacterial infections of the shell and plastron are one of the main causes of diseases affecting Testudines, frequently associated with high levels of environmental bacterial contamination.

Objective This case report describes the clinical presentation, diagnosis and treatment of a multidrug-resistant bacterial infection in a Geoffroy's side-necked turtle (*Phrynops geoffroanus*).

Case description A female Geoffroy's side-necked turtle, under *ex situ* management, presented a greenish-yellow, necrotic lesion in the abdominal and femoral scutes region on the right side of the plastron during the annual clinical evaluation.

Examination and diagnosis Physical examination revealed the presence of keratolysis and a malodorous content. The clinical suspicion of an abscess was confirmed by video-assisted exploration of the coelomic cavity. Multidrug-resistant *Pseudomonas aeruginosa* (MDR-PA) and *Proteus mirabilis* (MDR-PM) were identified through bacteriological analyses.

Treatment/therapies In addition to surgical intervention, six treatment cycles were established until the patient's clinical discharge. The therapeutic protocols included courses of antibiotics, pain management, multivitamins, fluid therapy, as well as wound cleansing. Antibiotic therapy was adjusted according to antibiogram tests, and in the final stages of healing, weekly sessions of low-level laser therapy were conducted.

Conclusion This case highlights the importance of using bacterial isolation and antibiogram tests as a reference for managing and resolving clinical cases. Through an integrated approach, the need for continuous clinical reassessment and therapeutic adjustments are always considered during the process, as well as nutritional and environmental management as part of the complete treatment.

Keywords antibiotic resistance | bacteriosis | bacteria identification | multidrug resistance | Testudines

Introduction

Phrynops geoffroanus (Schweigger, 1812) (Testudinata, family Chelidae), popularly known as the Geoffroy's side-necked turtle, is a semi-aquatic Testudine species with predominantly diurnal activity, commonly found in rivers, lakes, and streams with slow-flowing waters (Souza, 2004; Rueda-Almonacid *et al.*, 2007). It has a wide distribution throughout South America, occurring from the Colombian Amazon to southern Brazil and northern Argentina (Pritchard & Trebbau, 1984; Ernst & Barbour, 1989). The species is classified as Least Concern (LC) on the Brazilian Red List (ICMBio, 2018). Well adapted to anthropogenic impacts on the environment, the Geoffroy's side-necked turtle (*P.*

***Corresponding author** Email: domiciano.nicole@gmail.com

geoffroanus) is possibly the only freshwater testudine species capable of surviving in highly polluted environments, benefiting from the abundance of food derived from organic waste generated by human activities, as well as from the absence of competition and predators in these areas (Souza & Abe, 2000).

Opportunistic bacterial infections are one of the main causes of shell abnormalities in Testudines, commonly caused by Gram-negative bacteria and associated with high levels of environmental contamination (Oliveira, 2003; Barten, 2006). *Pseudomonas aeruginosa* (family Pseudomonadaceae) is a rod-shaped, Gram-negative facultative anaerobe widely found in soil and water and is resistant to several classes of antibiotics (Díaz Santos *et al.*, 2022). Presenting high flexibility and adaptability to environmental pressures, this pathogen secretes a variety of virulence factors, including lipopolysaccharides (LPS), outer membrane proteins (OMPs), and the ability to form biofilms (Behzadi *et al.*, 2022; Qin *et al.*, 2022). In this context, *P. aeruginosa* shows a high potential for infection in semi-aquatic Testudines, as these turtles are exposed to environments with high microbial contamination; they exhibit habits that make them susceptible, such as movement between ecosystems, and they are affected by habitat degradation and loss due to anthropogenic actions, which stimulate their ability to adapt to other environments (Mengistu *et al.*, 2022). In addition to its high prevalence in free-living reptiles, *P. aeruginosa* has been frequently described in species kept as pets or in captivity (Wendt *et al.*, 2017; Açik *et al.*, 2018; Tang *et al.*, 2020; Wickramanayake *et al.*, 2022; Xiong *et al.*, 2022; Ravindra *et al.*, 2023), raising public health concerns over its zoonotic potential and antibiotic resistance mechanisms. According to definitions derived from the consensus between the European Centre for Disease Prevention and Control (ECDC) and the Centers for Disease Control and Prevention (CDC), multidrug-resistant *P. aeruginosa* can be defined as a strain that is non-susceptible to at least one antimicrobial agent in three or more antimicrobial groups with described activity against *P. aeruginosa* (Magiorakos *et al.*, 2012).

Proteus mirabilis (family *Morganellaceae*) is a urease-positive, rod-shaped, Gram-negative facultative anaerobe that is abundant in the environment, mainly in water, soil, and the gastrointestinal tract of humans and non-human animals (Drzewiecka, 2016), and is frequently detected in wild, domestic, and production animals, as well as in foods of animal origin. Due to its epidemiology, pathogenicity, and zoonotic potential, *P. mirabilis* has raised increasing concern and caused significant impacts on global public health, as it is resistant to multiple antibiotics (Liu *et al.*, 2023; Liu *et al.*, 2025; Kimemia *et al.*, 2026). This opportunistic pathogen is frequently associated with community- and hospital-acquired urinary tract infections (UTIs), yet it is also recognized as capable of causing a broad spectrum of infections. Its ureolytic activity is one of its major bacterial virulence factors, along with biofilm formation, flagella, pili and hemolysins, providing high ability to colonize the host, damage tissues and evade immune responses (Konieczna *et al.*, 2012; Yang *et al.*, 2024, 2025). Wildlife has been recognized as an important reservoir for *P. mirabilis*, with the bacterium isolated from a wide range of species and their environments, comprising both *in situ* and *ex situ* management (Yu *et al.*, 2015; Sala *et al.*, 2016; Gao *et al.*, 2024; Eliopulos *et al.*, 2022; Lv *et al.*, 2022; Yang *et al.*, 2025). *P. mirabilis* has also been isolated from animal-derived foods, highlighting its zoonotic risk and posing a growing threat to both animal and human health due to rising antimicrobial resistance (Ma *et al.*, 2022).

Different types of bacteria can cause abscesses or "fibriscesses" in reptiles, characterized by fibrin deposition and encapsulation following the development of local inflammatory processes, resulting in a solid appearance (Huchzermeyer & Cooper, 2000; Almosny & Monteiro, 2006). Diagnosis is established based on the patient's clinical presentation, along with isolation and identification of the etiological agent (Hyndman & Marschang, 2017). As an initial treatment, until the results of bacterial isolation and antimicrobial susceptibility testing are available, the use of broad-spectrum antibiotics is recommended after surgical removal of the caseous material (Roffey & Miles, 2018). This case report aims to document the clinical presentation, diagnosis, therapeutic approach and clinical outcome of an infectious keratolysis with isolation of multidrug-resistant bacterial strains in a Geoffroy's side-necked turtle kept under *ex situ* management.

Case Description

A female, adult, Geoffroy's side-necked turtle (*P. geoffroanus*), weighing 2.22 kg, housed at the Parque Zoobotânico Getúlio Vargas in Salvador, Bahia, Brazil, presented a greenish-yellow, necrotic lesion in the region of the abdominal and femoral scutes on the right side of the plastron during the annual clinical evaluation of the entire collection. The animal exhibited lethargy and apathy. After being referred to the clinical sector by the zookeepers, detailed physical examination revealed the presence of an infectious keratolysis and a malodorous content in the affected area extending, apparently, into the coelomic cavity. The clinical suspicion of an abscess was later confirmed by video-assisted exploration. (**Figure 1**).

Treatment

Six treatment cycles were established until the patient's clinical discharge, carried out according to clinical progression and the results of bacterial isolation and identification with antimicrobial susceptibility testing. The initial therapeutic protocol, first cycle (day 1), consisted of 5% enrofloxacin (5 mg/kg) administered intramuscularly (IM) for seven consecutive days, and 1% ketoprofen (2 mg/kg) administered subcutaneously (SC) for three consecutive days, both once daily (SID), in addition to local wound cleaning with 2% degerming chlorhexidine, hydrogen peroxide, and 0.9% saline solution, followed by application of Furanil ointment and bandaging. Supportive treatment was also provided with Bionew® (0.5 mL/kg, IM, SID) for three consecutive days, as well as fluid therapy with lactated Ringer's solution (10 mL/kg, SC, SID) every 48 hours, for a total of three administrations.

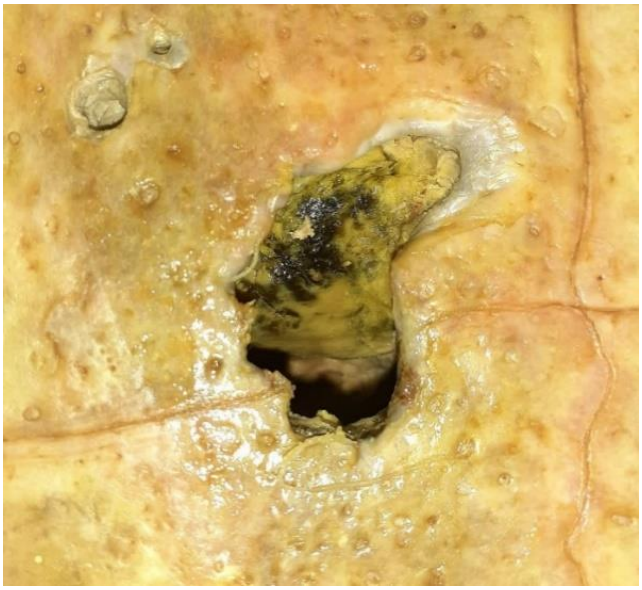

Figure 1 Necrotic lesion localized in the region of the right abdominal and femoral scutes of the plastron.

