Case Study

**Intervention to Improve the Quality of Life of a Bottlenose Dolphin That Developed Necrosis on the Tail Flukes**

Keiichi Ueda, DVM1,2)*, Masahito Murakami, PT, PhD3), Junichi Kato, MD, PhD4), Hirokazu Miyahara1), Yasuharu Izumisawa, PhD5)

1) Okinawa Churaumi Aquarium: 888 Ishikawa, Motobu-cho, Okinawa 905-0206, Japan. TEL: +81 980-48-2742, FAX: +81 980-48-4399
2) Research Center, Okinawa Churashima Foundation
3) Department of Physical Therapy, Faculty of Rehabilitation, Kobe International University
4) Hyogo Prefectural Rehabilitation Center, Nishiharima Hospital
5) Department of Veterinary Medicine, Rakuno Gakuen University

**Abstract.** [Purpose, Case, and Methods] A female bottlenose dolphin (Tursiops truncatus) in captivity developed necrosis of the tail flukes. Although the diseased site healed after surgical resection, the loss of approximately 75% of the tail greatly affected her swimming performance. To restore swimming ability, we developed artificial tail flukes as a prosthetic swimming aid and provided physical therapy that included swimming training from postoperative day 1 to day 1427. [Results] The prosthetic enabled the dolphin to recover swimming ability almost to the level prior to disease onset, but even acquire applied movement, and reestablish social relationships, thus greatly improving the animal’s quality of life. [Conclusion] The results clearly demonstrate that, as in postoperative rehabilitation in humans, the use of prosthetic devices in physical therapy can be beneficial for marine animals such as dolphins.

**Key words:** Dolphin, Artificial tail flukes, Physical therapy

(This article was submitted Feb. 27, 2013, and was accepted Apr. 14, 2013)

**INTRODUCTION**

An aquarium’s primary purpose is to exhibit the aquatic species in their habitat. It is also the mission of an aquarium to facilitate breeding by maintaining good animal health and a favorable environment. In Japan, the history of breeding and exhibition of cetaceans began at Nakanoshima Aquarium (currently known as Izu-Mito SeaParadise) in 1930. Continuous efforts were made to advance breeding skills through repeated trial and error, but it was quite some time before objective data was used to maintain the health of marine species in captivity. The opening of Kamogawa Sea World and its acquisition of killer whales in 1970 increased exchanges between Kamogawa Sea World and Okinawa Expo Aquarium in Japan and the United States in animal breeding, and these led to hematological testing of dolphins and pinnipeds at a number of Japanese aquariums1). In due course, data accumulated from such testing started to advance the health care of marine species in captivity.

In the United States, rehabilitation for animals, especially dogs, attracted the public’s attention in the 1980s and 1990s. Veterinary medicine has traditionally placed emphasis on diagnostic methods, medicinal and surgical treatment, and postoperative management, but in recent years this conventional healthcare approach to animals receiving treatment has been questioned by veterinarians who believe that not only the postoperative physical ability of animals, but also their quality of life (QOL) should be improved. As a consequence, the provision of physical therapy has become a well-established concept among staff at university veterinary hospitals and in some individual veterinary clinics2). However, the same notion has not been reported to have filtered through to marine species’ breeding and exhibition facilities, such as aquariums.

Here at the Okinawa Churaumi Aquarium, we have been actively treating the species under our care since the late 1990s. The majority of cases have involved administration of antibiotics for respiratory bacterial infections or relatively simple surgical procedures such as removal of skin abrasions, but none had required treatment involving physical therapy to improve functional ability and QOL of an animal with a healed wound. However, when a bottlenose dolphin (Tursiops truncatus) named Fuji lost approximately 75% of her tail flukes due to necrosis in 2002, we began developing artificial tail flukes as a prosthetic swimming aid for her, because the loss greatly affected her swimming ability and will to swim. This prosthetic development project was carried out, for the first time in the world, in parallel with prosthetic mounting training and swimming perfor-
mance recovery training as postoperative physical therapy. To accomplish the project we organized four teams: veterinarians responsible for health maintenance of the dolphin; engineers for the development of artificial tail flukes, who worked on selecting materials through to planning, designing, and producing the flukes; researchers for collecting and analyzing scientific data on prosthetics, such as durability; and aquarium staff for actually performing the pre- and post-prosthetic training for the dolphin. As the result of well-organized planning, Fuji’s swimming ability, which had deteriorated postoperatively, improved remarkably and she regained her will to swim and once again cohabited socially with other dolphins. We therefore became pioneers in providing physical therapy with prosthetics to captive species, and here we report the details of the work undertaken in the project. This paper marks the first report of physical therapy improving the QOL of a dolphin in captivity with a physical disability; we also report another case involving the development of artificial tail flukes for a dolphin at another aquarium.

