https://doi.org/10.20965/jrm.2021.p0475

Paper:

Logger Attaching System for Sperm Whales Using a Drone

Ryota Murakami*, Takumi Toyoshima*, Daichi Furusawa*, Masaru Suzuki*, Kazunari Masumoto*, Sho Owada*, Yuichi Tsumaki*, and Kyoichi Mori**

*Department of Mechanical Systems Engineering, Graduate School of Science and Engineering, Yamagata University
4-3-16 Jonan, Yonezawa City, Yamagata 992-8510, Japan
E-mail: tsumaki@yz.yamagata-u.ac.jp
**Department of Animal Science, Teikyo University of Science
2525 Yatsusawa, Uenohara, Yamanashi 409-0193, Japan
[Received December 20, 2020; accepted April 15, 2021]

The biologging approach of attaching a logger to the body of an animal provides information that cannot be obtained by conventional direct visual observation. Marine zoologists have used this technique for observing sperm whales preying on giant squids in the deep sea. However, it is almost impossible to capture a sperm whale to attach a logger, because of its large size. Therefore, researchers have used a long pole to attach a logger from a ship to the back of sperm whales. Unfortunately, this method is risky and requires a skilled team. In this paper, we propose a logger attaching system using a drone to solve this problem. The proposed method can be trained on land; thus, it is relatively easy to train a team, and the mobility of the drone can shorten the installation time. Several pieces of equipment developed for the proposed method are described in detail. Furthermore, field experiments were performed with sperm whales to confirm the feasibility of the system. A suction cup of the seventh prototype of the whale rover was adsorbed onto the back of a sperm whale. Although a complete installation was not possible, it was demonstrated that operation was possible in a short time using the proposed method.

Keywords: bio-logging, drone, whale rover, sperm whale, giant squid

1. Introduction

Over the last few decades, an ecological survey method called biologging has attracted the attention of zoologists. A logger that records various types of information from sensors is attached directly to the body of an animal to investigate its ecology. In the past, the mainstream of wildlife ecology research was visual observation from fixed points. However, many wildlife species live in places where direct observation is difficult. Biologging, on the other hand, removes this restriction by allowing the sensor to constantly record animal activity. By selecting a sensor, it is possible to record not only the position but also the biological information such as heartbeat at the same time [1, 2].

Sperm whales (*Physeter macrocephalus*) are targets of biologging. They dive deeper than 1,000 m [3] and prey on mesopelagic cephalopods and fishes, including giant squid (*Architeuthis* spp.) in the deep sea [4]. The diet of sperm whales has been clarified through a survey of stomach contents. However, the method of predation of sperm whales is not yet apparent. So far, marine zoologists have installed camera loggers on sperm whales [5], but they have not yet been able to capture the scene of predation. Shooting the moment of predation is valuable to solve the mystery of the predation method of sperm whales.

However, notably, due to the size of sperm whales, their biologging is more difficult than that of other animals. In other words, capturing sperm whales by attaching a logger is difficult. Fortunately, sperm whales have a tendency to dive deep for approximately an hour and subsequently swim slowly for approximately 5–10 min on the sea surface to take breaths. Thus far, researchers have approached sperm whales swimming on the surface by boat and attached a logger to their back using a long pole [6–8]. This approach reveals some behaviors of sperm whales; however, it has several problems, which are listed as follows:

1. Long approach time:
   The ship must approach slowly to avoid being noticed by the whale.
2. Special skills and experiences required of team members:
   Attaching a logger to a whale using a long pole is a difficult task.
3. Narrow observable range:
   When observing from a ship, the range of observation is limited due to the low viewpoint.
4. High risk to team members:
   Team members may face danger when the pole tip pierces the sea surface. In this situation, as the ship moves forward, the poles increasingly penetrate into the sea. Ultimately, if the pole base or the pole itself breaks, team members may be injured. There is also

the risk of approaching too close to the sperm whale and being hit by its giant tail fin.

Recently, drones have been increasingly used in various applications [9]. Drones fly through the air, and therefore can move faster and easier, even in areas that are difficult to access. They are also used for ecological observations because of their bird's-eye view [10–12]. Drone observations of whales have been conducted, videos have been recorded, and blow samples have been collected [13, 14].

On the other hand, we have developed a whale rover that is expected to moves to the mouth area after adsorbing the back of sperm whales [15]. By arriving near the mouth, the possibility of capturing predatory behavior increases. However, there was no other way to install it than to use the conventional small boat and a long pole.

In this paper, we employ a drone for the biologging of sperm whales and propose a logger attaching system. The issues associated with the conventional method can be solved using a drone. A fast operation can be expected, the drone operation is relatively easy, and training can be performed on land; thus, training operations can be relatively easy. In addition, the bird's-eye view enables observation over a wide area. Furthermore, there is no danger to humans as only the drone approaches the sperm whale. Although there are risks associated with using drones, we believe that they can be adequately addressed by taking countermeasures. Several pieces of equipment developed for the proposed approach are described in detail. We conducted field experiments with sperm whales to confirm the feasibility of the proposed system.

