10.1071/MF21217
Marine and Freshwater Research

Supplementary Material

Response of turtle hatchlings to light emitting diodes at sea

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Details on receiver deployment and testing

Hatchling movement was monitored through the nearshore on the night of 20 and 21 February 2017 using passive acoustic telemetry in waters adjacent to Thevenard Island (Fig. 1). An array of 36 (9 × 4 design) omnidirectional acoustic receivers (Vemco VR2W) was deployed underwater in the nearshore zone on the north-western side of the island. Receivers were deployed at distances to ensure detection ranges overlapped. Each receiver had a co-located synchronising tag (Vemco V9, 180kHz) with a nominal code transmission delay of 400–500 s attached ~0.5 m above it and 0.5 m below the water surface to synchronize the internal clocks of the receivers. Receiver spacing and VPS testing was conducted at this site the previous year (Wilson *et al*. 2018) so it was not repeated, however a time sync test was conducted to ensure time synchronisation between receivers. This involved deploying all 36 receivers (spaced 30 m apart) for 24 h, and then retrieving four of them to check for detection rates of neighbouring sync tags. The detection rate for direct neighbouring sync tags (30 m away) was between 70 to 80% of transmissions which was considered adequate for the study, therefore the 30 m spacing was retained. These receivers were then redeployed back to their same locations. The final array design consisted of four parallel lines of 9 receivers, spaced 30 m apart, with the first line starting ~50 m from the shoreline. The receivers passively detected signals from the V5 tags that were attached to the hatchlings and were used to determine their *x*–*y* positions as they moved through the array based on the difference in arrival times of the same signal at different receivers. Each receiver was attached to a mooring line using cable ties and was held in position with a 150-mm subsurface float and a 3-kg weight. Data was stored in the receivers and downloaded after completion of the study, then analysed by Vemco to determine animal positions.

Table S1. The lumen output of the LED floodlights (manufacturer specifications) that were used in this experiment.

Light wattage (W)	Lumen output (Lm)	Lumens/watt	Product code
10	794	79.4	VBLFL-832–4-40
30	2702	83.65	VBLFL-734–4-40
50	5922	112	VBLFL-736–4-40
70	7362	102	VBLFL-738–4-40
120	12763	106	VBLFL-744–4-40

All lights were manufactured in Australia by Vibe Lighting and had a correlated colour temperature of 4000 K (K) which equates to a cool white light.

Table S2. Timing of the experiments and order of the treatments over the two consecutive nights, mean (± s.d.) straight carapace length (SCL), straight carapace width (SCW) and weight of hatchlings tracked in each light treatment (0, 10, 30, 50, 70, 120 W), as well as collection times and dates.

Light location	Treatment	Start	End	Number tagged	SCL (mm)	SCW (mm)	Weight (g)	Collected	Number of nests
East 20–02–2017	70 W	2030	2040	6	58.2 ± 3.9	49.8 ± 0.8	32.9 ± 0.7	18-02-2017 21:00	A
	10 W	2105	2115	6	59.7 ± 1.4	49.6 ± 0.8	32.9 ± 1.1	18-02-2017 21:00	A
	30 W	2140	2150	6	60.0 ± 1.6	49.2 ± 2.0	33.6 ± 1.2	18-02-2017 21:00	A
	120 W	2215	2225	6	59.8 ± 0.9	49.1 ± 1.4	33.8 ± 1.0	18-02-2017 21:00	A
	Ambient	2250	2300	6	60.7 ± 1.2	49.2 ± 0.6	33.6 ± 0.6	18-02-2017 21:00	A
	50 W	2325	2355	6	59.9 ± 1.1	48.5 ± 1.6	33.2 ± 1.2	18-02-2017 21:00	A
	Overall			**36**	**59.7 ± 2.0**	**49.2 ± 1.3**	**33.3 ± 1.0**	**18-02-2017 21:00**	**1**
West 21–02–2017	30 W	2200	2210	5	61.1 ± 1.8	48.2 ± 1.6	37.4 ± 1.2	19-02-2017 23:00 & 20-02-2017 20:00	B, E, F
	Ambient	2235	2245	5	62.4 ± 1.0	48.4 ± 0.9	39.2 ± 0.8	19-02-2017 23:00 & 20-02-2017 20:00	B, E, F
	70 W	2310	2320	5	61.6 ± 1.0	47.0 ± 1.8	38.1 ± 1.2	20-02-2017 20:00	C, E, F
	50 W	2345	2355	6	61.9 ± 2.1	47.9 ± 1.6	38.6 ± 1.9	20-02-2017 20:00	C, E, F
	10 W	0020	0030	6	62.3 ± 1.1	47.3 ± 1.4	38.9 ± 0.6	20-02-2017 20:00	C, E, F
	120 W	0055	0105	5	62.0 ± 2.2	47.4 ± 2.9	38.9 ± 1.5	20-02-2017 20:00	D, E, G
	Overall			**32**	**61.9 ± 1.5**	**47.7 ± 1.7**	**38.5 ± 1.3**	**19-02-2017 23:00 & 20-02-2017 20:00**	**6**
	Total			**68**	**60.7 ± 2.1**	**48.5 ± 1.7**	**35.8 ± 2.9**	**18-02-2017 to 20-02-2017**	**7**