The second treatment cycle (day 8) consisted of analgesia with tramadol (10 mg/kg, IM), a single dose, and continuation of 1% ketoprofen (2 mg/kg, SC) for an additional seven days. At this stage, a blood collection was performed from the turtle's cervical sinus. Although the hematological indices were within the published reference values for chelonians, the red blood cell count was at the lower limit (0.3 x 10^6 erythrocytes/µL). The other parameters included hemoglobin (Hb: 8,7g/dL), hematocrit (Ht: 24%), mean corpuscular volume (MCV: 866,7fL), and total proteins (PT: 4,4g/dL). The surgical procedure was performed with video-assisted visualization of the coelomic cavity. The animal was premedicated with a combination of ketamine (15 mg/kg/IM), midazolam (0.5 mg/kg/IM), and morphine (0.5 mg/kg, IM). Anesthetic induction was then carried out with propofol (5 mg/kg/IV) via the occipital venous sinus, and anesthesia was maintained with isoflurane (1–4%) vaporized in 100% oxygen.

With the animal in dorsal recumbency, a small incision was made to access the femoral fossa (**Figure 2B**) for the insertion of a 10-mm, 0-degree rigid endoscope to evaluate the internal organs of the coelomic cavity, the extent of lesion dissemination throughout the body, and the possibility of sepsis. The oviduct, intestine, stomach, lung, and liver were visualized (**Figure 2A, C**). After identifying a caseous abscess between the coelomic membrane and the plastron, also associated with the presence of myiasis (**Figure 2D**), surgical intervention was performed to remove it. Plastronotomy was carried out through oblique grinding using a 150 W, 127 V DEXTER micro-grinder, with an aluminum oxide cutting disc (24 × 0.4 mm). At the end of the procedure, approximately 160 g of material was removed from the coelomic cavity (**Figure 3**).

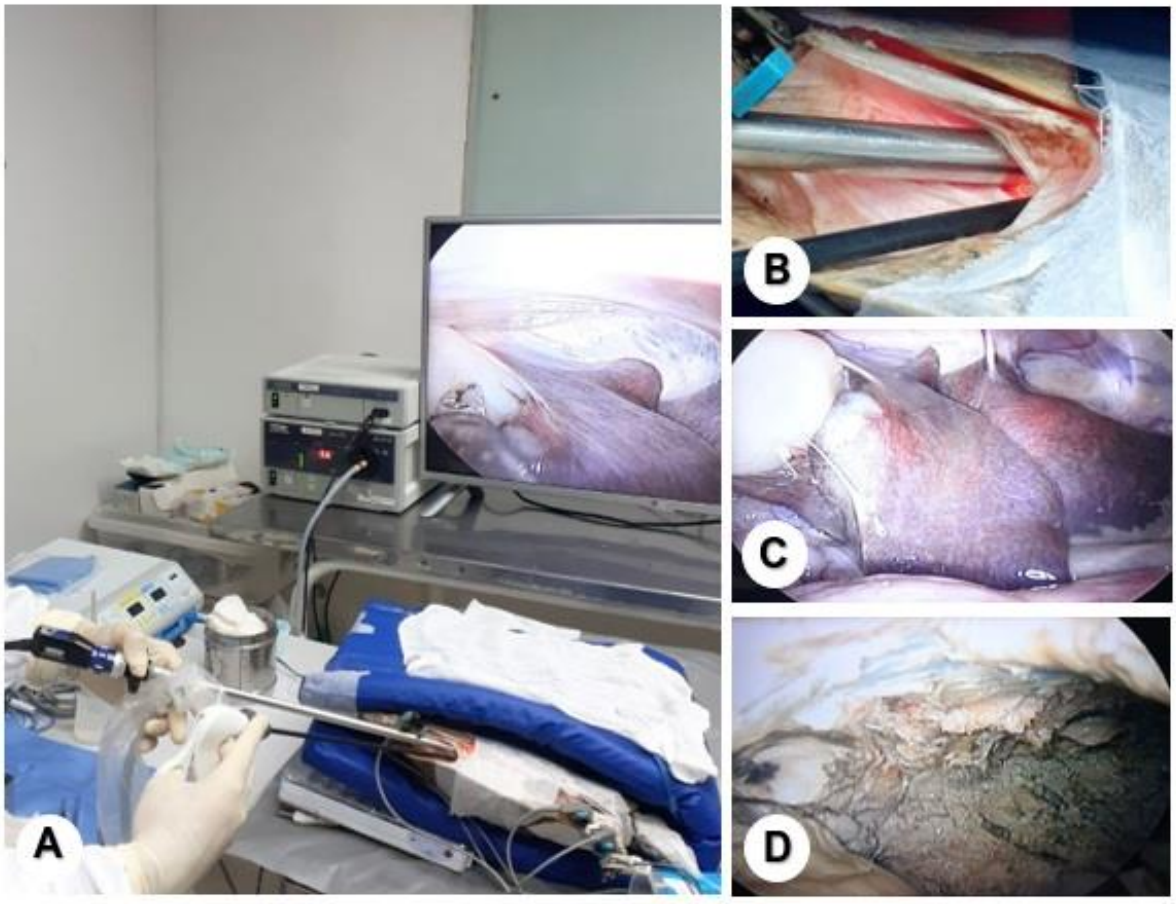

Figure 2 Video-assisted exploration of the coelomic cavity. (A) Evaluation of organs in the coelomic cavity. (B) Incision in the pre-femoral fossa to allow passage of the probe. (C) Visualization of the liver and adjacent organs shows no impairment. (D) Visualization of the lesion showing the presence of necrosis and myiasis.

Figure 3 Caseous abscess surgically excised.

Subsequently, the remaining fly larvae were removed with anatomical forceps, and the surgical wound was cleaned with povidone-iodine. An esophagostomy was also performed, and a diet was prescribed consisting of Super Premium dog food (minimum crude protein: 22%; minimum ether extract: 8%; maximum mineral matter; maximum crude fiber: 4%; calcium: 1–1.8%; minimum phosphorus: 0.70%; maximum moisture: 10%) at 8% of body weight (BW) every 48 hours. During postoperative treatment, the animal was kept at the clinic until full recovery.

For the first microbiological examination, prior to removal of the caseous abscess and cleaning of the surgical wound, a flush with sterile 0.9% saline solution was performed immediately after abrasion of the lesion margins using a micro-grinder, followed by sample collection using a swab with Stuart transport medium. The sample was sent to the Bacteriosis Laboratory of the Prof. Renato Rodemburg de Medeiros Neto Veterinary Medicine Hospital (Federal University of Bahia) for culture isolation and identification with Antimicrobial Susceptibility Testing (AST). For all bacteriological analyses, samples were processed using the streak plate technique on 6% sheep blood agar, MacConkey agar and/or EMB agar, and tryptose broth, and incubated at 37 °C for 24–48 hours under aerobic conditions. After the incubation period and subsequent microbial growth, the sample was subjected to analysis of morphotinctorial (**Table 1**) and biochemical characteristics according to routine laboratory techniques. All isolates were biochemically identified using Bactray 1, 2, and 3 systems (Laborclin, Brazil) following the manufacturer's protocol. Single colonies grown overnight at 37°C on blood agar and MacConkey agar were suspended in the supplied diluent to a 0.5 McFarland standard. Aliquots were inoculated into all reaction wells of the appropriate Bactray tray, which was then incubated aerobically at 37°C for 18 to 24 hours. Reactions were scored as positive or negative using the manufacturer's color chart, and the resulting biochemical profiles were compared with the corresponding Bactray 1, 2, or 3 identification tables to determine the most probable bacterial species. For *in vitro* evaluation of antimicrobial susceptibility of the microorganism isolated from the sample, the disk diffusion method was used (Bauer *et al.*, 1966) on Mueller–Hinton agar.

During the postoperative period and third treatment cycle (day 22), antibiotic therapy was adjusted according to the isolation of multidrug-resistant *P. aeruginosa* (susceptible to piperacillin–tazobactam, and possibly susceptible to ceftiofur and azithromycin if the dosing regimen is adjusted) and *S. pseudointermedius*, as described in **Table 2** in accordance with Clinical and Laboratory Standards Institute (CLSI) guidelines (CLSI, 2024). At this stage, daily cleaning of the surgical wound with povidone-iodine was instituted, along with administration of 5% ceftiofur (5 mg/kg, IM), both once daily for seven consecutive days. In addition, oral administration (PO) of metronidazole (40 mg/kg) was performed once daily for five consecutive days. Ketoprofen 1% was administered at a dose of 4 mg/kg IM on the first day and, from the second day onward, 2 mg/kg IM once daily for four consecutive days. Supportive therapy was also provided with Bionew® (0.5 mL/kg, IM, SID) for three consecutive days, as well as fluid therapy with lactated Ringer's solution (10 mL/kg, SC, SID) every 72 hours, for a total of three administrations.