The remainder of this paper is organized as follows. Section 2 proposes the concept of the system. Section 3 describes several pieces of equipment developed for the proposed system and the roles of individuals in the team. Section 4 describes the field experiments conducted with sperm whales. Section 5 discusses the feasibility of the proposed system and the remaining issues. Finally, Section 6 concludes the paper.

2. Concept of a Logger Attaching System Using a Drone

First, we introduce a logger attaching system using a drone. The concept of the proposed system is shown in **Fig. 1**. The drone is operated from the ship, and it takes off and lands on the ship. It is equipped with a logger that can be separated by an operator. The logger is adsorbed onto the body of the sperm whale with suction cups due to the impact of the collision caused by the fall. This system has the following advantages:

1. Easy and fast access to sperm whales:
   A drone can easily approach sperm whales as it is faster and more maneuverable than a ship.

2. Easy pilot training:
   Drone operation is relatively easy, and pilot training is mostly possible on land.

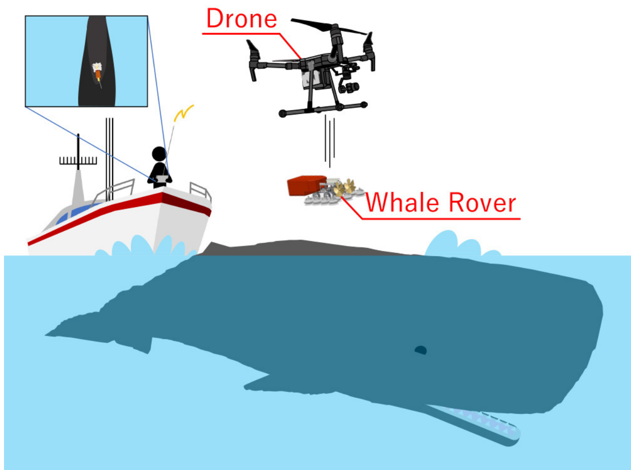


Fig. 1. Concept of the system.

3. Clear behavior observations:
   The bird's-eye view allows the whale's reactions to be observed clearly.

4. Highly safe for humans:
   The risks of conventional methods include the risk of approaching the vicinity of sperm whales and tool damage. In contrast, the proposed method can ensure safety because humans are not required to approach sperm whales. Although there are risks during the takeoff and landing of a drone, safety can be ensured using appropriate equipment.

5. Non-invasive to whales:
   As the logger is adsorbed using a suction cup, it does not hurt the whales.

The numbers of the advantage list correspond to those of the problem list of the conventional methods described in the introduction. The system was developed for operating on a small fishing boat (less than 20 tons).

3. Logger Attaching System Using a Drone

3.1. Overview of the System

The overview and configuration of the developed drone system are shown in **Figs. 2** and **3**, respectively. This drone system consists of four parts: a drone, a logger, a wireless detaching device, and emergency buoyancy system. The communication system is illustrated in detail in **Fig. 4**. In addition, special equipment is required for ships on which drones arrive and depart.

The details of each part are described as follows.

3.1.1. Drone

The drone needs to have sufficient payload to carry a logger and a detaching device, and sufficient flight time to install the logger. In addition, as sperm whales often blow, drones need to be waterproof. Therefore, we

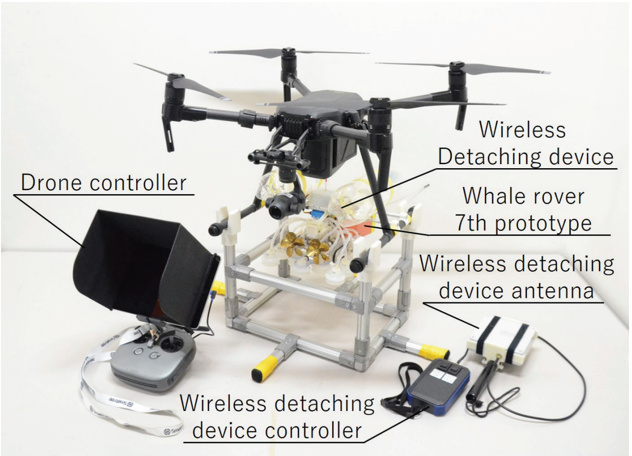


Fig. 2. Drone with equipment.

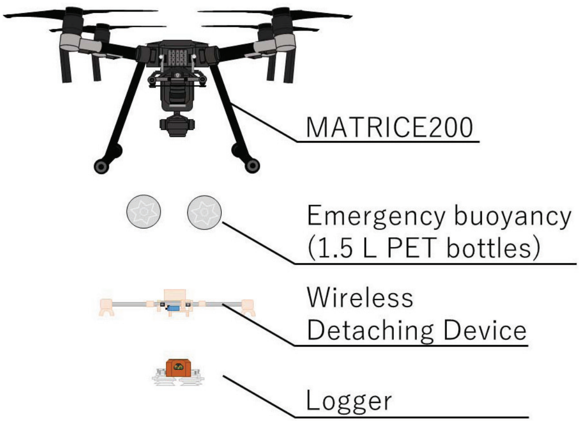


Fig. 3. Drone configuration.