CASE AND METHODS

CASE: A 30 year-old female bottlenose dolphin (Tursiops truncatus) named Fuji developed necrosis on both sides of her tip tail flukes due to circulation insufficiency caused by bacterial infection. Treatment with antibiotics and transfusion was started immediately after the onset of symptoms, but failed to stop the progression of necrosis (Fig. 1). Thermographic observation revealed circulatory insufficiency over 75% of the tail flukes (Fig. 2). Clinical examination indicated a lowered body temperature and laboratory tests revealed a significantly increased white blood cell count and lactate dehydrogenase level. Surgical resection of the necrotic area on the flukes was performed on day 23 after symptom onset, resulting in the loss of approximately 75% of the flukes (Fig. 3). We divided the animal’s treatment and physical program into three levels: impairment level, disability level, and handicap level, as described below.

IMPAIRMENT LEVEL

For dolphins, it is not possible to gather skin for surgical closure of the wound as can be done in humans and other animals and surgical wounds are left open. Our case animal, Fuji, received continuous antibiotic administration and thorough debridement for the prevention of secondary infection, followed by early stump reduction. After surgical resection of the distal ends of the tail flukes, she no longer performed dolphin kicks which involve shaking the flukes up and down, but instead started to shake the peduncle side to side, like a crocodile, when making a turn. She was also spending most of the day floating on the surface in the breeding pool and not participating in swimming activities with the other dolphins. Due to inadequate physical activity, Fuji started to gain weight and her total blood cholesterol level increased, indicating that she needed to reestablish a daily exercise routine. We therefore decided to provide immediate intervention to restore her willingness to swim and engage in daily physical activity.

As a treatment approach, antibiotics were started on postoperative day (POD) 2 and thorough debridement was performed twice a day. At the same time, to prepare for the development of artificial tail flukes to improve Fuji’s disability level, breeding staff started “examination position training” in which she was required to remain in a supine or prone position on the water surface during clinical examination. It took her 27 days (January 3–29, 2003; POD 57–83) to learn the position necessary for physical therapy, because, unlike small terrestrial animals, it is not easy for dolphins to remain still in the water. We then provided “prosthesis familiarization training” for 147 days for Fuji to become accustomed to the flukes (May 1–September 24, 2003; POD 175–321). The primary purpose of this training was to use enhanced operant conditioning, with bait as reinforcement, to establish an environment in which Fuji could continue training and wear the prosthetic device without refusal. The training also provided an opportunity for both Fuji and her trainers to become familiar with the handling of the artificial tail flukes. We initially focused on three specific activities: “tail holding” to extend the time Fuji learned to stay still on the surface while allowing a trainer to hold her tail fluke to 10 mins; “backstroking”, to reduce the burden on the tail flukes; and “rotation”, which involved turning the body while staying in the water to restore a proper dolphin kick. Training was provided for 15 min twice a day at feeding time during morning fasting when it is easier to handle and train dolphins.

DISABILITY LEVEL

Fuji’s tail flukes were reduced in size to approximately 25% following resection, and this adversely affected her will to swim as well as her swimming ability and speed. It was clear that a prosthetic swimming aid was needed to restore her swimming ability, and we received full cooperation from Bridgestone Co., a manufacturer of rubber products, in the implementation of a series of improvements designed to create a suitable prosthetic device.

Because dolphins intensely dislike foreign materials on their body, before actually mounting the prosthetic, we covered the dolphin’s flukes with wetsuit fabric at the start of the above-mentioned prosthesis familiarization training program. After complete wound closure and healing, a rubber-based prosthesis (Fig. 4a)—a trial version that was considerably smaller than real dolphin flukes—was mounted on Fuji’s flukes. Fuji did not reject the prosthetic and successfully performed a dolphin kick for the first time following surgery. Before starting “swimming performance recovery training”, we developed “cross-band model” tail flukes, a prosthesis that was easier to mount and more similar in size to normal dolphin flukes than the initial model, to increase the number of rotations, strengthen her dolphin kick, and introduced new tasks, called “wheel transport” and “target-touch”, involving touching a target 20 cm above the water while treading water. Training was provided for 15 min three times a day at feeding time in the morning and at the last feeding time when we could spare some extra time. This training step continued for 261 days (September
We further developed a new version of the prosthetic named the “cowling model” which had the capability to withstand more intense training. The shoulders and the distal ends of the artificial tail were covered by a carbon-fiber-