During the fourth treatment cycle (day 29), prolongation of systemic antibiotic therapy was established with administration of 5% ceftiofur (5 mg/kg, IM) in three doses, once daily. In addition, supportive care was continued with lactated Ringer's solution (10 mL/kg, PO) every 72 hours, for a total of three administrations. The diet consisting of dog food was maintained at a volume corresponding to 8% of body weight every 48 hours. Surgical wound cleansing with 2% chlorhexidine and application of a silver sulfadiazine–based cream were provided once daily. A new complete blood collection was performed. The results indicated a rise in the number of erythrocytes (0.55 x 10^6/µL), but did not reveal any noteworthy variations in the other parameters (hematocrit [Ht]: 26%; hemoglobin [Hb]: 7,5g/dL; mean corpuscular volume [MCV]: 436,4fL; total proteins [PT]: 4,2g/dL).

After the results of the second bacteriological examination, the fifth treatment cycle (day 70) comprised antibiotic therapy targeting multidrug-resistant *P. aeruginosa*. The antibiotic of choice was amikacin (5 mg/kg, IM), administered once daily at 48-hour intervals, for a total of four doses. At this stage, wound debridement was performed to remove necrotic tissue, followed by application of the CMR antibiotic and wound-healing ointment (*Bellis perennis; Calendula officinalis; Myristica sebifera*) after cleansing the lesion with 2% chlorhexidine. Due to persistent weight loss, a new nutritional support regimen was prescribed, consisting of Alcon® tortoise feed, one boiled chicken egg, and orange juice (the yolk as an iron source to prevent anemia and the orange juice to aid absorption), in

Table 1 Morphotinctorial characteristics of the bacterial isolates

Species	Morphotinctorial characteristics
Proteus mirabilis	Gram-negative bacilli
Pseudomonas aeruginosa	Gram-negative bacilli
Staphylococcus pseudintermedius	Gram-positive cocci

Table 2 Bacterial isolates with Antimicrobial Susceptibility Testing (AST) throughout the 140-day treatment period. Results were interpreted following CLSI standards (Clinical and Laboratory Standards Institute VET01—Performance Standards for Antimicrobial Disk and Dilution Susceptibility Tests for Bacteria Isolated From Animals)

Antimicrobial class	Antibiotic	First isolation (day 22)		Second isolation (day 70)	Third isolation (day 97)
		Pseudomonas aeruginosa	***Staphylococcus pseudointermedius***	***Pseudomonas aeruginosa***	***Proteus mirabilis***
β-Lactams (Penicillins)	Amoxicillin	R	S	R	R
	Amoxicillin + Clavulanate	*	*	R	R
	Ampicillin	R	S	R	R
	Penicillin G	*	*	R	R
	Piperacillin + Tazobactam	S	S	S	S
β-Lactams (Cephalosporins)	Ceftiofur	I	S	R	R
	Cephalexin	*	*	R	R
	Ceftazidime	*	*	R	R
Macrolides	Azithromycin	I	S	R	R
	Tylosin	*	*	R	R
Quinolones and Fluoroquinolones	Ciprofloxacin	R	S	R	R
	Enrofloxacin	R	S	R	R
Tetracyclines	Doxycycline	R	S	*	*
Nitroimidazoles	Metronidazole	R	S	R	R
Sulfonamides	Sulfamethoxazole + Trimethoprim	R	S	R	R
Aminoglycosides	Amikacin	*	*	S	S
Lincosamides	Clindamycin	*	*	R	R

I: Intermediate (Susceptible, increased exposure); S: Sensitive, standard dose; R: Resistant; *Not tested

volumes ranging from 80 to 100 mL every 48 hours. The iron dose was determined according to Carpenter & Harms (2022), based on the iron content of egg yolk, considering a value of 2.9 mg of iron per 100 g (NEPA, 2011).

Even after amikacin therapy, one focus of the lesion did not heal completely, and a new bacterial culture was performed. *P. aeruginosa* was not isolated, demonstrating the effectiveness of amikacin; however, multidrug-resistant *Proteus mirabilis* was isolated (susceptible to amikacin and piperacillin–tazobactam). As the lesion was in the final stage of healing and the animal had a history of prolonged use of three injectable antibiotics across different treatment cycles, the sixth treatment cycle (day 97) consisted of topical therapy with a 1% chlorhexidine–based antiseptic solution, application of CMR ointment, and weekly laser therapy sessions (**Figure 4**) to stimulate the wound-healing process. At this phase, the turtle regained its appetite and started eating on its own.

The specimen underwent low-level laser therapy with wavelengths ranging from 660 to 810 nm and an effective emitter power of 100 mW, in red light mode. The lesion (**Figure 5A**) was visually divided into zones (**Figure 5B**) based on characteristics related to lesion depth, tissue viability, and stage of healing. The stimulation points were distributed to cover the lesion area equidistantly (**Figure 5C**), and the protocol consisted of 6 J/cm² at three points in zone 1, 2 J/cm² at three points in zone 2, and 4 J/cm² at two points in zone 3, totalling 32 joules, repeated at weekly intervals until clinical discharge.

During hospitalization, the animal was housed in a water-filled container with access to a dry area, and feces were generally observed every 48–72 hours after feeding. Thirty days after the laser therapy sessions, a new blood collection was performed. The hematological indices revealed a notable rise in the hematocrit (Ht: 37%), the other parameters were as follows: 0.58 x 10^6 erythrocytes/µL; hemoglobin (Hb: 7,17g/dL); mean corpuscular volume (MCV: 637,9fL); total proteins (PT: 5,2g/dL). The animal was discharged following complete healing of the lesion, totalling 140 days of treatment. The plastron lesion was isolated with acrylic resin, allowing the animal to be released into the enclosure (**Figure 6**). A summary of the patient's clinical evolution is presented in **Table 3**.

Six months following, during the institution's routine evaluation of the entire collection, the absence of the resin plate at the lesion site was noted, along with the presence of mineralization, resulting in tissue with a similar appearance to the original plastron (**Figure 7**).

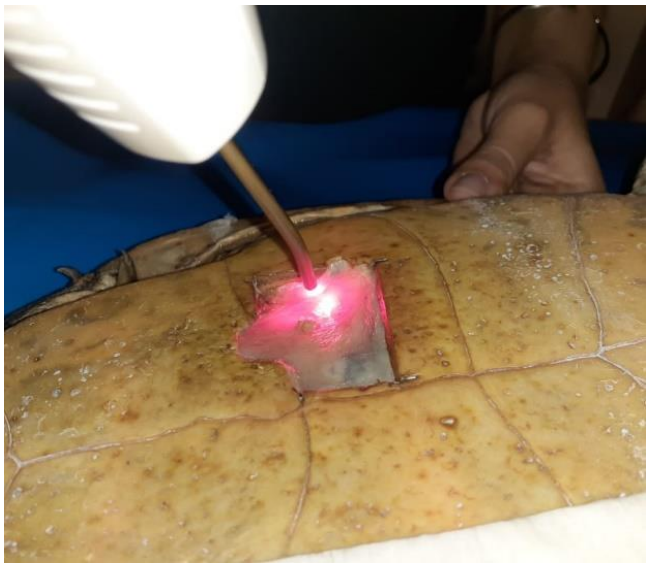

Figure 4 Low-level laser therapy applied to the surgical wound in the final stage of healing.

Discussion

Gram-negative bacteria are the most common etiological agents in shell lesions, in addition to representing the group of pathogens of greatest relevance in reptile medicine (Raphael, 2003; Jacobson, 2007). According to Mader (1996), erosions and superficial abscesses in chelonians are recognizable as changes in the coloration of the corneous scutes, with a certain degree of pallor or even hyperemia. Lesions commonly present a focal or multifocal pattern, but may occasionally become more diffuse if there is a high degree of infiltration. In addition, the affected scutes may be lost, totally or partially. The turtle presented keratolysis of the plastron, exposing the coelomic cavity and a greenish-yellow content on initial direct clinical inspection. Over the course of the evaluation, this content was identified as an abscess, which was surgically removed.

Abscesses or "fibriscesses" in reptiles (i.e., accumulation of white blood cells within a fibrous capsule) may be caused by a wide variety of bacteria. In these animals, encapsulation occurs during local inflammatory processes and has a solid appearance (unlike in mammals), due to the absence of enzymes that break down white blood cells and confer them a liquefied characteristic (i.e., pus). Thus, purulent exudate in birds and reptiles becomes caseous (Huchzermeyer & Cooper, 2000; Almosny & Monteiro, 2006). Concomitantly, fibrin spreads at the site of inflammation, immobilizing not only the pathogens but also inflammatory cells. Chronically, this process hinders the dissemination of pathogens within the reptile's body, thereby preventing sepsis (Beynon *et al.*, 1992; Huchzermeyer & Cooper, 2000).

