TRANSNAV International Journal on Marine Navigation and Safety of Sea Transportation
Volume 6 Number 1 March 2012

Feasibility on Infrared Detection of Cetaceans for Avoiding Collision with Hydrofoil

Y. Yonehara, L. Kagami, H. Yamada & H. Kato
Tokyo University of Marine Science and Technology, Tokyo, Japan
M. Terada & S. Okada
KHI JPS Co., Ltd., Kobe, Japan

ABSTRACT: To achieve safer navigation without sudden collisions with large cetaceans at high speed boats such as the hydrofoil, we examined its feasibility of an installation of the infrared camera. Because any cetaceans are of air-breathing animals, it is theoretically expected that they can be potentially detected through imaging of the infrared cameras. Thus, we examined the feasibility of detection with aiming at sperm whales in waters off Chichijima Islands (27°4'N, 142°13'E), Japan. Through the experiment, it was revealed that sperm whales could be detected stably within 200m, and detectable cue were blow, back body and fluke tails. However, boats and waves were also detected as noise images. Especially, waves greatly resemble the whale back bodies. Although potential of the infrared camera was confirmed, there are still necessities of further experiments including ones conducting at different temperate waters, to successfully install the infrared camera for earlier finding of large cetaceans.

1 INTRODUCTION

Concerning the problem of collision accident between large cetaceans and vessels, it is expected to identify the critical season and species of large cetacean in some courses of hydrofoils off Japan water and also to technically improve the Under Water Speaker (UWS) for repellent of cetaceans. However, it is necessary to take measures of not only repellent of cetacean but also actively cetacean avoidance. The UWS is one of the countermeasures for cetaceans to give way. For the safety navigation of hydrofoils, as part of these studies, we are envisaging an alert system triggered by the whale detection using infrared camera (thermography). Because any cetaceans are of air-breathing animals, they come to the surface inevitably in regular interval and their blow or body parts appear at the sea surface. In this system, we aim at these objects as detection cue by using infrared camera.

In this study, we examine the feasibility of the infrared camera on detecting large cetaceans. On that basis, we intended to form the foundation of early cetacean detection and alert system using infrared camera by formulating the necessary conditions or the method of infrared camera operation for detecting whales.

2 MATERIAL AND METHOD

2.1 *Equipments*

In this experiments, we used a Infrared Thermal camera; Thermo Tracer TH9260 made by NEC/Avio Infrared Technologies (Fig. 1). Its detector is uncooled focal plane array (microbolometer), and thermal image pixels is 640(H) × 480(V). The operating band is 8 to 13 μm, and it can measure objects from -40°C to 500°C. Optical field of view of this camera is fixed (21.7°(H)×16.4°(V)) . This camera obtains the images 30frame per second.

Figure 1 Infrared camera used in this study (TH9260)

Additionally, we used HD video camera (Sony Digital HD video camera recorder HDR-SR1) for recording normal images and thermal images in the same time as a control of the experiment. For measuring accurate distance between cetaceans and us, we used the Laser range finder (Bushnell Laser Rangefinder Elite 1500).

2.2 *Experiment of infrared detection on sperm whales in Bonin Water*

An infrared recording experiment of sperm whales was conducted off the South-East water off Chichijima island, Ogasawara Islands (also known as the Bonin Islands, a subtropical archipelago located ca. 1000 km directly south of central Tokyo in the western Pacific Ocean) from September 12 to 14, 2009 (Fig. 2).

We conducted this survey by chartered small fishing boat ”Shoeimaru” (Fig. 3). At eye level was approximately 2m since TH9260 was held at the bow. Captain and three researchers got on the boat and participate in this survey. We intended to investigate sperm whales mainly and record boats or sea surface at the same time. We left Futami port every morning and returned before sunset. The investigation time was less than 10 hours a day.

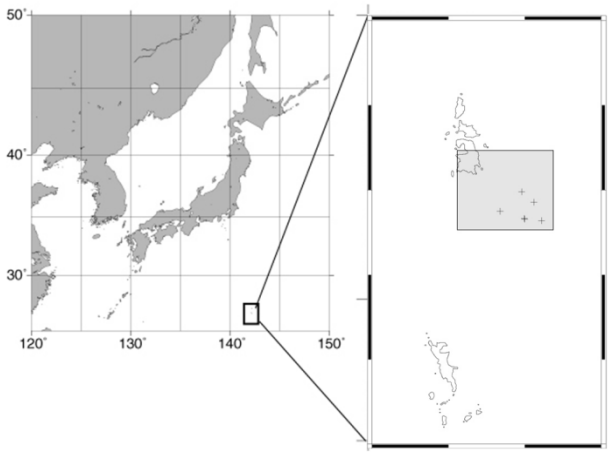

Figure 2 A survey area off Chichijima island (Bonin Islands).