Fig. 1. Temporal changes in hematological values and the antibiotic administration schedule

Fig. 2. Preoperative (a) photographic and (b) thermographic images of the dolphin’s tail flukes

Fig. 3. The dolphin’s tail flukes after surgery

Fig. 4. Tail fluke models: (a) trial model and (b) Olympic-type cowling model
reinforced plastic sheet to reduce drag, and the sheet was secured with nuts and bolts at the distal ends of the flukes. With this new prosthetic, multiple tasks such as twists and jumps (i.e., with the body up to 1 m above the water for ≥10 s) were introduced into training, and the load was gradually increased while carefully observing the dolphin’s physical recovery. These tasks required powerful kicks to keep the head or upper body above the surface. We also selected tool-based tasks with a preset goal to help the dolphin regain her willingness to swim while also improving her swimming performance. With an improved dolphin kick, Fuji became more proactive toward training, and successfully completed target-touch tasks even though her swimming speed was clearly slower than that of the other healthy bottlenose dolphins.

Training with the cowling model tail flukes was provided for 190 days (June 12–December 18, 2004; POD 583 – 771). In addition to target-touch, “twist,” “bow jump” (a crescent shape jump in the air), and “high jump” (a vertical jump into the air until the whole body is out of the water) were incorporated as main training tasks. Training was performed for 20 min five times a day at every feeding time.

The successful development of the Olympic-type cowling model allowed Fuji to make all movements that dolphins are capable of making (Fig. 4b). The main material of the prosthesis was silicone rubber (hardness, 40 degrees) and the core materials were fiberglass cloth plus high-modulus fibers (Vectran™). With Vectran™ as the core, we could increase the strength and bending rigidity of the tail wings, increase overall flexibility, and reduce drag. The part that is stretched when mounting the tail flukes was multi-layered with strong and highly flexible Vectran™, while highly compressed fiberglass and Vectran™ were used in other parts for lightness and strength. For safety and durability, the bolts were secured with recessed, pure titanium, seawater-resistant nuts. Twill-weave carbon-fiber cloth, plain-weave fiberglass cloth, and plain-weave Vectran™ were used in the cowling main body, and Everlight Moran™ was selected as internal cushion material.

In the main lagoon pool (25 × 17 × 4 m; 300 m³; 1200 m²), Fuji’s swimming performance with and without the Olympic-type cowling model was studied using a data logger (diameter, 21 mm; length, 113 mm; mass, 64 g; W190L–PD2GT, Little Leonardo Co., Tokyo, Japan). We recorded swimming speed every 0.125 s, diving depth every 1 s, two-axis acceleration every 1/32 s, and surrounding water temperature (environmental temperature) every 10 s. The data logger was attached to the lower left side of the dorsal fin by a suction cup. To record maximum swimming speed immediately prior to a high jump, time between diving and jumping was divided into a diving-initiation period (period D), acceleration period (period A), and just-before-jump period (period J). Mean speed was calculated for each period, and swimming behavior was videotaped underwater using a HVR-Z1 J video camera (Sony Co., Tokyo, Japan) mounted in a housing (VX-FX1; Sea & Sea Sunpak Co., Tokyo, Japan). Fuji’s swimming performance was also compared with that of healthy dolphins.

Due to a significant reduction in tail fluke size, Fuji could no longer swim parallel to other dolphins or perform various show events, and consequently she started to isolate herself and did not participate in social activities, except at feeding time. In addition to this issue, we also thought that she should spend her day without the prosthesis because a prosthetic with not-yet-sufficient durability should not be worn continuously.

We decided not to force Fuji to perform training tasks, but instead to take time and wait for her to participate voluntarily. We therefore extended the time breeding staff spent with Fuji and used tools such as a target to keep her spirits high. Fuji also participated in the aquarium’s “artificial dolphin fluke exhibition event” for the general audience to see progress in the artificial tail fluke development project and physical therapy using a prosthetic. This helped Fuji to develop a sense of regularity and goals in everyday life. Furthermore, we actively incorporated high-load tasks such as twists, bow jumps, and high jumps into training.