The main techniques indicated in the literature for the diagnosis of tegumentary bacterial infections in Testudines include the isolation and identification of the etiological agent(s) through traditional bacteriological methods, accompanied by antibiogram test (Antimicrobial Susceptibility Testing – AST); as well as molecular techniques such as PCR (Polymerase Chain Reaction), which provide high specificity and sensitivity in pathogen identification (Brown *et al.*, 2004). It is important to highlight that the type of sample collection and the collection site may also influence the isolation of the etiological agent. In addition, it is possible that the agent may not be identified in the tegumentary lesion, while still being isolated from the blood (Lovich *et al.*, 1996; Garner *et al.*, 1997).

Glazebrook & Campbell (1990a, b) isolated a range of potentially pathogenic Gram-negative bacteria from lesions in captive sea turtles. Some of these pathogens were isolated from tegumentary and shell lesions, e.g., *Vibrio alginolyticus*, *Aeromonas hydrophila*, *Pseudomonas* sp., and *Flavobacterium* sp. In addition, they were also isolated from caseous material lodged in the nasal passages of turtles affected by ulcerative stomatitis. In the present study, the isolation of *P. aeruginosa* was performed from material collected at the margin of the plastron lesion, and the internal organs of the coelomic cavity were also evaluated by video, with no apparent lesions detected.

Video exploration of the coelomic cavity may represent a differential approach in therapeutic management to assess the dissemination and severity of plastron lesions, thereby allowing better guidance for clinical and surgical decision-making. In many cases, evaluation of the coelomic cavity via plastrotomy provides access to perform the necessary surgical interventions, being an indicated and successful method for procedures such as the removal of foreign bodies and caseous formations (Oliveira *et al.*, 2009; Rodrigues *et al.*, 2015). In this case report, access to the coelomic cavity

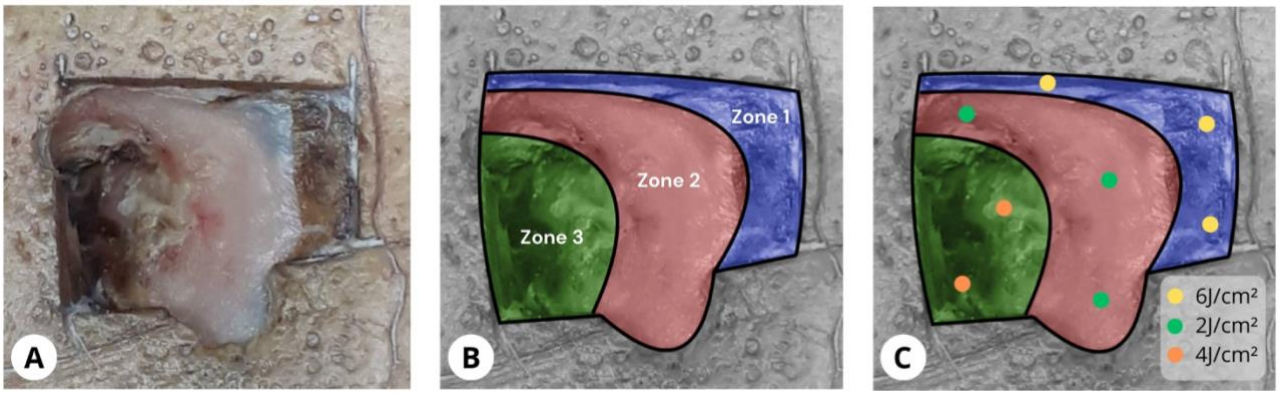

Figure 5 Low-level laser therapy in a Geoffroy's side-necked turtle. (A) Lesion undergoing the healing process. (B) Schematic illustration of the zones identified within the lesion. (C) Defined points for stimulation with red laser therapy.

Table 3 Summary of the patient's clinical evolution

Day	Notes
1st (first cycle)	Lethargic animal with necrotic lesion in the plastron. Physical examination reveals a keratolysis and the presence of an abscess was suspected. Treatment starts with pain management, supportive therapy and antibiotic therapy with enrofloxacin for seven consecutive days.
8th (second cycle)	Analgesia with tramadol, and continuation of 1% ketoprofen for an additional seven days. Hematological indices were within the reference values, but with the red blood cell count at the lower limit (0,3x10^6 erythrocytes/µL; hematocrit [Ht]: 24%; hemoglobin [Hb]: 8,7g/dL). The surgical procedure was performed with video-assisted visualization of the coelomic cavity, confirming the presence of a caseous abscess. An esophagostomy was also performed and a diet was prescribed to be administered every 48 hours.
22nd (third cycle)	Results of isolation and antibiogram test. Antibiotic therapy was adjusted according to the isolation of *P. aeruginosa* and *S. pseudointermedius*. Daily cleaning of the surgical wound with povidone-iodine was instituted, along with administration of 5% ceftiofur for seven consecutive days.
29th (fourth cycle)	Prolongation of systemic antibiotic therapy with 5% ceftiofur in three doses, once daily. The diet was maintained. The surgical wound cleansing and application of a silver sulfadiazine–based cream were performed once daily. A new blood collection was performed, results indicated a rise in erythrocytes (0,55x10^6/µL), but did not reveal any noteworthy variations in the other parameters.
70th (fifth cycle)	Results of second bacteriological examination, this time with *P. aeruginosa* showing resistance to ceftiofur. Antibiotic therapy is adjusted with the use of amikacin administered once daily every 48 hours, for a total of four doses. Topical therapy was maintained. A new nutritional support regimen was prescribed.
97th (sixth cycle)	New bacterial culture was performed. *P. aeruginosa* was not isolated, although the result revealed isolation of multidrug-resistant *Proteus mirabilis*. Antibiotic therapy was discontinued. Topical therapy was maintained and weekly laser therapy sessions were initiated. The animal regained its appetite.
140th (medical discharge)	The lesion healed completely and was carefully sealed with acrylic resin. The hematological indices presented a rise in erythrocytes (0,58x10^6/µL) and hematocrit (Ht: 37%). The animal was discharged, showing active, exploratory behaviour.

occurred through the humeral and femoral fossae to evaluate and confirm the suspicion of possible sepsis. It was determined that the lesion was confined to the plastron region, which indicated a better prognosis for the patient and supported a safer and more effective treatment decision.

In the postoperative period (third treatment cycle), antibiotic therapy was adjusted to ceftiofur 5% (5 mg/kg, IM), according to the isolation of *P. aeruginosa* and the antimicrobial susceptibility test. There are few pharmacokinetic studies on antimicrobials conducted in reptiles; however, effective doses of ceftiofur have already been established for iguanas, snakes, and Testudines, demonstrating that it is a good option as a broad-spectrum antibiotic and for the treatment of more severe infections, since it is a third-generation cephalosporin (Carpenter & Harms, 2022; Đuričić *et al.*, 2025). Metronidazole (40 mg/kg/PO), also administered during the third cycle, was used with a focus on anaerobic bacteria (NCBI, 2025b), reducing the risk of infection and enabling a more satisfactory postoperative recovery.

Ketoprofen 1% exhibits dual action against cyclooxygenase (COX) enzymes 1 and 2, in addition to providing effective analgesic activity (NCBI, 2025c). As a nonselective cyclooxygenase inhibitor, ketoprofen is among the most appropriate nonsteroidal anti-inflammatory drugs for use in reptiles when compared with selective inhibitors, since the literature suggests greater efficacy, given that the inflammatory pattern in reptiles is characterized by a predominance of COX-1 (Royal *et al.*, 2012; Thompson *et al.*, 2018; Sadler *et al.*, 2016; Ting *et al.*, 2022). Fluid therapy and supplementation with B-complex vitamins, butafosfan, and amino acids were performed to improve tissue perfusion, restore hydric balance, and stimulate the patient's appetite, as well as energy production, aiming to provide adequate energetic and hydroelectrolytic support throughout treatment (Klaphake *et al.*, 2018).

Hematology analysis was performed to assess the turtle's overall health status and the need for therapeutic adjustments throughout treatment. Complete blood counts were performed at three distinct moments. Although in the first analysis (day 8), all the hematological indices were within the published reference values for chelonians (Saggese, 2009; Anselmo *et al.*, 2025), the erythrocyte count was noteworthy as it was at its lower limit (0.3 x 10^6/µL). Nonregenerative anemia is the most common manifestation of anemia in reptiles, highly associated with infectious diseases. However, only a limited number of cases will be severe enough to fall under the lower ranges (Jacobson, 2007; Saggese, 2009). Therefore, precaution when interpreting these hematological values in reptile patients are required, considering all the factors that may cause significant variati-

Figure 6 Final appearance of plastron closure with acrylic resin.

