Local Variation in Feeding Ground Utilization of Dugongs (*Dugong dugon*) Across Two Intertidal Seagrass Beds in Talibong Island, Thailand

Supplemental Materials

Chiaki Yamato,[1] Kotaro Ichikawa,[2]
Kongkiat Kittiwattanawong,[3] and Nobuaki Arai[2]

[1]Graduate School of Informatics, Kyoto University, Yoshida-Honmachi, Sakyo-ku, Kyoto, 606-8501, Japan
E-mail: yamato.chiaki.82a@gmail.com
[2]Field Science Education and Research Center, Kyoto University,
Kitashirakawa-Oiwakecho, Sakyo-ku, Kyoto, 606-8502, Japan
[3]Department of Marine and Coastal Resources, 120 Moo 3, Chaeng Watthana Road,
Thung Song Hong, Khet Lak Si, Bangkok, 10210, Thailand

Supplemental Material S1. Methods to Estimate Body Length

Outline of Methods

The body length of the dugongs was estimated using two methods. All individuals were estimated using the method described in the main manuscript (Method_main), whereas four of the 64 individuals were additionally measured using orthophotos from this area (Method_orthophoto). The Method_orthophoto is described in this section:

1. A georeferenced aerial image (orthophoto) of the observation area is generated. First, aerial photographs were acquired at a resolution of 1 cm/pixel during automated flights using a drone (Phantom4 PRO V2.0; Da-Jiang Innovations Science and Technology Co., Ltd., Shenzhen, China) equipped with a global navigation satellite system (GNSS) receiver (Topodrone PPK Upgrade Kits; Topodrone, Montreux, Switzerland). The flight courses were programmed using commercial software (*UgCS*, Version 4.1; SPH Engineering Co., Ltd., Riga, Latvia). Aerial photographs were geometrically corrected at points with known coordinates. The points were evenly spaced at 100 m apart. The coordinates were measured using a GNSS receiver (DG-PRO1 RWS; BizStation Corp., Nagano, Japan) and a real-time kinematic method. An orthophoto at 1 cm/pixel resolution was generated using photogrammetric software (*Metashape Professional Edition*, Version 1.5.4; Agisoft LLC, Saint Petersburg, Russia).

2. Videos of the dugongs were recorded at an altitude of 40 m using a drone (Mavic 3; Da-Jiang Innovations Science and Technology Co., Ltd.). The most distinctive images of the surfacing dugong were extracted from each video on *Films & TV*, Version 10.22091.10031.0 (Microsoft Corporation, Redmond, WA, USA). The most representative frame in which the dugong was flat, horizontal, or straight (neither twisted nor inclined) and its extremities were distinct was extracted.

3. Each frame was manually transformed by rotating, rescaling, translating, and overlaying the orthophoto such that the seagrass patches in the frame matched those in the orthophoto. *Adobe Photoshop*, Version 24.1.1 (Adobe Systems Inc., San Jose, CA, USA), was used for analysis. The length of the straight-line from the snout tip to the medial notch of the fluke was measured.

Performance of Length Estimation

A field survey was conducted to evaluate the accuracy of length estimation using the two methods described above. Steel angles of 1.2 m were used as the measurement targets. A field survey was conducted on the seashore of Shirahama Town, Wakayama Prefecture, Japan, on 22 February 2023 (Figure S1). All the aerial surveys were conducted in accordance with the Aviation Law announced in 2022 by the Ministry of Land, Infrastructure, Transport, and Tourism of Japan. The same drone used to estimate the body length of the dugongs was also used in the field survey.

The two steel angles were set on land (Point A) and horizontal to the water surface (Point B). The depths of the angles at Point B varied between 0 and 80 cm as the tidal level changed. Another angle, color-coded at 10 cm intervals, was placed next to the angle at Point B. Water depth during each flight was determined by observing the position of the water surface at a color-coded angle.