This final training step lasted 656 days (December 18, 2004–October 4, 2006; POD 772–1427). We continued to use twists, bow jumps, and high jumps as the major training tasks to maintain Fuji’s performance level. In addition, to facilitate Fuji’s social reintegration, such as swimming with other dolphins, we involved her in the aquarium’s Dolphin Show, in training events with another dolphin, and in the artificial dolphin fluke exhibition event. She subsequently participated in an exhibition event that was held for 20 min once daily and training for that event was performed for 20 min four times a day at four feeding times.

RESULTS

The outcomes of the three different levels of physical therapy are shown in Fig. 5. With regard to impairment level, granuloma formation began along the edge of surgical wound around POD 31. Administration of antibiotics was terminated on POD 59 after normalization of body temperature and hematological values. After continuous disinfection and debridement two to three times a day, closure and healing of the diseased sites was confirmed on POD 197. During this period, as a part of the training, Fuji was instructed to stay still for examination that included disinfection and debridement, and she learned to maintain an examination position steadily for more than 10 min when instructed. She also mastered rotation, backstroking, and proper dolphin kicks. Because of these training tasks and a diet plan, Fuji’s weight reduced from 230 kg to a desirable 220 kg. Her total cholesterol also reduced from the peak level of 295 mg/ml to 200 mg/ml and stabilized.

With regard to disability, through training using the prosthesis, Fuji strengthened her dolphin kick and successfully mastered target-touch tasks, becoming a willing trainee with no signs of resistance to wearing the different types of prosthetics. The prosthesis clearly improved Fuji’s swimming speed and jumping performance. The average speeds that the Fuji achieved during the D, A, and J periods were 3.10 ± 0.81, 4.28 ± 0.57, and 5.33 ± 0.74 m/s with the
prosthesis, and 2.40 ± 0.89, 3.87 ± 0.84, and 5.01 ± 0.61 m/s without, respectively. In comparison, the average speeds of the healthy dolphins was 2.87 ± 1.35, 3.88 ± 0.85, and 5.50 ± 0.69 m/s, respectively. Fuji was able to swim notably faster with the artificial tail flukes than without them (Table 1), reaching a speed of 5 m/s just before jumping, compared to the 6–7 m/s of healthy dolphins. The prosthesis also enabled Fuji to jump to a 3 m target.

Video analysis of Fuji’s underwater behavior and that of healthy dolphins showed that her swimming ability did not recover to the level of healthy dolphins even with the prosthesis. Healthy dolphins kicked their tail 4 times during period A, which lasted for 3 s (Fig. 6), while Fuji kicked up to 7 times over 4.5 s. Nonetheless, the dolphin’s activities in daily life clearly improved.

Concerning handicap, rehabilitation enabled Fuji to regain a dynamic “high jump” movement and regularly participate in exhibition events. She was also able to swim with other dolphins without her prosthesis on a daily basis and to steadily perform a perfect bow jump. Although we decided to discontinue physical therapy at this point, Fuji continued to participate in exhibition events and training sessions with the other dolphins, and she was wearing the artificial tail flukes for 6 hours each day.

DISCUSSION

We expected to see some degree of functional decline in Fuji’s swimming ability when we decided to resect approximately 75% of her necrotic tail flukes due to bacterial infection and circulatory insufficiency. However, we did not expect Fuji would completely lose the will to swim and become socially inactive. Moreover, her weight and cholesterol level increased due to lack of exercise, prompting us to immediately intervene to remediate the situation.

Large underwater animals, such as cetaceans and sirenians, need to be handled differently from land animals. Because of the difficulties involved in their handling, medical treatment for these marine mammals largely remains within the scope of internal medicine, such as oral drug administration, and it is extremely rare to provide surgical treatment, let alone physical therapy for the reversal postoperative functional decline. Moreover, our understanding of “rehabilitation” for marine mammals, including dolphins, at that time concerned temporary intervention provided for animals captured in the wild and held in a facility such as an aquarium to provide nutritional supplementation, medical treatment, and/or parasite removal before being released back into the wild\(^3\). The term “rehabilitation” at that time was never used to describe a case like this one in which physical therapy was provided with the use of a prosthesis.