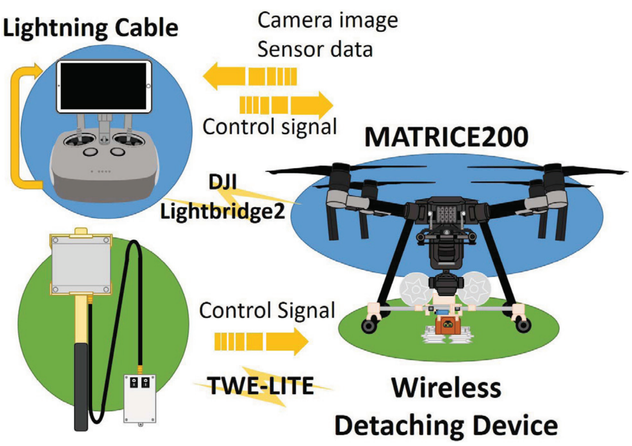


Fig. 4. Communication system.

adopted DJI's Matrice200, which has IP43 waterproofness. The drone is equipped with a camera gimbal Zenmuse X4S and two TB50 batteries. Even with the camera gimbal and battery, the maximum additional payload is 2,087 g. The flight time at that time is 13 min, which is sufficient, as sperm whales remain at the sea surface for approximately 10 min.

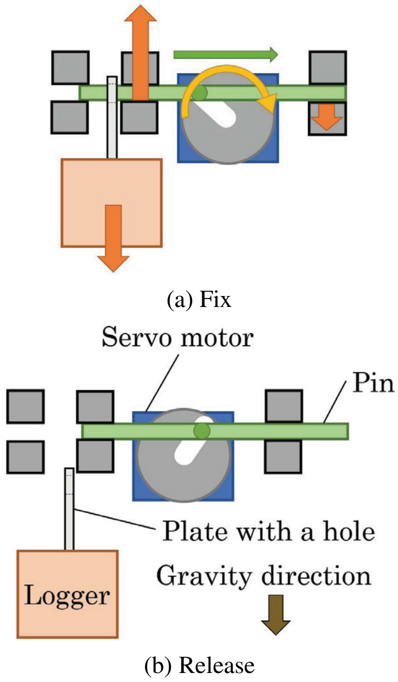


Fig. 5. Mechanism of the detaching device.

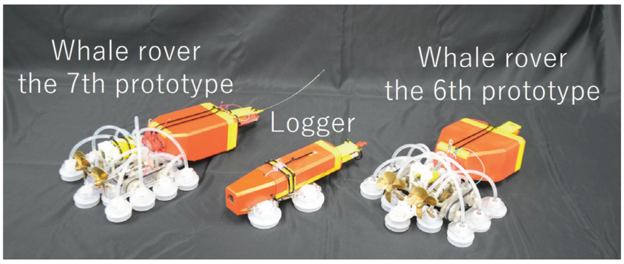


Fig. 6. Three types of loggers.

3.1.2. Detaching Device

We have developed a detachable device that separates the drone and the logger using wireless remote commands. This device weighs 342 g. An operator is employed to operate the device, and therefore, the drone pilot could concentrate on flying operations. Hence, the communication system of the device was made independent of that of the drone. A small and lightweight wireless microcomputer module, TWE-LITE RED, was employed for the communication.

Disconnection is performed by pulling out the pin using a servomotor HS-5086WP with IP67 waterproofness. **Fig. 5** shows details of the mechanism. A 9 V rechargeable battery is employed in the device. The detachable device is attached to the aluminum pipes that bridge the skid of the drone. In addition, logger support apparatuses are attached to the detachable device to suppress the attitude fluctuation of the logger during flight.

3.1.3. Logger

In this system, three types of loggers are employed, as shown in **Fig. 6**. The device in the middle is a logger

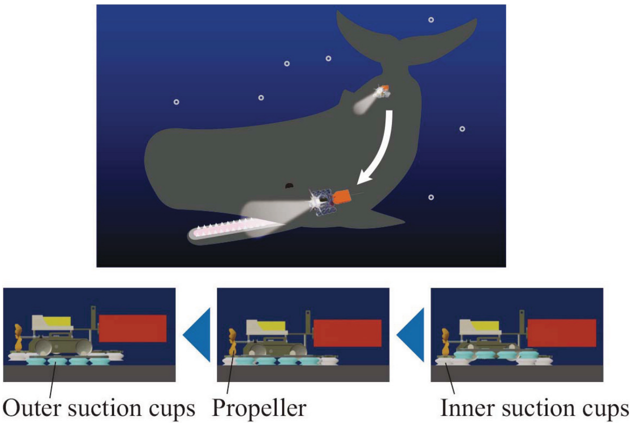


Fig. 7. Concept of the whale rover.