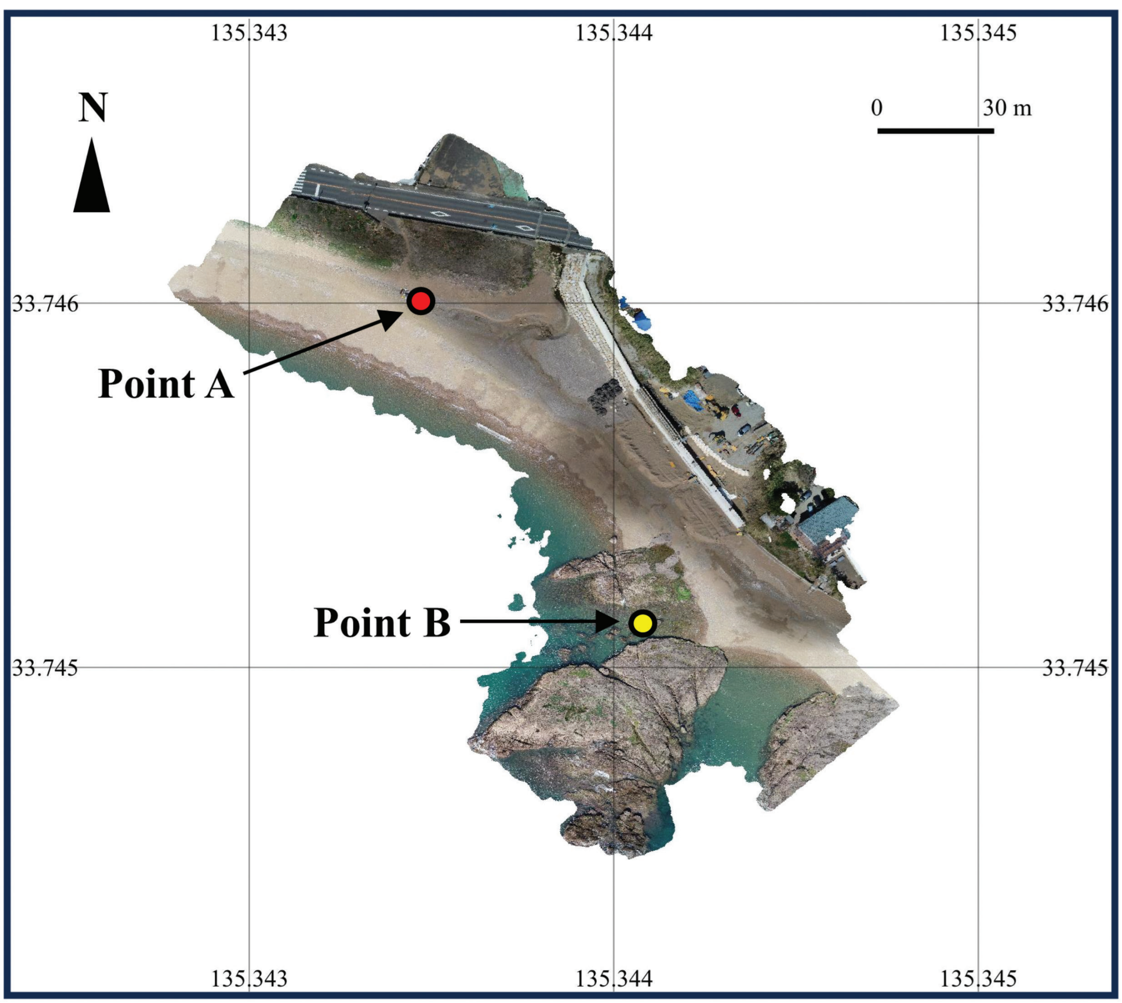

Figure S1. Study site: Point A was located on land, while Point B was underwater.

The drone was launched, and photographs of the angle were taken at an altitude of 40 m, both with and without a 7x zoom, ensuring that the angle was centered in the image frame. The drone was restarted after landing. This procedure was repeated nine times at Point A and 30 times at Point B. Subsequently, the angle lengths were estimated using these two methods.

The highest accuracy, with an error of less than 1% in the object length, was achieved in the on-land test using Method_orthophoto (Table S1-1). This indicates that calibrating the image frame with reference to the orthophotos minimizes the estimation performance. In contrast, although the same dataset was used, the route mean square error (RMSE) of Method_main was 15.1% of the object length. This error may have been caused by miscalculations of altitude by the drone.

The RMSE of the underwater test using Method_orthophoto was 8.8% higher than that of the on-land test using the same method (Table S1-1). This error can be attributed to the altitude errors calculated by the drone and difficulty in determining the edge of the underwater object.