---

**Table 1.** Comparison of swim speeds (m/s\(^{-1}\)) achieved during different swimming periods (mean ± SD)

|                     | Period D      | Period A      | Period J      |
|---------------------|---------------|---------------|---------------|
| With artificial tail| 3.10±0.81     | 4.28±0.57     | 5.33±0.74     |
| Without artificial tail | 2.40±0.89   | 3.87±0.84     | 5.01±0.61     |
| Healthy dolphins    | 2.87±1.35     | 3.88±0.85     | 5.50±0.69     |

Diving time prior to making a jump was divided into 3 periods: the diving-initiation period (period D), the acceleration period (period A), and the just-before-jump period (period J). With the artificial tail flukes, the speeds achieved by the dolphin during periods D and A were faster than those achieved by healthy dolphins; however, the speed during period J (5.33 ± 0.74 m/s) was slower than that of healthy dolphins (5.50 ± 0.69 m/s).

---

**Fig. 5.** The dolphin’s physical therapy program

---

**Table 1.** Comparison of swim speeds (m/s\(^{-1}\)) achieved during different swimming periods (mean ± SD)

|                     | Period D      | Period A      | Period J      |
|---------------------|---------------|---------------|---------------|
| With artificial tail| 3.10±0.81     | 4.28±0.57     | 5.33±0.74     |
| Without artificial tail | 2.40±0.89   | 3.87±0.84     | 5.01±0.61     |
| Healthy dolphins    | 2.87±1.35     | 3.88±0.85     | 5.50±0.69     |
Only a few domestic and international studies have reported the development of animal prostheses for functional recovery: an artificial fin for a loggerhead turtle in the United States in 1985, a prosthesis for a giraffe at Omoriyama Zoo in Akita, Japan, and an artificial beak for a penguin at Yumemigasaki Zoological Park in Kanagawa, Japan. In all cases, however, the quality of the prostheses was not high, and intervention did not go beyond simple shape supplementation to provide systematic physical therapy for functional recovery.

This was the first study to perform research and development of artificial tail flukes as a prosthesis for a bottlenose dolphin and to concurrently provide physical therapy. Coincidentally, the physical therapy program we used was similar to the approach used in the prosthetic rehabilitation of humans: medical treatment including stabilization, immobilization, and deformity correction; compensation for lost body parts and functioning; and improvement of physical and mental status. The aim of our artificial tail fluke development program was not to supplement the loss, but to create a “fully functional prosthetic swimming device”, meaning that the use of artificial tail flukes in physical therapy would enhance Fuji’s swimming ability through the improvement of the muscles used in swimming that had atrophied postoperatively.

Swimming performance analysis of the dolphin with the prosthesis conducted in the breeding pool revealed that faster swimming speeds and higher vertical jumps were achieved, while fewer kicks were needed to reach the highest speed just prior to jumping. These results clearly demonstrate the benefit of the artificial tail flukes as a swimming aid. We modeled the prosthesis on the real tail flukes of healthy bottlenose dolphins and the cowling model as the mounting method. A reinforcement plate was inserted into the core to provide sufficient rigidity as well as flexibility, and the inner surface of the artificial flukes was covered with a protective sheet of water-retentive FPDM foam rubber (ethylene-propylene-diene rubber, Everlight Moran™) to prevent skin abrasions.

The fact that swimming speed and jumping performance did not reach those of healthy dolphins did not cause any problem. Fuji’s daily activities, and she could master tasks that exerted high loads on the tail flukes, such as twists, bow jumps, and high jumps. Fuji was later able to achieve a perfect bow jump without the prosthesis (Fig. 7). When she had restored her social relationships with other dolphins with or without the prosthesis, physical therapy was switched from strength-based training to maintenance training. During this transition from the recovery phase to maintenance phase of rehabilitation, aquarium staff resumed routine daily breeding activities for all dolphins including Fuji.

This physical therapy-based approach enabled Fuji to regain her will to swim, her swimming ability, and her social interactions with other dolphins. This development has introduced a novel concept to the care of aquarium exhibition.
animals: that the QOL of animals with a disability can be improved.

In 2010, with our help and the provision of artificial tail flukes like those of the present case, the Notojima Aquarium in Ishikawa, Japan successfully improved the swimming ability of a Pacific white-sided dolphin that had lost 60% of the tail flukes. Our story has also inspired aquariums around the world to follow our example, including the Clearwater Marine Aquarium in Florida, the United States, which has been attempting to restore the swimming ability of a bottlenose dolphin that suffered complete loss of the tail flukes. The artificial tail fluke prosthesis we developed was granted a patent as a swimming aid in 2009 (Patent No. 4421491).

The present case was the first instance of an aquarium: using to use thermography to accurately diagnose a dolphin’s necrotized tail flukes, performing surgery with an electrocautery knife to amputate a large portion of the tail flukes which are essential for swimming, developing artificial tail flukes, and providing physical therapy using a prosthesis. Each of these actions helped to introduce the novel concept of prosthetic rehabilitation for the improvement of QOL to other aquariums that aim to breed, exhibit, and conduct research.