(L × W × H: 313 × 152 × 92 mm) that is adsorbed using four suction cups, similar to the conventional type. It is designed to be adsorbed by the impact force of a fall [16]. The devices on both sides are whale rovers, the right-side device is the sixth prototype (L × W × H: 439 × 245 × 125 mm) [15], and the left side device is the seventh prototype (L × W × H: 436 × 220 × 125 mm). By converting the flow of water into power with a propeller, the whale rover is adsorbed and moves forward against the flow. By using only the mechanism, it has pressure resistance performance in the deep sea while remaining compact. **Fig. 7** illustrates the concept and basic mechanisms. The sixth prototype has 11 suction cups, and the seventh prototype has three additional suction cups to improve the adsorption force. Each logger is equipped with both a deep-sea camera logger (DVL1300-VD3GT, Little Leonardo) and a transmitter (BLT-03-1, Circuit Design, Inc.) required to retrieve the logger. The adsorption logger, the sixth prototype, and the seventh prototype weighed 556, 1,518, and 1,427 g, respectively.

3.1.4. Emergency Buoyancy System

The emergency buoyancy system is mounted on the skid, and therefore, if the drone crashes into the sea, it can be retrieved and repaired. Two durable, lightweight, 1.5 L polyethylene terephthalate (PET) bottles for carbonated beverages were employed in this system. A small, inflatable life preserver was one of the candidates because of the lower air resistance during flight. However, it did not satisfy the weight restrictions. Through flight experiments, we confirmed that the PET bottles had no significant effect on the flight.

3.2. Landing Net

Takeoff and landing are extremely difficult on a small boat because of the narrow space and wave movement. To tackle this problem, a drone landing net was developed to make landings safe and reliable land in such an environment. **Fig. 8** shows the landing net. This net can be easily raised and lowered using three vertically extended columns. During drone landing, the net is raised to ensure safety; otherwise, the net is lowered to secure visibility. **Fig. 9** shows the drone landing on the landing net. On the other hand, hand release was adopted for quick takeoff, as shown in **Fig. 10**.

(a) Up

(b) Down

Fig. 8. Landing net.

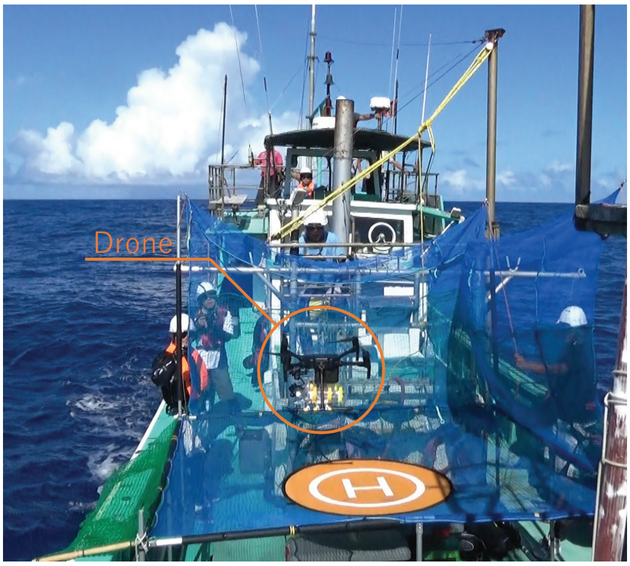


Fig. 9. Drone landing on the landing net.

3.3. Roles Within the Team

The main roles required for the operation are a pilot, subpilot, takeoff assistant, and takeoff subassistant. The pilot is responsible for operating the drone. The subpilot is in charge of operating the detachable device when dropping the logger onto the sperm whale. The takeoff

Fig. 10. Hand release.

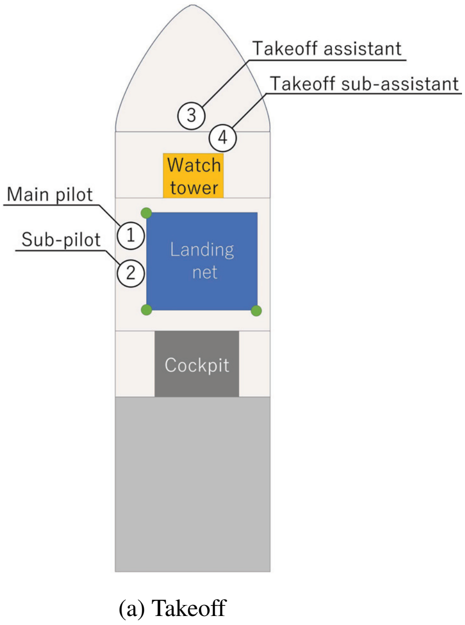


Fig. 11. Roles within the team.

assistant assists in takeoff by holding the drone in hand (hand release). The takeoff subassistant delivers the drone to the takeoff assistant and supports the takeoff assistant's body as the swaying of the ship threatens safety. The sub-pilot, takeoff assistant, and takeoff subassistant can move up the net when landing; thus, the minimum number of members required to operate the proposed system is four, as shown in **Fig. 11**. In practice, the crew of the ship and marine zoologists will also contribute to the search for sperm whales and lead the pilot toward the direction of the whales.