Note this is for all 68 turtles. All experiments occurred during last quarter moon after moon set when current speeds were low and flowing towards the east.

Table S3. A list of tags (*n* = 15) for which a predation event occurred, their light treatment (intensity), light location (east or west of the release point, conducted over 1 night for each), the category they were assigned to, where in the array the predation event likely occurred and the analysis that they were included in.

Tag	Intensity	Light location	Category	Where predation event occurred	Analysis		
					Speed /bearing	Time spent	Pred. rate
44031	0	West	Detached	Release (within 30 m)	N	N	Y
44036	30	West	Detached	~50 m from release	Y	N	Y
44039	50	West	Detached	Release (within 30 m)	N	N	Y
44087	120	West	Detached	Release (within 30 m)	N	N	Y
44058	120	East	Detached	Release (within 30 m)	N	N	Y
44059	10	East	Detached	~90 m from release	Y	N	Y
44061	120	East	Detached	~70 m from release	Y	N	Y
44066	30	East	Detached	Release (within 30 m)	N	N	Y
44067	30	East	Detached	~70 m from release	Y	N	Y
44069	10	East	Detached	Release (within 30 m)	N	N	Y
44072	10	East	Detached	Release (within 30 m)	N	N	Y
44076	70	East	Detached	~100 m from release (near light)	Y	N	Y
44033	70	West	Ingested	Unsure	N	N	Y
44054	120	East	Ingested	Unsure	N	N	Y
44064	30	East	Ingested	~120 m from release	Y	N	Y
44079	120	West	NA	Unsure if hatchling or predator	N	N	N

Also listed is one tag that displayed very slow movement through the array, so it was unclear if it was a predator or a hatchling. The 51 tags assigned as 'dispersed' have not been included in this table as they were included in all analyses.

Table S4. Model output table (up to 2 ΔAIC_c) ranked by Akaike's Information Criteria for small sample sizes (AICc) and Bayesian Information Criteria (BIC) for generalised additive mixed models fitted to test the relationship between response variables mean speed and time spent in the array and predictor variables, light intensity, wave steepness, current speed, wind speed, wind direction and wave period for each night (lights to the east and lights to the west).