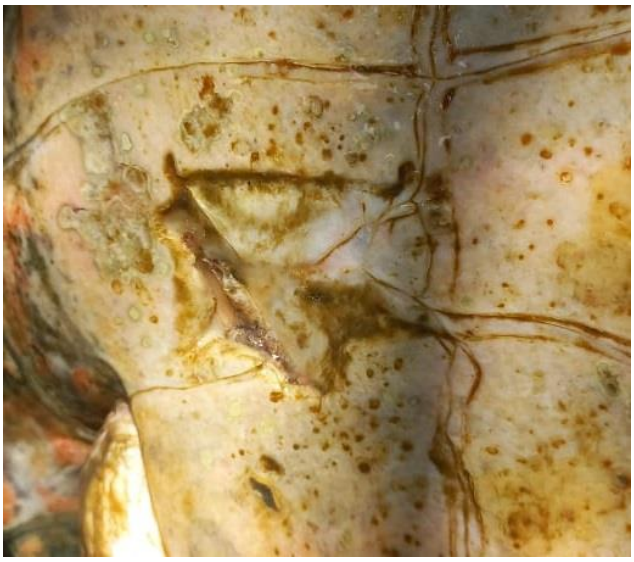

Figure 7 Plastron tissue regeneration, showing a calcified appearance and absence of the acrylic resin layer after release.

ons (e.g, species, sex, age, physiological status, environmental conditions, diet). The second hematological analysis (day 29) revealed an increase in erythrocytes (0.55 x 106/µL) after introducing nutritional support. As it is well established that chronic infectious diseases may cause iron sequestration by bacteria (Skaar, 2010; Parrow *et al.*, 2013) and lead to ferropenic anemia, an iron-rich diet was prescribed (day 70) in order to maintain the prevention of a significant fall in the number of erythrocytes and to restore immune function. These nutritional adjustments may have directly contributed to increased erythrocyte counts and hematocrit values, which served as positive indicators for an improved clinical outcome.

Following the second bacteriological examination (fifth treatment cycle), antibiotic therapy was readjusted according to the antimicrobial susceptibility test results, which demonstrated resistance to ceftiofur. Furthermore, additional antibiotics were tested this time. Multidrug-resistant *P. aeruginosa* showed susceptibility only to amikacin and piperacillin + tazobactam. At this point, therefore, amikacin was selected as the antibiotic of choice (NCBI, 2025d). The desired therapeutic effect of the antibiotic therapy was observed, as evidenced by the absence of bacterial isolation in the subsequent bacteriological examination. Thus, the importance of antibiogram-guided antibiotic therapy is emphasized. Multidrug-resistant *P. aeruginosa* is among the high-priority pathogenic agents, according to the updated list of bacterial pathogens of public health importance released by the World Health Organization (WHO) in 2024 (WHO, 2024).

Since these pathogens are well adapted to grow in oxygen-limited environments, a number of factors may have favored a successful infection, including but not limited to their virulence factors, the host's general and immune status, and the environmental microbial contamination load. Additionally, the infectious response in reptiles naturally promotes the formation of caseous abscess, isolating the infection and reducing the chances of sepsis, which might explain why MDR-*P. aeruginosa* and MDR-*P. mirabilis* were isolated from the lesion. Notably, the variation in bacterial isolates obtained from the sequential cultures underscores a critical aspect of chronic wound treatment with polymicrobial infections. *P. aeruginosa* and *Staphylococcus* spp. are often coisolated from chronic wounds, as it occurred on our first isolation with *S. pseudintermedius* being identified alongside *P. aeruginosa*. Both bacteria can coexist, enhancing virulence and creating significant resistance to antibiotics, since polymicrobial biofilm formation increases tolerance to traditional antimicrobial treatments (Nocera & De Martino, 2024; Di Lodovico *et al.*, 2026). Moreover, coinfection can lead to stronger immune responses and greater tissue damage compared to single-species infections, often delaying wound healing and posing significant clinical challenges (Bessa *et al.*, 2015; Mariani & Galvan, 2023). In this context, *P. aeruginosa* often drives the severity of the infection and presents much higher intrinsic and acquired antimicrobial resistance. These factors would help explain the subsequent *P. aeruginosa* isolation.

After antibiotic therapy adjustments, the third bacteriological examination identified MDR-*Proteus mirabilis*. The isolation of different species following antibiotic therapy is often expected, as it tends to successfully target the most common and dominant organisms, but also provides unoccupied niche space for different bacterial species to colonize (Tipton *et al.*, 2017). It is fundamental to understand compositional change throughout treatment, as wound microbiome communities are highly variable over time. Although antibiotic therapy improves healing rates by successfully removing targeted bacterial species, antibiotics promote community compositional changes, which may lead to infection recurrence, mainly in immunosuppressed patients. Interestingly, current human studies suggest that increased bacterial diversity and instability of the wound microbiome might be associated with improved outcomes and shorter duration of the patient's disease (Loesche *et al.*, 2017; Xu & Hsia, 2018; Tipton *et al.*, 2020; Mihai *et al.*, 2024). The emergence of multidrug-resistant (MDR) strains has

increasingly limited therapeutic options. In recent years, extensively drug-resistant (XDR) and even pandrug-resistant (PDR) strains have been described (Algammal *et al.*, 2021; Mendes *et al.*, 2024; Liu *et al.*, 2025), emphasizing the importance of surveillance. Therefore, the dissemination of clinical reports with therapeutic success can contribute to the improvement of bacterial disease control strategies and clinical approaches for wildlife medicine.

Although multidrug-resistant *P. mirabilis* was isolated as a result of microbial succession, the lesion was in the final stage of healing; therefore, topical treatment and photodynamic therapy were recommended. The objective was to avoid the use of amikacin and preserve renal health during the final treatment cycle. CMR ointment has phytotherapeutic properties and is indicated for the treatment of contaminated lesions and wounds in animals. Its use in association with antibiotic therapy during the fifth treatment cycle and laser therapy during the final cycle showed satisfactory efficacy, promoting rapid healing, although the mechanisms of action of photostimulation in the wound-healing process are not yet fully elucidated.

Among the proposed hypotheses, one highlights the absorption of light by specific chain proteins, such as porphyrins and flavoproteins, promoting an increase in intracellular oxygen concentration and stimulating RNA and DNA synthesis. Another theory points to the photoexcitation of chromophores of the cytochrome c oxidase (CCO) enzyme, resulting in increased cellular metabolism and enhanced production of factors related to tissue repair (Karu *et al.*, 2004; Cusack & Divers, 2019). Even without a full understanding of the underlying dynamics, the modulatory and pro-healing effects of laser therapy have been described in the literature for different reptile species, such as *Testudo hermanni*, *Trachemys scripta*, *Pelodiscus sinensis*, *Python regius*, and *Bothrops moojeni* (Kraut *et al.*, 2013; Pelizzone *et al.*, 2014; Cole *et al.*, 2015; Rameh-de-Albuquerque *et al.*, 2021).

Following the laser therapy sessions, the patient was medically discharged after complete healing. Total healing was confirmed by the presence of fibroelastic pink connective tissue, which led to re-epithelialization of the previously exposed skin. Currently, the tissue is mineralized, resembling the original plastron tissue, with rigid consistency and no recurrence of infection, approximately four years after treatment. The shell is composed of axial endochondral elements of the trunk, overlain by a mosaic of dermal bones and an external epidermal layer composed of non-overlapping keratinous scutes (Burke *et al.*, 2007; Zonneveld & Bartels, 2022). It is possible that calcium and other minerals that constitute the bone matrix were recruited following the proliferation of fibrous connective tissue and its subsequent remodeling, processes that may occur over 42 to 135 days (Negrini *et al.*, 2016) and vary depending on the animal's nutritional status. In the present study, connective tissue proliferated completely within 140 days, allowing subsequent application of acrylic resin and medical discharge. Mineralization of the healed area was confirmed approximately six months after discharge.

Conclusion

Bacterial isolation and antimicrobial susceptibility testing provide a critical framework for the appropriate management and successful resolution of multidrug-resistant infections. Through an integrated approach, the need for clinical reassessment, the use of complete blood counts to evaluate overall health status, imaging examinations to assess lesion extent and infection dissemination to other organs, as well as therapeutic adjustments throughout the course of treatment, are always considered. Nutritional and environmental management are a crucial part of comprehensive care. In this case report, no recurrence of infection was observed twelve months post-treatment, highlighting the effectiveness of the established therapeutic approach and its adjustments throughout the patient's clinical progression.

Acknowledgments The authors express their gratitude to all collaborators of the Parque Zoobotânico Getúlio Vargas (Salvador Zoo) for their invaluable assistance during animal examination, treatment, and care. Acknowledgments are extended to the Fauna Management Coordination (CGFau) of the Sustainability and Conservation Directorate (Disuc), Environmental and Water Resources Institute (Inema).

Funding Not applicable.

Conflict of interest All authors declare no conflict of interest in relation to this case report.

Author contribution NJD: Conceptualization, data curation, methodology, visualization, writing – original draft; RCC: Investigation, methodology; RLRM: Investigation, methodology; LCAS: Methodology, visualization; ELSS: Investigation, methodology; MVB: Investigation, methodology; LRM: Investigation, methodology; PRBF: Conceptualization, data curation, methodology, supervision, writing – review & editing.