3.4. Personal Equipment

All the participants were equipped with helmets with a safety shield. The takeoff assistants were equipped with gloves, blade-proof arm covers, elbow pads, kneepads, and a chest protector so that they could be at the position closest to the drone. Some members on board were equipped with transceivers; thus, the voice of the pilot could be heard over the sound of the engine and wind.

Fig. 12. Drone approaching the sperm whale.

4. Field Experiments

We conducted a logger mounting experiment with sperm whales from October 16 to October 19, 2019, using our system in Ogasawara, Japan. **Fig. 12** shows a snapshot of the drone approaching the sperm whale.

4.1. Procedure

First, the direction of the sperm whale is located by a hydrophone acoustic exploration. Next, the sperm whale is visually searched from the ship. The procedure of the experiment is as follows:

1) All the members of the crew visually search for the blows of sperm whales, and inform the other members when they find them.
2) The pilot and takeoff assistant prepare the drone for takeoff while the captain approaches the sperm whale from a distance of 100–200 m.
3) The pilot launches the drone and raises its altitude to search for sperm whales.
4) The pilot lowers the pitch axis of the camera to search for sperm whales.
5) The pilot captures the sperm whale in the camera's vision, relying on the crew's instructions.
6) The pilot moves the drone just above the sperm whale and matches the drone direction to that of the sperm whale.
7) The pilot lowers the altitude of the drone to 1–2 m above the sperm whale while constantly adjusting the drone so that it remains just above the sperm whale.
8) The subpilot activates the separation device aiming at the time when the back of the sperm whale appears at the sea surface.
9) The pilot increases the drone altitude and observes the dropped logger and the sperm whale.

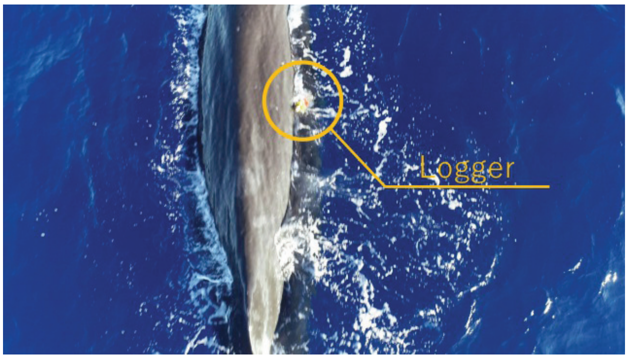


Fig. 13. Attaching the logger to the sperm whale (drone perspective).

10) The pilot returns the drone to the ship.
11) The landing net is raised by three persons to prepare for landing.
12) The pilot lands the drone on the landing net.
13) After the drone lands, the crew retrieves the logger from the ship using a spoon net.

Here, the operations of tasks 5), 7), 8), and 12) are difficult. It is not easy to capture sperm whales within the field of view of a camera. Instructions from other crewmembers are required. However, once the sperm whale is captured by the camera, it can be approached easily. In addition, maintaining the drone just above the sperm whale is not easy when its altitude is lowered. It is difficult for the subpilot to determine the timing of the fall. A video delay also occurs. Furthermore, landing a drone on a rocking ship is not easy for pilots, even with a landing net.

4.2. Experimental Results

A total of 38 flights were performed over four days. The drone could find sperm whales using the camera in 36 out of the 38 flights. Loggers could be dropped on sperm whales in 11 out of the 36 cases.

Among the remaining 25 cases, the dropping was stopped in 11 cases because the whales were with calves, in 12 cases where the sperm whales dived, in one case where the battery ran out, and in another case where the logger fell before tracking.

The logger was dropped 11 times, hit the body of the sperm whale eight times, and one of the suction cups was adsorbed twice. One of these cases is shown in **Fig. 13**. In both cases, the seventh prototype of the whale rover was adsorbed. However, the whale rover slipped backward and became peeled off from the body of the whale before it dived. Although the adsorption was incomplete, the operational procedure of the system was established.

Here, we investigate the time taken by the flight operations. **Table 1** lists the flight times recorded in the experiment. The flight time is divided into three categories depending on the situation: (A) from takeoff to sperm whale discovery, (B) from discovery to the drone flying just above the sperm whale, and (C) from the drone flying just above the sperm whale to logger drop. All the times are average values. Cases that did not satisfy each condition were excluded from the study. The denominator number of flights is shown on the right side of the average time. The overall average time of (A) was 51 s, which is less than 1 min. The key to this task is how the crew who finds the whales informs the pilot regarding the direction of the whales. A shorter average time on the fourth day indicated better team collaboration. The total average time of (B) was 32 s, indicating that the pilot was making the drone approach the whale in a short time.

Table 1. Daily average time.