Gray square indicates survey area (26°55′ to 27°05′ N, 142°11′ to 142° 24′ E). Cross marks indicates the position sperm whale sighted.

Figure 3 Syoeimaru; Length:12m,

After leaving port, we began a search of sperm whales by eyes. When we found the sperm whale, we tried to approach them and began the IR recording experiment in diverse distance. A researcher held the IR camera. Others served the distance measurement and data notation, or filming the behavior of sperm whale and the research status by the HD camera. When the blow or body of sperm whales appeared above sea surface, we noted whether researcher could perceive it on the display of IR camera (Success or Failure) with visual assistance of sperm whale behavior made by other researchers and an experienced operator of “Shoeimaru” in sperm whale sightings around the waters. And we also noted the time, type of the object and distance from the object at the same time. We saved a thermal image or thermal movie if at all possible. The distance from the object was measured by use of Laser range finder. If it couldn’t, researcher measured the distance with the eye.

Acquired infrared data were conducted an analysis of temperature measurement using dedicated software (NS9205Viewewr program made by NEC/Avio infrared technology). We measured temperatures of objects as T_a and temperatures of sea surface around the objects as T_{sea} (Fig. 4) and calculated the difference in temperature ($\Delta T = T_a - T_{sea}$).

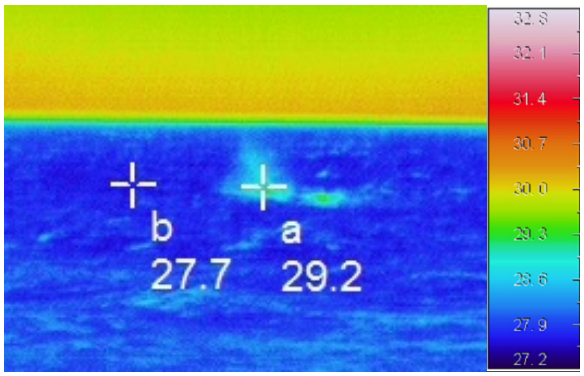

Figure 4 The example of measuring method that of T_a and T_{sea} by using software (This is the magnified figure). In this figure, point ‘a’ indicates the temperature of T_a and ’b’ indicates that of T_{sea}.

3 RESULTS

We could conduct the experiment in three days. Table1 shows the summary of the experiments. In this experiment, we could observe and obtain data from Sperm whale, small boat and sea surface. Show the result of observation below.

Number of IR detection indicates the number of data that we noted whether or not to perceive sperm whales on IR camera in diverse distances. We excluded the data that noted same result (S or F), same distance and within three minutes to avoid data bias. However, it has potentially observed same individu-

al, other cases of data were dealt with the different results since it is very hard to identify that the whale examined previously or not. Number of thermal images indicates the whole number of saved thermal images through the experiment.

Table 1 Summary of the experiment in waters off Ogasawara, 2010.

Date	12 Sept.	13 Sept.	14 Sept.
Observed whale groups	2	2	2
Number of IR detection	21	8	33
Number of thermal images	184	794	1371

3.1 *Sperm whale*

In this experiment, sperm whale's blow, back body and tail flukes were detected by using TH9260 (Fig. 5). As for object range, we could always detect these sperm whale objects on the display of TH9260 within a range of 150m. However, we never detect them out of a range of 350m. Within a range of 160m to 300m, we could detect or not (Table 2 and Fig. 5). The maximum distance of laser range finder was 118m.

Table 2 The result of IR sperm whale detection in each distance.