It is the mission of an aquarium to keep their exhibition animals healthy. It is also the responsibility of an aquarium to provide care when animals are sick and make efforts to restore their health to the best of their ability. Because breeding environments differ from natural habitats, it is not rare for animals to lose their functionality due to disease or accidents. However, in most cases, animals receive only supportive care or a simple surgical procedure before they are removed from exhibition programs or ultimately die without regaining functionality. Tail flukes are the most important locomotor organ for dolphins. In the present case, our dolphin completely lost her will to swim and did not participate in social activities after the extensive loss of her tail flukes. We developed artificial tail flukes and provided rehabilitation to restore her daily activity almost to the level prior to disease onset. Unlike rehabilitation for terrestrial animals, it is extremely difficult to perform rehabilitation for perioperative management and functional recovery of aquatic animals. However, despite the challenge, this study showed that it is possible to treat an aquatic animal with serious injury if proper care is provided in line with an individualized treatment plan that meets the original functionality of the animal.

We continue to gather objective scientific data at every occasion and make them public to prevent this whole development from becoming a transient one. In addition, we plan to proactively manage the health of exhibition animals under our care without setting any limitations.

ACKNOWLEDGMENTS

We would like to thank Mr. Shingo Kato of Bridgestone Flowtech Corp. and Mr. Shinji Saito, Takashi Yokoi, and Wataru Seki of Bridgestone Co. for their collaboration throughout the artificial tail fluke development project, and also the staff at the Okinawa Churaumi Aquarium for animal training and handling, and Dr. Seiji Otani for his analysis of swimming performance. We are grateful to Dr. Hideaki Miyata and Mr. Yoshihiro Tsuchiya at the Department of Environmental Engineering, The University of Tokyo, and Dr. Toru Sato at the Graduate School of Frontier Sciences, The University of Tokyo, for their assistance in the towing tank experiments. We also thank Dr. Tsutomu Kanbe for his valuable advice throughout the project and Dr. Haruka Ito at the Fisheries Research Agency for reading this manuscript and providing helpful advice. We also thank Mr. Kazuhiro Yakushiji for producing a replica of the tail and Bridgestone EMK Co. and Mr. Kazuhiro Takenaka for production of the artificial flukes.

REFERENCES

1) Murayama T, Soichi M, Uchida S: Marine Mammal Aquarium. Hadano: Tokai University Press, 2010, pp 12–27.
2) Millis DL: Responses of musculoskeletal tissues to disuse and remobilization. In: Canine Rehabilitation & Physical Therapy. Philadelphia: Saunders, 2004, pp 11–24.
3) Mignucci-Giannoni AA: Marine mammal captivity in the Northeastern Caribbean, with notes on the rehabilitation of stranded whale, dolphins, and manatees. Caribb J Sci, 1998, 34: 191–203.
4) White JR: Manatee: Living in the Sea. Kamiya T, trans-de. Tokyo: Kodansha, 1993, pp 100–103.
5) The Japan Orthopaedic Association, The Japanese Association of Rehabilitation Medicine: Checkpoint of Prosthetics and Orthotics, 7th ed. Tokyo: Igaku-Shoin Ltd., 2007, p 18.
6) Seki W, Kato S, Satio S, et al.: Design of artificial tail flukes for a bottlenose dolphin. In: Bio-mechanisms of Swimming and Flying. Tokyo: Springer, 2007, pp 79–90.
7) Ueda K, Yoko T, Seki W, et al.: Artificial dolphin fluke project. In: proceedings from the 18th Symposium of Ocean Engineering, 2005, Tokyo: Society of Naval Architects of Japan, 2005, pp 27–28.
8) Seki W, Kato S, Satio S, et al.: Development of artificial dolphin tail flukes. Seibutsu no Kagaku. Iden, 2006, 61: 33–37 (in Japanese).
9) Kato S, Seki W, Yoko T, et al.: Development of artificial tail flukes for the bottlenose dolphin. Nippon Gomu Kyokaishi, 2005, 78: 336–339 (in Japanese). [CrossRef]
10) Otani S, Ueda K, Miyahara H, et al.: Artificial tail flukes3 – swimming behavior. In: Proceedings of the 16th Biennial Conference on the Biology of Marine Mammals, 2005: San Diego, 214.