Date	Average time		
	(A) Searching	(B) Approaching	(C) Following
Day 1 (6 flights)	1′10 (6 flights)	0′26 (4 flights)	0′34 (2 flights)
Day 2 (5 flights)	0′42 (4 flights)	0′43 (4 flights)	2′30 (2 flights)
Day 3 (11 flights)	1′16 (10 flights)	0′38 (10 flights)	0′40 (2 flights)
Day 4 (16 flights)	0′16 (16 flights)	0′23 (12 flights)	0′45 (5 flights)
Total	0′51 (36 flights)	0′32 (30 flights)	1′07 (11 flights)

Table 2. Average time of cases with the logger dropping.

Case	Average time			
	(A) Searching	(B) Approaching	(C) Following	Total
With the logger dropping (11 flights)	0′24	0′33	1′01	1′59

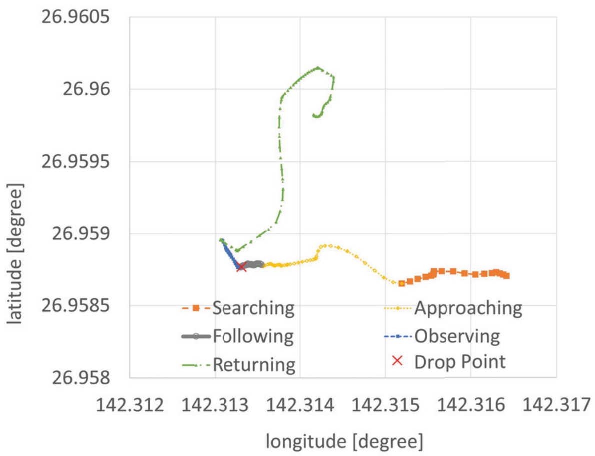
As shown in **Table 2**, the total average time from takeoff to logger fall in cases with logger drop (11 flights) was 1 min 59 s. This shows that the proposed system can operate in a short time.

Figure 14 shows the flight logs of the two successful adsorptions. **Fig. 14** is obtained from the GPS data of the drone. The thick line with white circles in **Fig. 14** represents the trajectory during period (C). It is apparent that the sperm whale in flight No.6 is moving straight, and the sperm whale in flight No.10 almost stops. It can be observed that both cases were relatively easy. Notably, obtaining such data is also an advantage of using drones.

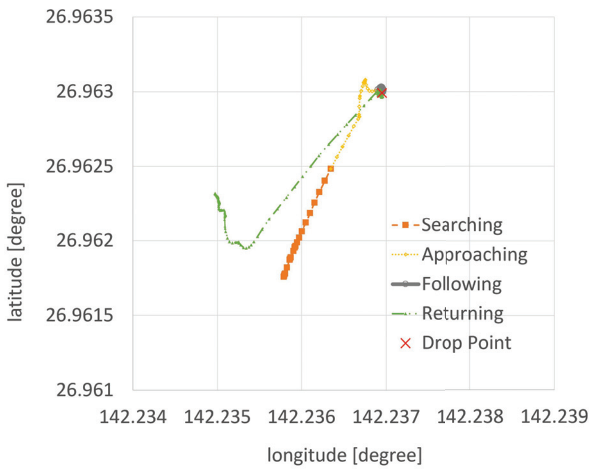
5. Discussion

We discuss the extent to which the proposed method solves the problems of the conventional approach described in the Introduction section.

First, the experimental results showed that fast and stable access to sperm whales was achieved. Unfortunately,



(a) Flight No.6



(b) Flight No.10

Fig. 14. Flight log (GPS).

we could not obtain any objective data on the access time through the conventional approach using a boat. However, drones can move quickly through the air above the whale, whereas boats must approach at a low speed. In other words, it is obvious that drones are faster. However, it takes time for the drone pilot to find the whale after launching the drone. To shorten this time, it is important for the pilot to cooperate with the crewmembers who find the whale from the ship.

Second, with regard to training and skills, we spent a considerable amount of time training drones in flight. However, drone maneuvering skills are more versatile, and several professionals already have these skills. In other words, the drone approach can be achieved more easily than the conventional approach. A logger technology that facilitates firm adsorption simply by dropping needs to be developed. Notably, in Japan, government permission is required to drop an object from a drone.

Third, **Fig. 13** shows that observations from drones are far superior to those obtained from the conventional approach. However, notably drones have a limited flight time.

Fourth, the proposed approach is safer than the conventional approach because the researchers themselves do not have to approach the whale. However, there are dangers associated with drones. Therefore, as shown in **Fig. 10**, it is necessary to wear appropriate protective equipment and perform regular drone maintenance. Regarding the safety of whales, in normal operations, the risk to whales is considered low. However, it is difficult to eliminate the possibility of hitting a whale due to drone failure. It may be necessary not to use a large drone or to reduce the speed in the vicinity of whales.