Distance (m)	Success	Failure	Sum
～50	6	0	6
51～100	12	0	12
101～150	12	0	12
151～200	11	6	17
201～250	2	7	9
251～300	3	1	4
301～	0	2	2
	46	16	62

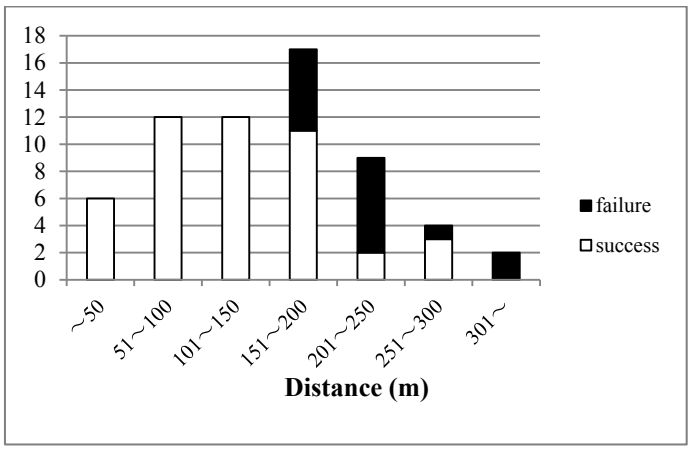

Figure 6 Numbers of success or failure in IR detection experiment each distances.

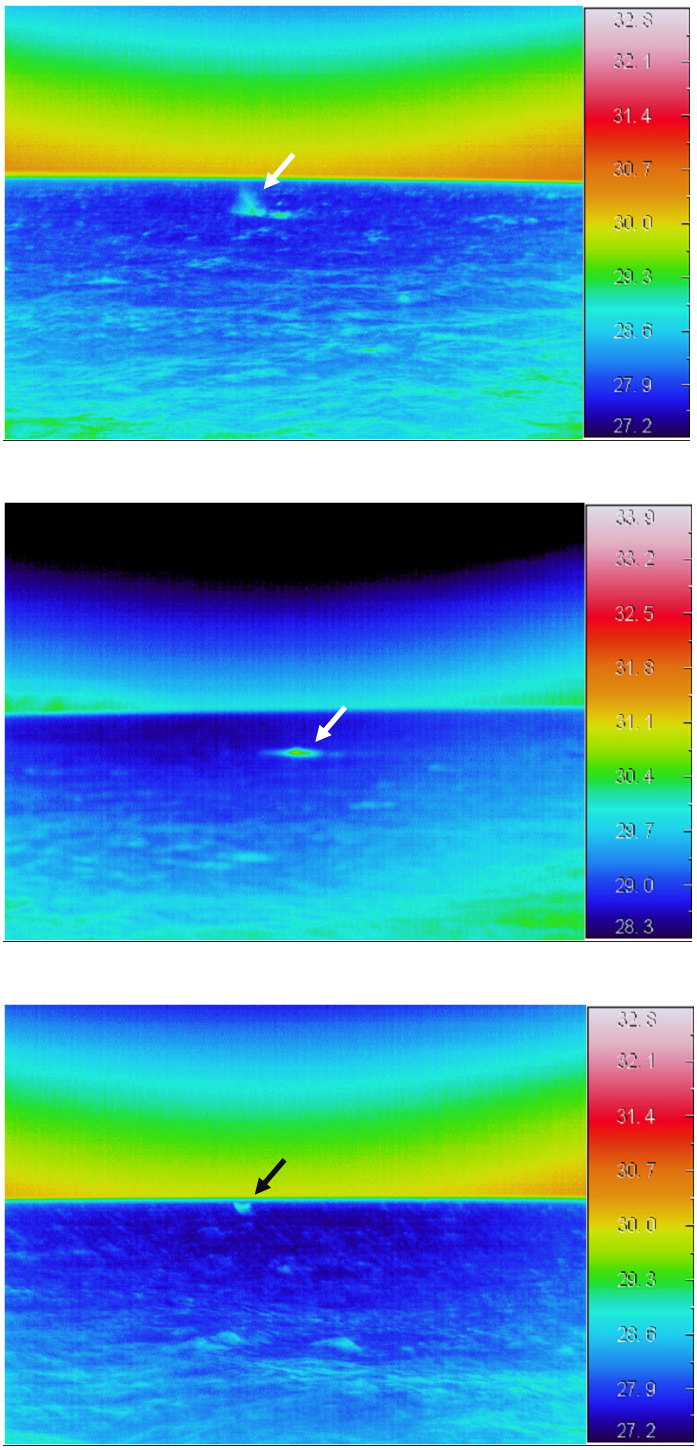

Figure 5 Thermal images of sperm whale's objects detected by TH9260. Objects were indicated by arrows.

Top: blow (100m away), Middle: dorsal part of body (117m away) and Bottom: tail fluke (200m away).