Availability of data and materials All data are available in the manuscript.

Received 3 March 2026 | **Revised** 30 April 2026
Accepted 6 May 2026 | **Published online** 2 June 2026

References

Açik MN, Ünsaldi S, Melek Ş, Çetinkaya B: First isolation of *Pseudomonas aeruginosa* from ear abscess of a red-eared slider (*Trachemys scripta elegans*). 2018. *Kafkas Universitesi Veteriner Fakultesi Dergisi*, 24 (4): 623–625. DOI: 10.9775/kvfd.2018.19410.

Algammal AM, Hashem HR, Alfifi KJ, Hetta HF, Sheraba NS, Ramadan H, El-Tarabili RM. 2021. atpD gene sequencing, multidrug resistance traits, virulence-determinants, and antimicrobial resistance genes of emerging XDR and MDR-*Proteus mirabilis*. *Scientific Reports*, 11(1): 9476. DOI: 10.1038/s41598-021-88861-w.

Almosny NRP, Monteiro AO. 2006. Patologia clínica. *In*: Cubas ZS, Silva JCR, Catão-Dias JL. Tratado de animais selvagens – medicina veterinária. São Paulo: Roca, Cap. 59. Pp. 939–964.

Anselmo NP, Liebl ARS, Aride PHR, Dias FVN, Maia L, Oliveira A. 2025. Hematology and biochemistry of Chelonians from the Amazon region: a literature review. *Actapesca*, 22: 140–152. DOI: 10.46732/Actafish.22.140-152.

Barten SL. 2006. Shell damage. *In*: Divers S, Mader D. eds. Reptile medicine and surgery. 2nd ed. Saunders Elsevier. Pp. 893–899.

Bauer AW, Kirby WM, Sherris JC, Turck M. 1966. Antibiotic susceptibility testing by a standardized single disk method. *American Journal of Clinical Pathology*, 45(4): 493–496.

Behzadi P, Ambrosi C, Scribano D, Zanetti S, Sarshar M, Gajdács M, Donadu MG. 2022. Editorial: current perspectives on *Pseudomonas aeruginosa*: epidemiology, virulence and contemporary strategies to combat multidrug-resistant (MDR) pathogens. *Frontiers in Microbiology,* 13: 975616. DOI: 10.3389/fmicb.2022.975616.

Bessa LJ, Fazii P, Di Giulio M, Cellini L. 2015. Bacterial isolates from infected wounds and their antibiotic susceptibility pattern: some remarks about wound infection. *International Wound Journal*, 12(1): 47–52. DOI: 10.1111/iwj.12049.

Beynon PH, Lawton MPC, Cooper JE. 1992. BSAVA manual of reptiles. Cheltenham, British Small Animal Veterinary Association. Pp 75.

Brown DR, Zacher LA, Farmerie WG. 2004. Spreading factors of *Mycoplasma alligatoris*, a flesh-eating mycoplasma. *Journal of Bacteriology,* 186(12): 3922–3927. DOI: 10.1128/jb.186.12.3922-3927.2004.

Burke AC, Cebra-Thomas JA, Gilbert SF. 2007. How the turtle gets its shell. *In*: Wyneken J, Godfrey MH, Bels V (eds). Biology of turtles. CRC Press. Pp 2.

Carpenter JW, Harms C. 2022. eds. Carpenter's exotic animal formulary. 6th ed. Philadelphia: Saunders.

CLSI [Clinical and Laboratory Standards Institute]. 2024. Performance standards for antimicrobial disk and dilution susceptibility tests for bacteria isolated from animals. CLSI VET01. 6th ed. Wayne, Pennsylvania (US): Clinical and Laboratory Standards Institute.

Cole GL, Lux CN, Schumacher JP, Seibert RL, Sadler RA, Henderson AL, Odoi A, Newkirk KM. 2015. Effect of laser treatment on first-intention incisional wound healing in ball pythons (*Python regius*). *American Journal of Veterinary Research*, 76(10): 904–912. DOI: 10.2460/ajvr.76.10.904.

Cusack LM, Divers SJ. 2019. Photobiomodulation (low-level laser therapy). *In*: Divers SJ, Stahl SJ (eds). Mader's reptile and amphibian medicine and surgery. 3rd ed. WB Saunders. Pp 1221-1224. DOI: 10.1016/B978-0-323-48253-0.00129-X.

Di Lodovico S, De Pasquale V, Nocera FP, Petrini M, Di Fermo P, Diban F, Pinti M, De Martino L, Tafuri S, Cellini L, Di Giulio M, D'Ercole S. 2026. Recombinant NK1 protein and LEDs: an innovative strategy to counteract resistant *Staphylococcus pseudintermedius* and *Pseudomonas aeruginosa* Strains. *Probiotics and Antimicrobial Proteins*, 18: 2599–2611. DOI: 10.1007/s12602-025-10702-3.

Díaz Santos E, Mora Jiménez C, Del Río-Carbajo L, Vidal-Cortés P. 2022. Treatment of severe multi-drug resistant *Pseudomonas aeruginosa* infections. *Medicina Intensiva*, 46(9): 508-520. DOI: 10.1016/j.medine.2022.06.014.

Drzewiecka D. 2016. Significance and roles of *Proteus* spp. bacteria in natural environments. *Microbial Ecology*, 72(4): 741–758. https://doi.org/10.1007/s00248-015-0720-6.

Đuričić D, Lukac M, Faraguna S, Javor A, Miljković J. 2025. Right hemithorax pneumonia in red-eared slider (*Trachemys scripta elegans*, Wied-Neuwied, 1839). *International Journal of Veterinary Sciences and Animal Husbandry*, 10(3): 262–265. https://doi.org/10.22271/veterinary.2025.v10.i3d.2144.

Eliopulos N, Alsina L, Diana L, Brandl S. 2022. Multiple antimicrobial resistance in Enterobacteriaceae isolated from a sea lion (*Otaria flavescens*) specimen from Isla de Lobos, Uruguay: a case report. *Brazilian Journal of Animal and Environmental Research*, 5(4): 3477–3486. DOI: 10.34188/bjaerv5n4-001.

Ernst CH, Barbour RW. 1989. Turtles of the world. Washington DC (US) and London (UK): Smithsonian Institution Press. Pp 313.

Gao J, Liu S, Bano S, Xia X, Baloch Z. 2024. First report of complete genome analysis of multiple drug resistance *Proteus mirabilis* KUST-1312 isolate from migratory birds in China: a public health threat. *Transboundary and Emerging Diseases*. 2024: 8102506. DOI: 10.1155/2024/8102506.

Garner MM, Herrington R. Howerth EW, Homer BL, Nettles VF, Isaza R, Shotts EB, Jacobson ER. 1997. Shell disease in river cooters (*Pseudemys concinna*) and yellow-bellied turtles (*Trachemys scripta*) in a Georgia lake. *Journal of Wildlife Diseases*, 33(1):78–86. DOI: 10.7589/0090-3558-33.1.78.

Glazebrook JS, Campbell RSF. 1990a. A survey of the diseases of marine turtles in Northern Australia. I. Farmed turtles. *Diseases of Aquatic Organisms,* 9: 83–95. DOI: 10.3354/dao009083.

Glazebrook JS, Campbell RSF. 1990b. A survey of the diseases of marine turtles in northern Australia. II. Oceanarium-reareo and wild turtles. *Diseases of Aquatic Organisms*, 9: 97–104. DOI: 10.3354/dao009097.

Huchzermeyer FW, Cooper JE. 2000. Fibriscess, not abscess, resulting from a localised inflammatory response to infection in reptiles and birds. *Veterinary Record*, 147: 515-517. DOI: 10.1136/vr.147.18.515.

Hyndman T, Marschang RE. 2017. Infectious diseases and immunology. *In*: Doneley B, Monks D, Johnson R, Carmel B. eds. Reptile medicine and surgery in clinical practice. Wiley. Pp. 211. DOI: 10.1002/9781118977705.ch16.

ICMBio [Instituto Chico Mendes de Conservação da Biodiversidade]. 2018. Livro vermelho da fauna Brasileira ameaçada de extinção. Brasília: ICMBio/MMA. Pp 171. Link https://www.gov.br/icmbio/pt-br/centrais-de-conteudo/publicacoes/publicacoes-diversas/livro_vermelho_2018_vol1.pdf.

Jacobson ER. 2007. Bacterial diseases of reptiles. *In*: Jacobson ER. eds. Infectious diseases and pathology of reptiles. Boca Raton: CRC Press. Pp. 462–526. DOI: 10.1201/9781420004038.

Karu TI, Pyatibrat LV, Kalendo GS. 2004. Photobiological modulation of cell attachment via cytochrome c oxidase. *Photochemical and Photobiological Sciences*, 3(2): 211-216. DOI: 10.1039/b306126d.