Response	Model	AICc	BIC	ΔAICc	ΔBIC	ωAICc	ωBIC	Dev. Exp.
Mean speed	**Null**	**–85.83**	**–83.47**	**0**	**0**	**0.191**	**0.323**	**0**
(Light east)	Current speed	–85.76	–82.13	0.067	1.341	0.185	0.165	0.115
	Intensity	–84.14	–80.58	1.686	2.885	0.082	0.076	0.006
	Wave steepness	–83.72	–80.44	2.104	3.026	0.067	0.071	0.012
Mean speed	Intensity	–64.05	–60.76	0	0.944	0.247	0.192	0.181
(Light west)	**Null**	**–63.795**	**–61.70**	**0.258**	**0**	**0.217**	**0.307**	**0**
	Wave period	–63.23	–60.39	0.818	1.312	0.164	0.159	0.071
	Wave steepness	–62.86	–60.01	1.195	1.689	0.136	0.132	0.058
	Current speed	–62.01	–59.17	2.038	2.532	0.089	0.087	0.028
Time spent	**Null**	**150.46**	**152.35**	**0**	**0**	**0.673**	**0.769**	**0**
(Light east)	Intensity	154.55	157.43	3.741	4.094	0.087	0.061	0.02
Time spent	**Null**	**137.80**	**139.80**	**0**	**0**	**0.64**	**0.759**	**0**
(Light west)	Wave period	140.91	144.04	3.112	4.246	0.135	0.091	0.107

Also shown are the change in AICc and BIC from the top ranked model (ΔAIC_c and ΔBIC), the weight of evidence for each model (ωAICc and ωBIC) and the proportion of deviance explained (Dev. Exp). The top ranked model is in bold.