Concerning measured temperature, Median T_a and ΔT of sperm whale obtained by TH9260 was 29.2°C and 1.30°C (Table 3 and Fig. 7). Median ΔT of each sperm whale's detected objects were 1.10°C (blow), 1.40°C (back body), and 1.30°C (tail fluke) (Table 4, Fig.8). As a result, ΔT of sperm whale's body parts indicates high value compared with that of their blow, however statistical significant difference didn't shown in Tukey-Kramer's multiple comparisons (P=0.185) between ΔT of sperm whale objects.

Table 3 T_a and ΔT estimated in each objects.

T_a of each objects (°C)			
	Whale (n=41)	Boat (n=8)	Wave (n=13)
Median	29.2	33.9	29.4
Max	32.2	38.8	30.3
Min	25.8	32.7	27.1
ΔT of each objects (°C)			
	Whale (n=41)	Boat (n=8)	Wave (n=13)
Median	1.3	6.3	1.2
Max	2	11.3	1.5
Min	-0.3	5.1	0.4

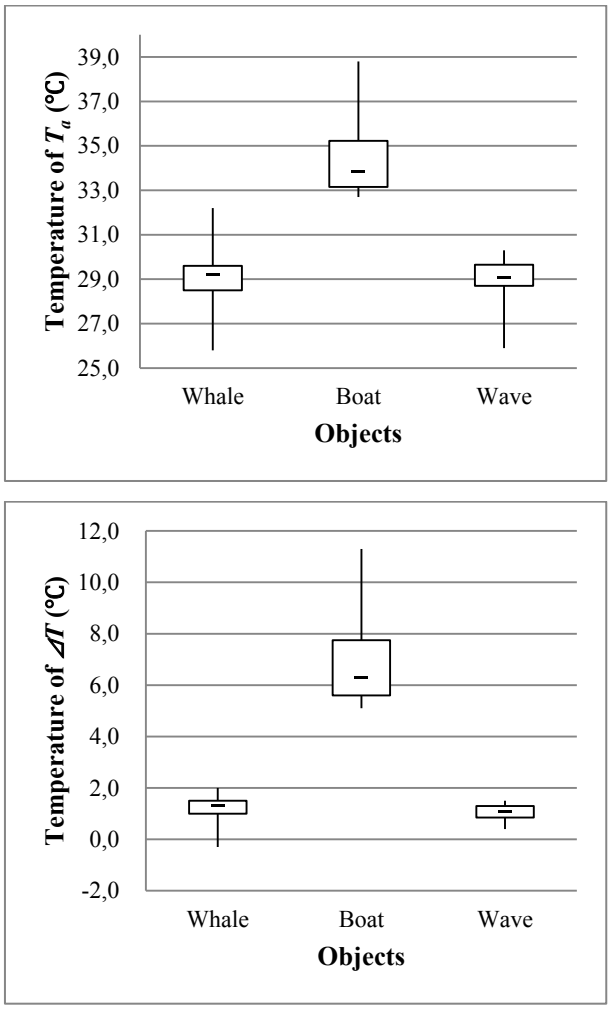

Figure 7 Box-plot of T_a and ΔT of each objects
Vertical bar indicates the maximum and minimum value. Box indicates lower and upper quartile point. Short crossbar indicates median value.

Table 4 T_a and ΔT estimated in each objects

T_a of sperm whale's objects (°C)			
	Blow (n=19)	Back (n=16)	Fluke (n=6)
Median	28.8	29.15	29.65
Max	30.7	32.2	30.2
Min	25.9	27.1	25.8
ΔT of sperm whale's objects (°C)			
	Blow (n=19)	Back (n=16)	Fluke (n=6)
Median	1.1	1.4	1.3
Max	1.9	2	2
Min	-0.3	0.5	1.1