Kimemia BB, Musila L, Langat S, Odoyo E, Wataka A, Khamadi S, Johnson J, Egbo, T, Garges E, Haynes R, Kellar GG, Eads J, Eyase F. 2026. Characterization of *Proteus mirabilis* isolated from ticks collected in Isiolo and Kilifi Counties, Kenya. *Microbiology Spectrum,* 14(1): e0227125. DOI: 10.1128/spectrum.02271-25.

Klaphake E, Gibbons PM, Sladky KK, Carpenter JW. 2018. Reptiles. *In*: Carpenter JW, Marion CJ (eds). Exotic animal formulary. 5th ed. St. WB Saunders. Pp 81–166. DOI: 10.1016/B978-0-323-44450-7.00004-7.

Konieczna I, Zarnowiec P, Kwinkowski M, Kolesinska B, Fraczyk J, Kaminski Z, Kaca W. 2012. Bacterial urease and its role in long-lasting human diseases. *Current Protein & Peptide Science*, 13(8): 789–806. DOI: 10.2174/138920312804871094.

Kraut S, Fischer D, Heuser W, Lierz M. 2013. Laser therapy in a soft-shelled turtle (*Pelodiscus sinensis*) for the treatment of skin and shell ulceration. a case report. *Tierarztliche Praxis. Ausgabe K, Kleintiere/Heimtiere*, 41(4): 261–266. https://pubmed.ncbi.nlm.nih.gov/23958710/.

Liu L, Dong Z, Ai S, Chen S, Dong M, Li Q, Zhou Z, Liu H, Zhong Z, Ma X, Hu Y, Ren Z, Fu H, Shu G, Qiu X, Peng G. 2023. Virulence-related factors and antimicrobial resistance in *Proteus mirabilis* isolated from domestic and stray dogs. *Frontiers in Microbiology*, 14: 1141418. DOI: 10.3389/fmicb.2023.1141418.

Liu X-L, Wu S-Y, Yu Z. 2025. Zoonotic risks of *Proteus mirabilis*: Detection, pathogenicity, and antibiotic resistance in animals and animal-derived foods. *Microorganisms*, 13: 2060. DOI: 10.3390/microorganisms13092060.

Loesche M, Gardner SE, Kalan L, Horwinski J, Zheng Q, Hodkinson BP, Tyldsley AS, Franciscus CL, Hillis SL, Mehta S, Margolis DJ, Grice EA. 2017. Temporal stability in chronic wound microbiota is associated with poor healing. *The Journal of Investigative Dermatology,* 137(1): 237–244. DOI: 10.1016/j.jid.2016.08.009.

Lovich JE, Gotte SW, Ernst CA, Harshbarger JC, Laemmerzahl AF, Gibbons JW. 1996. Prevalence and histopathology of shell disease in turtles from Lack Blackshear, Georgia. *Journal of Wildlife Diseases,* 32(2): 259–265. DOI: 10.7589/0090-3558-32.2.259.

Lv P, Hao G, Cao Y, Cui L, Wang G, Sun S. 2022. Detection of Carbapenem Resistance of *Proteus mirabilis* strains isolated from foxes, raccoons and minks in China. *Biology (Basel)*, 11(2): 292. DOI: 10.3390/biology11020292.

Ma W-Q, Han Y-Y, Zhou L, Peng W-Q, Mao L-Y, Yang X, Wang Q, Zhang T-J, Wang H-N, Lei C-W. 2022. Contamination of *Proteus mirabilis* harbouring various clinically important antimicrobial resistance genes in retail meat and aquatic products from food markets in China. *Frontiers in Microbiology,* 13: 1086800. DOI: 10.3389/fmicb.2022.1086800.

Mader DR. 1996. Reptile medicine and surgery. Philadelphia (US): WB Saunders Company.

Magiorakos AP, Srinivasan A, Carey RB, Carmeli Y, Falagas ME, Giske CG, Harbarth S, Hindler JF, Kahlmeter G, Olsson-Liljequist B, Paterson DL, Rice RB, Stelling J, Struelens MJ, Vatopoulos A, Weber JT, Monnet DL. 2012. Multidrug-resistant, extensively drug-resistant and pandrug-resistant bacteria: an international expert proposal for interim standard definitions for acquired

resistance. *Clinical Microbiology and Infection*, 18(3): 268–281. DOI: 10.1111/j.1469-0691.2011.03570.x.

Mariani F, Galvan EM. 2023. *Staphylococcus aureus* in polymicrobial skin and soft tissue infections: impact of inter-species interactions in disease outcome. *Antibiotics*, 12(7): 1164. DOI: 10.3390/antibiotics12071164.

Mendes PD, Paulo SE, Santos CM, Fonseca AB, Melo CJ, Pereira ÁA and Caneiras C. 2024. Extensively drug-resistant *Pseudomonas aeruginosa*: clinical features and treatment with ceftazidime/avibactam and ceftolozane/tazobactam in a tertiary care university hospital center in Portugal – a cross-sectional and retrospective observational study. *Frontiers in Microbiology,* 15: 1347521. DOI: 10.3389/fmicb.2024.1347521.

Mengistu TS, Garcias B, Castellanos G, Seminati C, Molina-López RA, Darwich L. 2022. Occurrence of multidrug resistant Gram-negative bacteria and resistance genes in semi-aquatic wildlife - *Trachemys scripta*, *Neovison vison* and *Lutra lutra* - as sentinels of environmental health. *Science of the Total Environment*, 830: 154814. DOI: 10.1016/j.scitotenv.2022.154814.

Mihai MM, Bălăceanu-Gurău B, Ion A, Holban AM, Gurău C-D, Popescu MN, Beiu C, Popa LG, Popa MI, Dragomirescu CC, Preda M, Muntean A-A., Macovei IS, Lazăr V. 2024. Host–microbiome crosstalk in chronic wound healing. *International Journal of Molecular Sciences*, 25(9): 4629. DOI: 10.3390/ijms25094629.

NCBI [National Center for Biotechnology Information]. 2025a. PubChem Compound Summary for CID 6328657, Ceftiofur. *PubChem*. https://pubchem.ncbi.nlm.nih.gov/compound/Ceftiofur.

NCBI [National Center for Biotechnology Information]. 2025b. PubChem Compound Summary for CID 4173, Metronidazole. *PubChem*. https://pubchem.ncbi.nlm.nih.gov/compound/Metronidazole.

NCBI [National Center for Biotechnology Information]. 2025c. PubChem Compound Summary for CID 3825, Ketoprofen. *PubChem*. https://pubchem.ncbi.nlm.nih.gov/compound/Ketoprofen

NCBI [National Center for Biotechnology Information]. 2025d. PubChem Compound Summary for CID 37768, Amikacin. *PubChem*. https://pubchem.ncbi.nlm.nih.gov/compound/Amikacin.

Negrini J, Ginel PJ, Novales M, Guerra R, Mozos E. 2016. Clinical and histological findings of cutaneous wound healing in the red-eared slider turtle (*Trachemys scripta elegans*) housed in unheated outdoor enclosures. *Veterinary Dermatology*, 27(5): 413–e106. https://doi.org/10.1111/vde.12346.

NEPA [Núcleo de Estudos e Pesquisas em Alimentação]. 2011. Tabela brasileira de composição de alimentos (TACO). 4. ed. rev. e ampl. Campinas: NEPA-UNICAMP. Pp 56-57. Link https://www.gov.br/agricultura/pt-br/assuntos/inspecao/produtos-vegetal/legislacao-de-produtos-origem-vegetal/biblioteca-de-normas-vinhos-e-bebidas/tabela-brasileira-de-composicao-de-alimentos_taco_2011.pdf.

Nocera FP, De Martino L. 2024. Methicillin-resistant *Staphylococcus pseudintermedius*: epidemiological changes, antibiotic resistance, and alternative therapeutic strategies. *Veterinary Research Communications*, 48(6): 3505–3515. DOI: 10.1007/s11259-024-10508-8.

Oliveira PMA. 2003. Animais silvestres e exóticos na clínica particular: peixes, anfíbios, répteis. 1ª ed. São Paulo: Editora Roca. Chapter 4. Pp 314–324.

Oliveira FS, Delfini A, Martins LL, Faria Jr D, Machado MRF. 2009. Obstrução intestinal e enterotomia em tigre d'água (*Trachemys dorbignyi*). *Acta Scientiae Veterinariae,* 37(3): 307–310. DOI: 10.22456/1679-9216.16355.

Parrow NL, Fleming RE, Minnick MF. 2013. Sequestration and scavenging of iron in infection. *Infection and Immunity*, 81(10): 3503–3514. DOI: 10.1128/IAI.00602-13.

Pelizzone I, Di Ianni F, Parmigiani E. 2014. Laser therapy for wound healing in chelonians: two case reports. *Veterinaria (Cremona),* 28(5): 33–38.

Pritchard PCH, Trebbau P. 1984. The turtles of Venezuela. Society for the Study of Amphibians and Reptiles, Contributions in Herpetology Vol 2. Pp 1–403.

Qin S, Xiao W, Zhou C, Pu Q, Deng X, Lan L, Liang H, Song X, Wu M. 2022. *Pseudomonas aeruginosa*: pathogenesis, virulence factors, antibiotic resistance, interaction with host, technology advances and emerging therapeutics. *Signal Transduction and Targeted Therapy*, 7(1): 199. DOI: 10.1038/s41392-022-01056-1.