Finally, we discuss why the loggers and rovers were not completely adsorbed onto the whale. This may have been due to the water flowing down to the surface of the sperm whale rising from the sea. It is desirable to drop the logger when the flow of water decreases. However, it is difficult to predict the flow of water based on images with a time lag due to communication delay. Another reason for this phenomenon is the rotation of the posture while the logger is falling. The sea breeze and drone's downburst may be the main cause for this rotation, but the drone tilt during acceleration also affects the operation. Pilots often command the drone just above the whale, which can cause drone fluctuations. It is necessary to achieve a stable flight. The introduction of a video transmission system with a small time-lag may solve both these problems.

6. Conclusions

A novel logger mounting system using a drone was proposed for the ecological survey of sperm whales. In the proposed system, a drone is launched from a ship, and a logger is dropped from above the sperm whale. The dropped logger is expected to be adsorbed onto the body of the whale because of the impact of the fall. Field experiments were performed to confirm the feasibility of the proposed system. Experimental results showed that one of the suction cups of the whale rover was adsorbed onto the body of the sperm whale. The operation took approximately 2 min from takeoff to logger drop. Although further improvement is necessary, the effectiveness of the proposed system was demonstrated.

Acknowledgements

The experiment was conducted under a special permit (No.1903) from the Ogasawara Whale Watching Association to avoid excessive burden on the whales. This study was supported by the JSPS KAKENHI Grant-in-Aid for Scientific Research on Innovative Areas (Grant Number JP16H06537). We wish to thank Prof. Katsufumi Sato and Dr. Kagari Aoki at The University of Tokyo for valuable information on the bio-logging science of sperm whales. We are deeply grateful to Dr. Ryosuke Okamoto and Mr. Koki Tsujii at the Ogasawara Whale Watching Association for their dedicated local support.

References:

[1] C. Rutz and G. C. Hays, "New frontiers in biologging science," Biol. Lett., Vol.5, No.3, pp. 289-292, 2009.

[2] P. J. Bulter, J. A. Green, I. L. Boyd, and J. R. Speakman, "Measuring metabolic rate in the field: the pros and cons of the doubly labelled

water and heart rate methods," Functional Ecology, Vol.18, No.2, pp. 168-183, 2004.

[3] K. Aoki, M. Amano, M. Yoshioka, K. Mori, D. Tokuda, and N. Miyazaki, "Diel diving behavior of sperm whales off Japan," Mar. Ecol. Prog. Ser., Vol.349, pp. 277-287, 2007.

[4] H. Whitehead, "Sperm Whale: Physeter Macrocephalus," B. Wuersig, J. G. M. Thewissen, and K. M. Kovacs (Eds.), "Encyclopedia of Marine Mammals, Third Edition," pp. 919-925, Academic Press, 2017.

[5] K. Aoki, M. Amano, T. Kubodera, K. Mori, R. Okamoto, and K. Sato, "Visual and behavioral evidence indicates active hunting by sperm whales," Mar. Ecol. Prog. Ser., Vol.523, pp. 233-241, 2015.

[6] K. Aoki, M. Amano, K. Mori, A. Kourogi, T. Kubodera, and N. Miyazaki, "Active hunting by deep-diving sperm whales: 3D dive profiles and maneuvers during bursts of speed," Mar. Ecol. Prog. Ser., Vol.444, pp. 289-301, 2012.

[7] S. L. Watwood, P. J. O. Miller, M. Johnson, P. T. Madsen, and P. L. Tyack, "Deep-Diving Foraging Behaviour of Sperm Whales (Physeter Macrocephalus)," J. of Animal Ecology, Vol.75, No.3, pp. 814-825, 2006.

[8] M. P. Johnson and P. L. Tyack, "A Digital Acoustic Recording Tag for Measuring the Response of Wild Marine Mammals to Sound," J. of Oceanic Engineering, Vol.28, No.1, pp. 3-12, 2003.

[9] K. Nonami, "Drone Technology, Cutting-Edge Drone Business, and Future Prospects," J. Robot. Mechatron., Vol.28, No.3, pp. 262-272, 2016.

[10] J. Xu, G. Solmaz, R. Rahmatizadeh, D. Turgut, and L. Bölöni, "Animal Monitoring with Unmanned Aerial Vehicle-Aided Wireless Sensor Networks," Proc. of 2015 IEEE 40th Conf. on Local Computer Networks (LCN), pp. 125-132, 2015.

[11] L. N. Kloepper and M. Kinniry, "Recording animal vocalizations from a UAV: bat echolocation during roost re-entry," Scientific Reports, Vol.8, Article No.7779, doi: 10.1038/s41598-018-26122-z, 2018.

[12] T. Fettermann, L. Fiori, M. Bader, A. Doshi, D. Breen, K. A. Stockin, and B. Bollard, "Behaviour reactions of bottlenose dolphins (Tursiops truncatus) to multirotor Unmanned Aerial Vehicles (UAVs)," Scientific Reports, Vol.9, Article No.8558, doi: 10.1038/s41598-019-44976-9, 2019.

[13] L. G. Torres, S. L. Nieukirk, L. Lemos, and T. E. Chandler, "Drone Up! Quantifying Whale Behavior From a New Perspective Improves Observational Capacity," Frontiers in Marine Science, Vol.5, Article 319, doi: 10.3389/fmars.2018.00319, 2018.