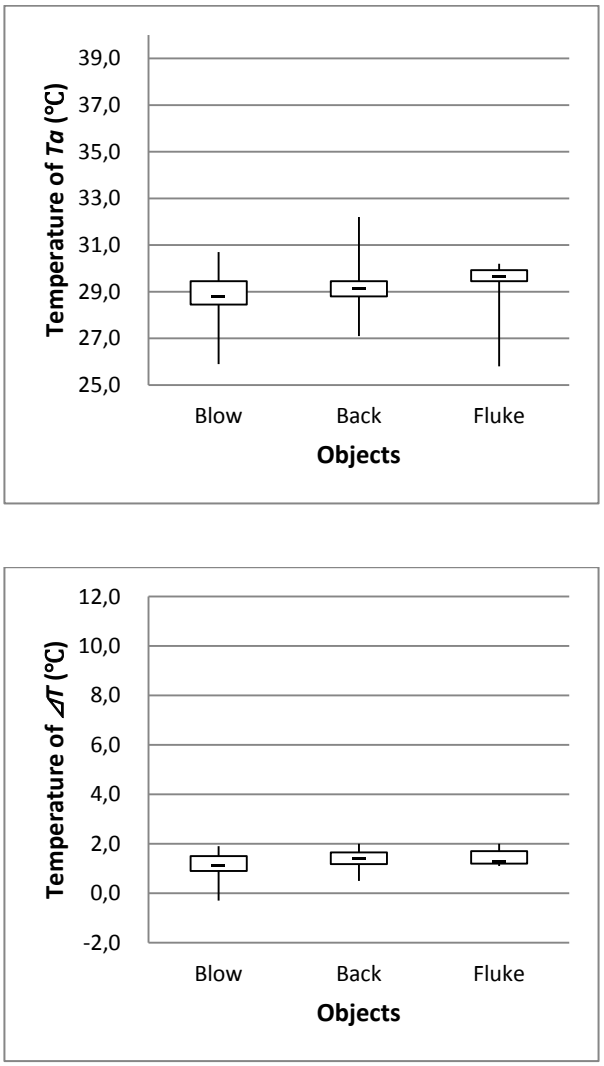

Figure 8 Box-plot of T_a and ΔT of sperm whale's objects

Vertical bar indicates the maximum and minimum value. Box indicates lower and upper quartile point. Short crossbar indicates median value.

3.2 *Small boat*

We could observe a small boat employed for whale watching. The boat appeared very strong on the display of TH9260 since it has high rate of infrared radiation (Fig. 9). Median T_a and ΔT of small boat was 33.4°C and 6.30°C (Table 3 and Fig. 7). It was highest temperature in this study, and statistical significant difference was showed in Tukey-Kramer's multiple comparisons ($P<0.01$) between ΔT of boat and sperm whale or wave.

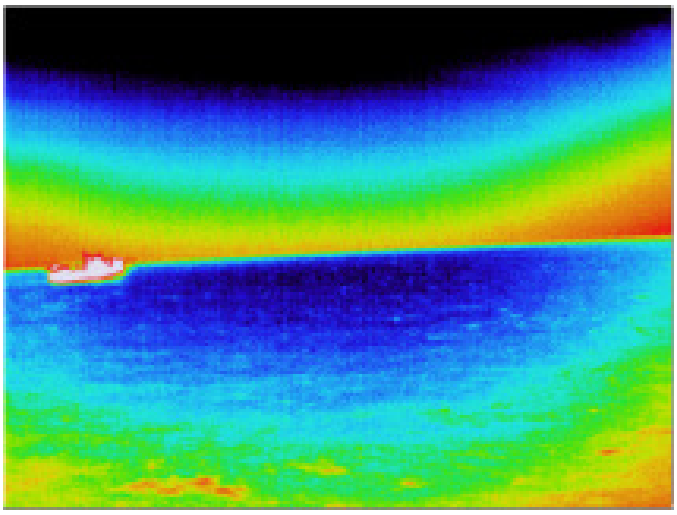

Figure 9 A small boat detected by TH9260.

3.3 *Sea surface*

In the display of TH9260, concentric temperature gradient always appeared on the sea surface (e.g. Fig. 7 and 11). Waves such as white caps were also detected on the display of TH9260 (e.g. Fig. 7). As for temperature, median T_a and $\triangle T$ of waves was 29.10°C and 1.10°C (Table3 and Fig. 7).

4 DISCUSSION

4.1 *Detectable range*

In this experiment, it is suggested that maximum surely detectable range of TH9260 was 150m and stable detectable range of it seems to be approximately 200m (Table 2 and Fig. 6). However, it is considered that the measured instances aren't enough to conclude it. In early studies, McCafferty *et al.* (2007) introduced that Infrared camera has the potential for measuring mammals as far as 1000m or more. Barber *et al.* (1991) could detect walruses on the sea surface away from more than 2000m above in the sky. Thus, infrared camera might be able to detect large cetaceans at more long distance. The possible way to improve the detectable range of infrared cameras is using telephotographic lens and higher resolution infrared camera.