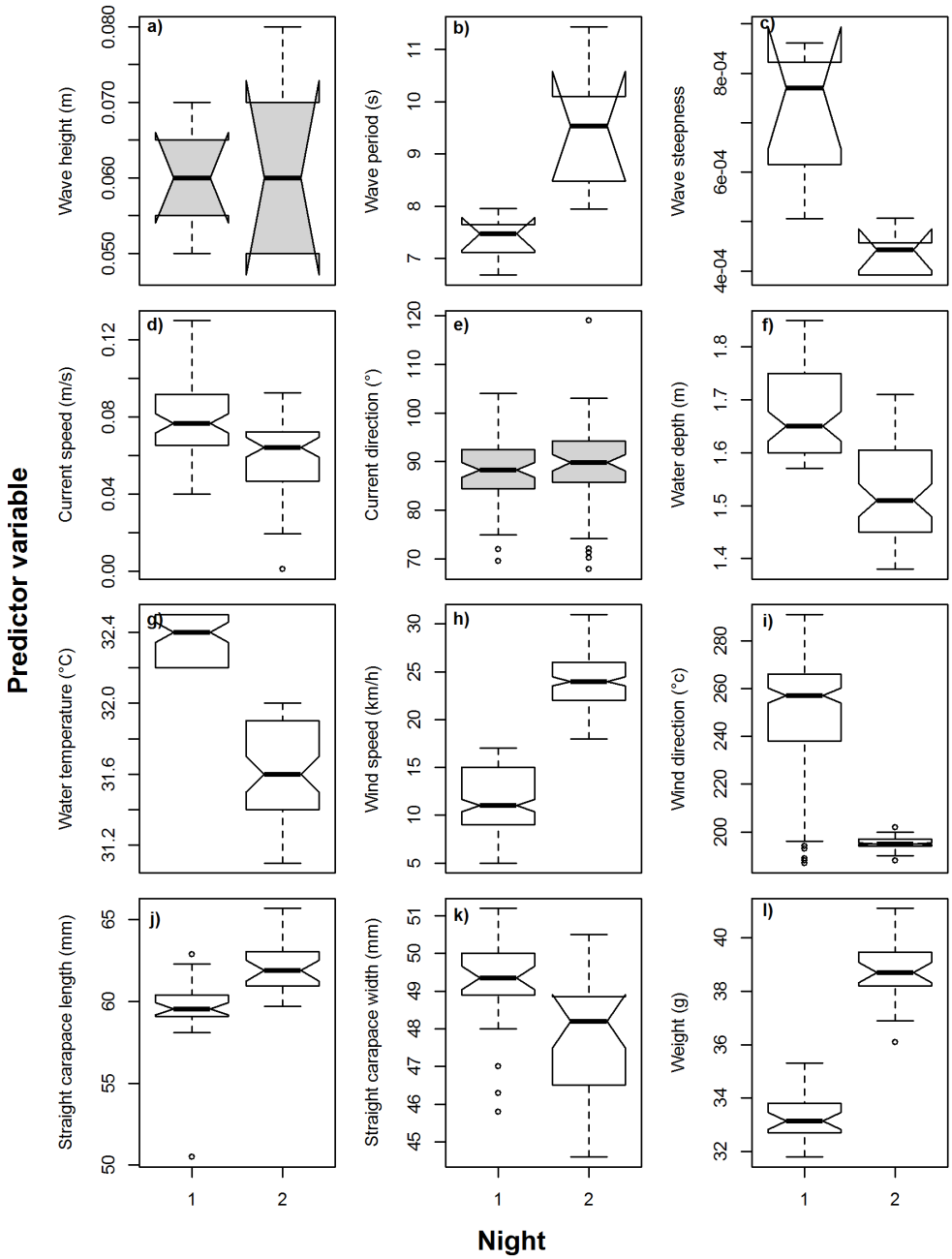

Figure S1. Boxplots of the data showing median values (solid black line within each box), the upper and lower hinges and the extreme of the upper and lower whiskers of physical parameters (a: wave height, b: wave period, c: wave steepness, d: current speed, e: current direction, f: water depth, g: water temperature) recorded by the Acoustic Doppler Current Profiler in the study area and wind data (h: wind speed, i: wind direction) recorded at Onslow airport (obtained from the Bureau of Meteorology) during the experiment each night (lights to the east on Night 1 and to the west on Night 2). Also shown is difference in hatchling size per night (j: straight carapace length, k: straight carapace width, l: weight). Data points beyond the whiskers are shown as open circles and are outliers. The model with night had majority support over the null model (providing support for a difference between nights) for all predictors except wave height and current direction (shaded in grey).