[14] V. Pirotta, A. Smith, M. Ostrowski, D. Russell, I. D. Jonsen, A. Grech, and R. Harcourt, "An Economical Custom-Built Drone for Assessing Whale Health," Frontiers in Marine Science, Vol.4, Article 425, doi: 10.3389/fmars.2017.00425, 2017.

[15] K. Tsuchiya, Y. Tsumaki, K. Mori, and R. Okamoto, "Whale rover moving along the surface of sperm whale," Advanced Robotics, Vol.33, Nos.3-4, pp. 195-206, 2018.

[16] K. Masumoto, R. Murakami, S. Owada, and Y. Tsumaki, "Development of a Drop Type Absorption Logger for Whales Using a Check Valve," Proc. of JSPE Conf. of Tohoku Branch, B08, 2019 (in Japanese).

Name:
Ryota Murakami

Affiliation:
Department of Mechanical Systems Engineering, Graduate School of Science and Engineering, Yamagata University

Address:
4-3-16 Jonan, Yonezawa City, Yamagata 992-8510, Japan

Brief Biographical History:
2018 Received B.E. from Yamagata University
2020 Received M.E. from Yamagata University

Name:
Takumi Toyoshima

Affiliation:
Department of Mechanical Systems Engineering, Graduate School of Science and Engineering, Yamagata University

Address:
4-3-16 Jonan, Yonezawa City, Yamagata 992-8510, Japan

Brief Biographical History:
2018 Received B.E. from Yamagata University
2020 Received M.E. from Yamagata University

Name:
Daichi Furusawa

Affiliation:
Department of Mechanical Systems Engineering, Graduate School of Science and Engineering, Yamagata University

Address:
4-3-16 Jonan, Yonezawa City, Yamagata 992-8510, Japan

Brief Biographical History:
2018 Received B.E. from Yamagata University
2020 Received M.E. from Yamagata University

Name:
Masaru Suzuki

Affiliation:
Department of Mechanical Systems Engineering, Graduate School of Science and Engineering, Yamagata University

Address:
4-3-16 Jonan, Yonezawa City, Yamagata 992-8510, Japan

Brief Biographical History:
2020 Received B.E. from Yamagata University

Name:
Kazunari Masumoto

Affiliation:
Department of Mechanical Systems Engineering, Graduate School of Science and Engineering, Yamagata University

Address:
4-3-16 Jonan, Yonezawa City, Yamagata 992-8510, Japan

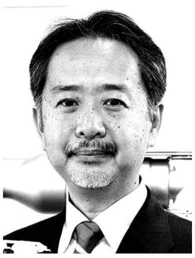
Brief Biographical History:
2020 Received B.E. from Yamagata University

Name:
Sho Owada

Affiliation:
Project Researcher, Department of Mechanical Systems Engineering, Graduate School of Science and Engineering, Yamagata University

Address:
4-3-16 Jonan, Yonezawa City, Yamagata 992-8510, Japan

Brief Biographical History:
2011 Received B.E. from Yamagata University
2013 Received M.E. from Yamagata University
2019- Project Researcher, Yamagata University



Name:
Yuichi Tsumaki

Affiliation:
Professor, Department of Mechanical Systems Engineering, Graduate School of Science and Engineering, Yamagata University

Address:
4-3-16 Jonan, Yonezawa City, Yamagata 992-8510, Japan

Brief Biographical History:
1992-1994 Kamakura Works of Mitsubishi Electric Co., Ltd.
1994-2000 Research Associate, Tohoku University
1999 Visiting Researcher, NASA Jet Propulsion Laboratory, California Institute of Technology
2001-2006 Associate Professor, Hirosaki University
2006 Visiting Researcher, Versailles University
2008- Professor, Yamagata University

Main Works:
- "Whale rover moving along the surface of sperm whale," Advanced Robotics, Vol.33, No.3, pp. 195-206, 2019.

Membership in Academic Societies:
- The Institute of Electrical and Electronics Engineers (IEEE)
- The Robotics Society of Japan (RSJ)
- The Japan Society of Mechanical Engineers (JSME)
- The Society of Instrument and Control Engineers (SICE)
- The Virtual Reality Society of Japan (VRSJ)

Name:
Kyoichi Mori

Affiliation:
Professor, Department of Animal Sciences, Teikyo University of Science

Address:
2525 Yatsusawa, Uenohara, Yamanashi 409-0193, Japan

Brief Biographical History:
1994- Ogasawara Whale Watching Association
2009- Teikyo University of Science

Main Works:
- "Visual and behavioral evidence indicates active hunting by sperm whales," Marine Ecology Progress Series, Vol.523, pp. 233-241, 2015.
- "First-ever observations of a live giant squid in the wild," Proc. of the Royal Society B: Biological Sciences, Vol.272, No.1581, pp. 2583-2586, 2005.

Membership in Academic Societies:
- The Mammal Society of Japan (MSJ)
- The Japanese Society of Fisheries Science (JSFS)