4.2 *Ta and ⊿T estimated in each objects*

Cuyler *et al.* (1992) made a survey of large cetaceans and taking their temperature using infrared camera in the northern Norway water (68~80°N). They resulted that $\triangle T$ of sperm whale's blow and tail fluke was +3.00°C and +6.00°C. The tendency that body parts exceed blow in $\triangle T$ corresponds to Cuyler *et al.* (1992). However, the $\triangle T$ of our survey showed lower temperature than that of Cuyler *et al.* (1992). It is suggested that this caused by the difference of the regions that Cuyler *et al.* (1992) investigated in high latitude water (air temperature was 2.5 ~13.0°C and water temperature was 2.7~10.1°C during investigation period), in contrast, we investigated in subtropical water (air temperature was 28.1~33.5°C and water temperature was 27.0~30.5°C during investigation period). Thus, it is considered that surrounding temperature make a large effect on cetacean detection using infrared camera. If this idea is correct, it is suggested the cetacean detection using infrared camera will be more effective in cool winter season at the sea off Japan. Especially, early detection of large cetaceans and alert system using infrared camera is expected to be more effective in the winter Sea of Japan which is hard to find cetaceans by the naked eye.

In our experiment, we also could detect a small boat, sea surface and waves through the thermal images as a noise of cetacean detection. The boat is thought to be able to distinguish from cetacean objects easily on the thermal images since it was indicated that the boat has large difference of temperature between sea surface and it emitted definitely high thermal energy than other objects (Table 3, and Fig. 5 and 9). Concerning concentric temperature gradient on sea surface and the temperature indicated by waves, it is inconsiderable that they reflect the real variation in water temperature. Though Infrared has directionality, it is suggested that apparent variation in temperature was occurred by changing the shooting angle between infrared camera and objects of shooting. Additionally, the configuration and the T_a composition of waves were similar to these of the sperm whale's back body in thermal images (Figs. 5, 7 and 8, and Table 3, 4). Therefore, it seems to be difficult to distinguish sperm whale's back body from waves in thermal images. It is suggested that cetacean detection using infrared camera will be hard to operate in heavy weather which waves appear a lot on the sea surface.

5 CONCLUSION

From this study, it was revealed that the infrared camera has the feasibility to detect large cetaceans on the sea around Japan. However, it is difficult to say that we obtained a sure result for the detectable range since the shortage of data. Therefore, it is necessary to accumulate more data of detectable range.

It is suggested that oceanic condition and air or water temperature affect the result of cetacean detection using infrared camera. Thus, we should conduct more elaborate survey of environmental factor that infrared cetacean detection works effectively. It is also concluded that sperm whales are difficult to distinguish from waves in thermal images. Therefore, we should devise the technique to distinguish them not only by temperature.

In addition, early study, Cuyler *et al.* (1992) conducted cool water and obtained more pronounced difference in temperature between cetaceans and sea surface than our study that conducted subtropical water. Thus, summer Bonin island water might be too warm to investigate the feasibility of infrared camera to detect large cetaceans, and it is necessary to make more practical verification surveys in an environment similar to the course of hydrofoils off Japan.

ACKNOWLEDGEMENT

This study was supported by KHI JPS Co., Ltd. and Kawasaki Shipbuilding Corporation. We wish to thank M. Yamaguchi and A. Nakajima for getting on the boat and carrying out the experiment with us. We are grateful to Ogasawara Marine Center and Ogasawara Whale Watching Association for support conducting the survey off Chichijima, Ogasawara (Bonin Islands).

REFERENCES

Barber, D. G., Richard, P. R., Hochheim, K. P., Orr J. 1991. Calibration of aerial thermal infrared imagery for walrus population assessment. *Arctic*, 44, 58-65.

Cuyler, L. C., Wiolsrod, R., Oritsland, N. A. 1992. Thermal infrared radiation from free living whales. *Marine Mammal Science*, 8(2): 120-134.

McCafferty, D. J. 2007. The value of infrared thermography for research on mammals: previous applications and future direction. *Mammal Rev.* 2007, Volume 37, No. 3, 207-233.

Shakata, K., Odagawa, A., Yamada, H., Matsunaga, H., Kato, H. 2008. Toward to avoiding ship strike of cetaceans with the high-speed HF (1) Identifying expected cetacean species on the track lines of HF. 2008 Annual meeting of M. S. J. summary: 135