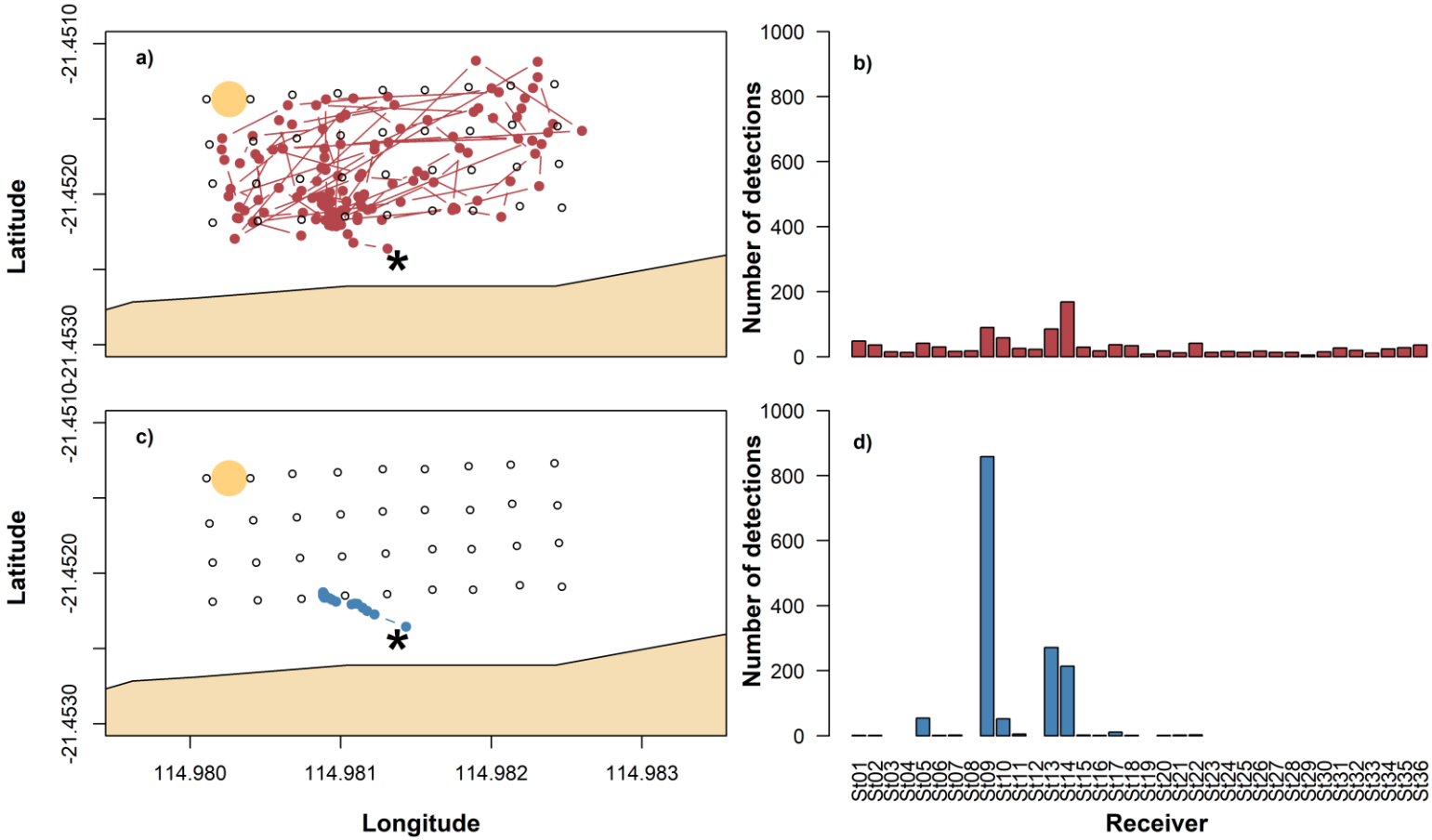

Figure S2. Representative examples of calculated positions (left panels) and the number of acoustic detections on each receiver (right panels) from one individual assigned to each category; 'ingested' (a) and b), tag 44033 from the 70-W treatment ingested by a predator) and 'detached' (c) and d), tag 44036 from the 30-W treatment knocked off likely during a predator attack). Left panels show the calculated positions (filled circles), and right panels show the number of detections on each receiver (Stations 1–36) of the same individual, detected for 25.7 h (a) and b), 'ingested') and 31.1 h (c) and d), 'detached). The hatchling release point, acoustic receivers and the light location are shown by the asterisk, open circles and orange circle respectively in a) and c) and the beach is shown in beige.