There was no notable difference in the estimation performance between the underwater tests using Method_orthophoto and Method_main methods.

The RMSE for Method_orthophoto did not increase with increasing water depth (Table S1-2). The minimal impact of water refraction was likely because the photographs were captured above this angle. However, for Method_main, the performance deteriorated at water depths of 40 to 50 cm. When the water depth was less than 30 cm, the RMSE is < 12 cm (less than 10% of the length of the object). This suggests that measurements should ideally be conducted when dugongs are near the water surface.

In conclusion, the performance of Method_orthophoto was superior to that of Method_main. However, a maximum error of 10% of the actual body length should be anticipated when measuring underwater objects near the water surface using both estimation methods.

Table S1-1. Accuracy of estimated length for a 1.2 m angle. RMSE (route mean square error) and ME (mean error) are provided for each measurement. A measurement was conducted for each angle and flight. When two angles were photographed in a single flight, two measurements were conducted. The percentage in the parentheses indicates the error as a proportion of the angle's length.

	Method	RMSE (m)	ME (m)	Number of measurements	Number of flights
On land	Method_main	0.18 (15.1%)	0.18 (14.9%)	9	9
Underwater	Method_main	0.13 (10.9%)	0.13 (10.9%)	33	30
On land	Method_orthophoto	0.01 (0.7%)	0.00 (-0.2%)	9	9
Underwater	Method_orthophoto	0.11 (9.5%)	-0.11 (-9.4%)	60	30

Table S1-2. Estimation performance for the underwater test for each water depth. RMSE (route mean square error) and ME (mean error) are provided for each measurement. A measurement was conducted for each angle and flight.

	Method_main			Method_orthophoto		
Depth (m)	RMSE (m)	ME (m)	Number of observations	RMSE (m)	ME (m)	Number of observations
0-0.1	0.06	0.06	2	0.11	-0.11	12
0.1-0.2			0	0.06	-0.12	3
0.2-0.3	0.12	0.12	12	0.12	-0.12	16
0.3-0.4	0.15	0.14	4	0.11	-0.11	7
0.4-0.5	0.27	0.12	5	0.11	-0.11	8
0.5-0.6	0.13	0.13	7	0.11	-0.11	7
0.6-0.7	0.11	0.16	3	0.11	-0.11	4
0.7-0.8			0	0.12	-0.12	3

Table S2. Body length of dugongs (*Dugong dugon*) estimated using two methods.

	Body length (m)	
ID	Method_main	Method_orthophoto
WB	2.45 (2.23-2.68; *n* = 14)	2.28 (2.26-2.33; *n* = 3)
N	2.60 (2.50-2.79; *n* = 6)	2.43 (*n* = 1)
WBS	2.85 (2.70-2.88; *n* = 3)	2.50 (*n* = 1)
WF	2.19 (*n* = 1)	2.34 (*n* = 1)

Table S3. Resighting record of individuals at Site B. The checkmarks indicate the presence of dugongs, while the hyphens indicate their absence.

Month	Date	ID																																																	
		HC	OJ	PC	PC1	PC2	MT	HJ	7_3	7_4	TEN	DR	HRS	SF	TPC	FP	BB	NK	RE	SC	WP	WT	TT	JN	TP	LS	JWB	NAD	SFR	PP	MM	WBI	SL	SHL	MF	RSF	VNK	DOT	DNT	SWB	Y	KHC	DDT	WWB	F	AM	DC	KST	TS	DL	DM	MH	RWB
Oct	5	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	6	✓	-	-	-	-	-	-	-	-	-	✓	✓	✓	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	7	✓	✓	-	-	-	-	-	-	-	-	✓	✓	✓	-	-	✓	✓	✓	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	8	-	-	-	-	-	-	-	-	-	-	✓	✓	-	-	-	-	-	-	-	-	✓	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	✓	-	-	-	-	-	-	✓	✓	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nov	21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	✓	✓	-	-	-	-	-	-	-	✓	✓	✓	✓	✓	✓	-	-	-	-	-	-	-	-	-	-
	29	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	✓	✓	✓	-	-	-	-	-	-	-
Dec	5	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	✓	✓	✓	✓	✓	-
	8	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	✓	✓	-	-	-	-	-	✓