Rameh-De-Albuquerque LC, Grego KF, Alves LCF. 2021. Uso de laserterapia de baixa intensidade como adjuvante na cicatrização de feridas por segunda intenção em *Bothrops moojeni*. *In*: WildLife Clinic Congresse. 2ª edição. https://certificates-congresse-me.herokuapp.com/wcc/resumos/13601.pdf?version=original.

Raphael BL. 2003. Chelonians. *In*: Fowler ME, Miller RE (eds). Zoo and wild animal medicine. 5th ed. Philadelphia (US): Saunders. Pp 48–58.

Ravindra BG, Shashidhar Ballari, T Rajendra, Harish Kulkarni, V Shivamurthy, Vivek R Kasaralikar, NA Patil, PK Patil. 2023. Concurrent infection of *Pseudomonas* and *Haemogregarina* sp. in fresh water turtle (*Lissemys Punctata*). *International Journal of Veterinary Sciences and Animal Husbandry*, 8(1): 49–51. DOI: 10.22271/veterinary.2023.v8.i1a.484.

Rodrigues MC, Lima WC, Quessada AM, Silva FAN, Silva LMC, Souza AB, Moura CRC, Lima DASD. 2015. Celiotomy by plastrotomy in a yellow-footed tortoise (*Geochelone denticulata*). *Pesquisa Veterinária Brasileira*, 35(2): 173–176. DOI: 10.1590/S0100-736X2015000200014.

Roffey J, Miles S. 2018. Turtle shell repair. *In*: Doneley B, Monks D, Johnson R, Carmel B (eds). Reptile medicine and surgery in clinical practice. Hoboken, New Jersey (US): John Wiley & Sons Ltd. Pp 398–399.

Royal LW, Lascelles D, Lewbart GA, Correa MT, Jones SL. 2012. Evaluation of cyclooxygenase protein expression in traumatized versus normal tissues from eastern box turtles (*Terrapene carolina carolina*). *Journal of Zoo and Wildlife Medicine*, 43: 289–295. DOI: 10.1638/2011-0154.1.

Rueda-Almonacid JV, Carr JL, Mittermeier RA, Rodríguez-Mahecha JV, Mast RB, Vogt RC, Rhodin AGJ, de la Ossa-Velasquez J, Rueda JN, Mittermeier CG. 2007. Las tortugas y los cocodrilianos de los países andinos del trópico. Serie de guías tropicales de campo No 6. Conservación Internacional. Editorial Panamericana, Formas e Impresos. Bogotá, Colombia. Pp 538. Link https://www.researchgate.net/publication/261875715_Las_Tortugas_y_los_Cocodrilianos_de_los_Paises_Andinos_del_Tropico.

Sadler RA, Schumacher J, Rathore K, Newkirk KM, Cole G, Seibert R, Cekanova M. 2016. Evaluation of the role of the cyclooxygenase signaling pathway during inflammation in skin and muscle tissues of ball pythons (*Python regius*). *American Journal of Veterinary Research*, 77(5): 487–494. DOI: 10.2460/ajvr.77.5.487.

Saggese MD. 2009. Clinical approach to the anemic reptile. *Journal of Exotic Pet Medicine*, 18(2): 98–111. DOI: 10.1053/j.jepm.2009.04.003.

Sala A, Taddei S, Santospirito D, Sandri C, Magnone W, Cabassi CS. 2016. Antibiotic resistance in conjunctival and enteric bacterial flora in raptors housed in a zoological garden. *Veterinary Medicine and Science*, 2(4): 239–245. DOI: 10.1002/vms3.38.

Skaar EP. 2010. The battle for iron between bacterial pathogens and their vertebrate hosts. *PLoS Pathogens*, 6(8): e1000949. DOI: 10.1371/journal.ppat.1000949.

Souza FL. 2004. A review on activity patterns, reproduction, and feeding habits of Brazilian chelid turtles (Testudines, Chelidae*). Phyllomedusa: Journal of Herpetology,* 3(1): 15–27. DOI: 10.11606/issn.2316-9079.v3i1p15-27.

Souza FL, Abe AS. 2000. Feeding ecology, density and biomass of the freshwater turtle, *Phrynops geoffroanus*, inhabiting a polluted urban river in south-eastern Brazil. *Journal of Zoology*, 252: 437–446. DOI: 10.1111/j.1469-7998.2000.tb01226.x.

Tang PK, Divers SJ, Sanchez S. 2020. Antimicrobial susceptibility patterns for aerobic bacteria isolated from reptilian samples submitted to a veterinary diagnostic laboratory: 129 cases (2005–2016). *Journal of the American Veterinary Medical Association*, 257(3): 305–312. DOI: 10.2460/javma.257.3.305.

Thompson KA, Papich MG, Higgins B, Flanagan J, Christiansen EF, Harms CA. 2018. Ketoprofen pharmacokinetics of R- and S-isomers in juvenile loggerhead sea turtles (*Caretta caretta*) after single intravenous and single- and multidose intramuscular administration. *Journal of Veterinary Pharmacology and Therapeutics*, 41(2): 340–348. DOI: 10.1111/jvp.12460.

Ting AK, Tay VS, Chng HT, Xie S. 2022. A critical review on the pharmacodynamics and pharmacokinetics of non-steroidal anti-

inflammatory drugs and opioid drugs used in reptiles. *Veterinary and Animal Science,* 17: 100267. DOI: 10.1016/j.vas.2022.100267.

Tipton CD, Mathew ME, Wolcott RA, Wolcott RD, Kingston T, Phillips CD. 2017. Temporal dynamics of relative abundances and bacterial succession in chronic wound communities. *Wound Repair and Regeneration*, 25(4): 673–679. DOI: 10.1111/wrr.12555.

Tipton CD, Wolcott RD, Sanford NE, Miller C, Pathak G, Silzer TK, Sun J, Fleming D, Rumbaugh KP, Little TD, Phillips N, Phillips CD. 2020. Patient genetics is linked to chronic wound microbiome composition and healing. *PLoS Pathogens*, 16(6): e1008511. DOI: 10.1371/journal.ppat.1008511.

Wickramanayake KS, De Silva D, Heo G.-J. 2022. *Pseudomonas aeruginosa* from pet Chinese stripe-necked turtles (*Ocadia sinensis*) demonstrating antimicrobial and heavy metal resistance. *Veterinary Integrative Sciences*, 20(3): 761–773. DOI: 10.12982/VIS.2022.059.

Wendt M., De Silva B. C. J., Heo G.-J. 2017. Virulence factors and antimicrobial resistance of *Pseudomonas aeruginosa* isolated from pet turtles. *Asian Journal of Animal and Veterinary Advances,* 12(4): 205–211. DOI: 10.3923/ajava.2017.205.211.

WHO [World Health Organization]. 2024. Bacterial priority pathogens list: bacterial pathogens of public health importance to guide research, development and strategies to prevent and control antimicrobial resistance. Accessed 20 October 2025. https://www.who.int/publications/i/item/9789240093461.

Xiong Y, Wu Q, Qin X, Yang C, Luo S, He J, Cheng Q, Wu Z. 2022. Identification of *Pseudomonas aeruginosa* from the skin ulcer disease of crocodile lizards (*Shinisaurus crocodilurus*) and probiotics as the control measure. *Frontiers in Veterinary Science*, 9: 850684. DOI: 10.3389/fvets.2022.850684.

Xu Z, Hsia HC. 2018. the impact of microbial communities on wound healing: a review. *Annals of Plastic Surgery*, 81(1): 113–123. DOI: 10.1097/SAP.0000000000001450.

Yang A, Tian Y, Li X. 2024. Unveiling the hidden arsenal: new insights into *Proteus mirabilis* virulence in UTIs. *Frontiers in Cellular and Infection Microbiology*, 14: 1465460. DOI: 10.3389/fcimb.2024.1465460.

Yang Y, Liu Y, Wang J, Li C, Wu R, Xin J, Yang X, Zheng H, Zhong Z, Fu H, Zhou Z, Liu H, Peng G. 2025. *Proteus mirabilis* from captive giant pandas and red pandas carries diverse antimicrobial resistance genes and virulence genes associated with mobile genetic elements. *Microorganisms,* 13(8):1802. DOI: 10.3390/microorganisms13081802.

Yu W, He Z, Huang F. 2015. Multidrug-resistant *Proteus mirabilis* isolated from newly weaned infant rhesus monkeys and ferrets. *Jundishapur Journal of Microbiology*, 8(6): e16822. DOI: 10.5812/jjm.8(6)2015.16822.

Zonneveld JP, Bartels WS. 2022. The occurrence of bone modification features in the carapace and plastron of the extant red-eared slider *Trachemys scripta elegans* (Wied-Neuwied, 1839): implications for paleoecological analyses of fossil turtle assemblages. *Palaios*; 37 (9): 499–519. DOI: 10.2110/palo.2022.018.