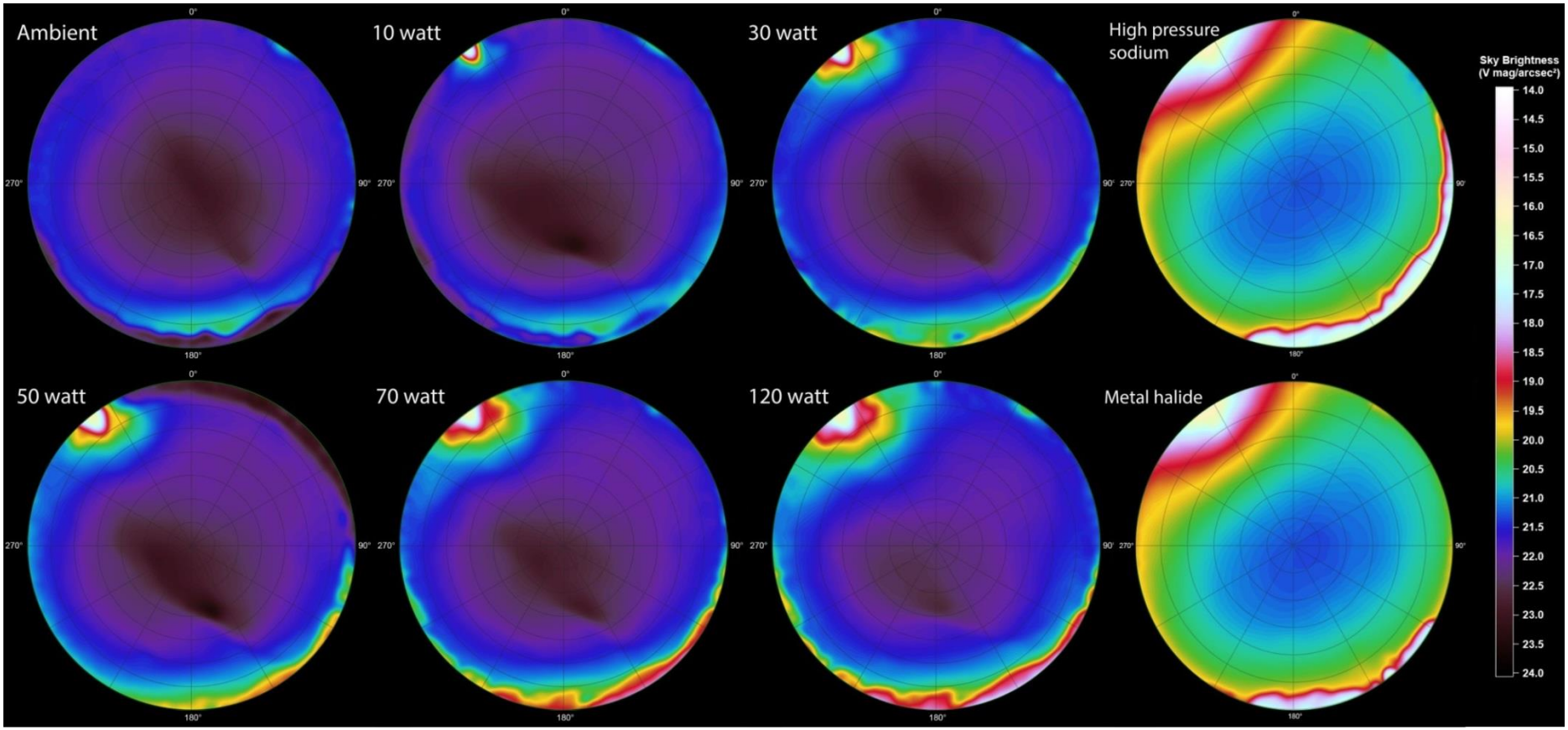

Figure S3. Isophote images of sky brightness measured in magnitude per arc second^2 (the larger the value, the darker the night sky) assessed from night sky photos taken in ambient and each light emitting diode (LED) treatment (10, 30, 50, 70 and 120 W) during the experiment when the light was located to the west of the hatchling release point and from a 400-W high-pressure sodium and metal halide light source (for comparison) located in the same direction offshore obtained from previous experiments (Wilson *et al*. 2018). The lights were located at an angle of ~320° from the camera, which was deployed on the beach close to the hatchling release point. There was an increase in horizon brightness between angles 90–210° during the light treatments (30–120 W) due to the light from the vessel reflecting off shoreline sand dunes.

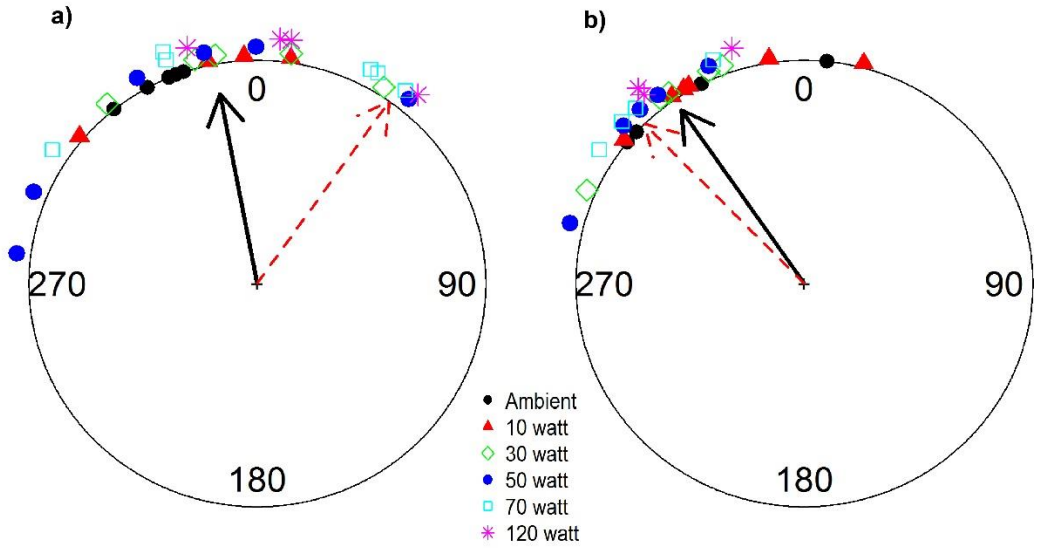

Figure S4. Raw data plots of hatchling mean circular bearing a) when the light was located to the east of the hatchling release point and b) when the light was located to the west of the hatchling release point. The red dashed arrow is the bearing to the light source from the hatchling release point (Light east on night 1: 35.3°, Light west on night 2: -44.4° relative to 0°) and the black arrow is the mean bearing of all hatchlings (treatments combined).

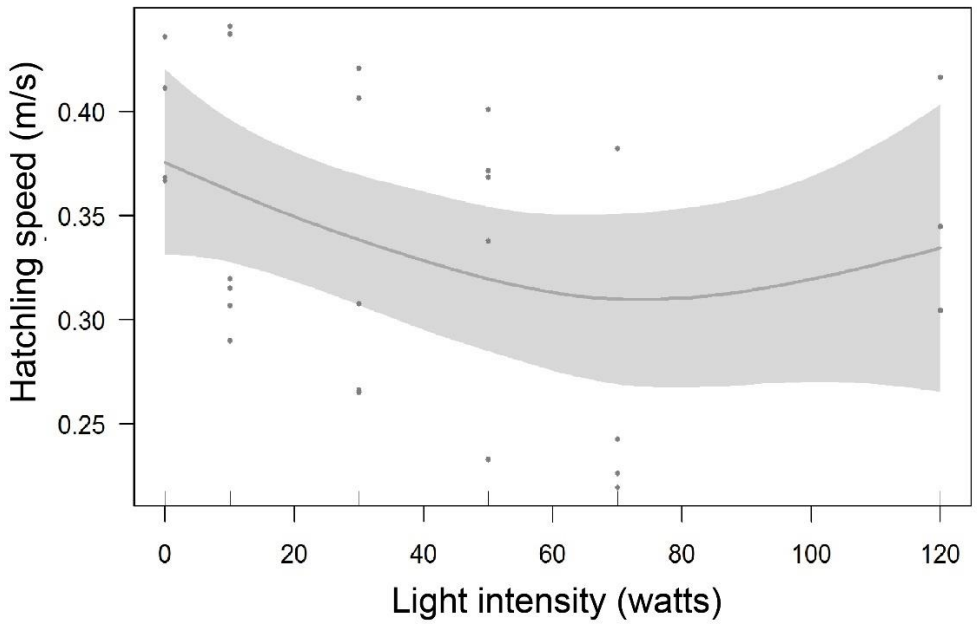

Figure S5. The predicted relationship between mean speed and light intesity when lights were positioned to the west of the hatchling release point for models ranked by Akaike's Information Criteria for small sample sizes (AICc), up to 2 ΔAIC_c but the null model was the most parsimonious (within two AICc points of the top ranked model).

Reference

Wilson, P., Thums, M., Pattiaratchi, C., Meekan, M. G., Pendoley, K., Fisher, R., and Whiting, S. (2018). Artificial light disrupts the nearshore dispersal of neonate flatback turtles (*Natator depressus*). *Marine Ecology Progress Series* **600**, 179–192. doi:10.3354/meps12649