The following supplements accompany the article

Movement patterns of two carangid species in inshore habitats characterised using network analysis

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Supplement 1

Detailed description of the method used to analyse the effects of fish size and environmental factors on year-season and year-month average path length (APL), network density, network diameter and network cluster using linear mixed effects models. The following sections describe the procedures used to run the analyses.

Data exploration

Prior to analyses, data distribution, outliers, normality and homogeneity of variance were tested using boxplot, histogram and QQ-Plot (Zuur et al. 2010). *Gnathanodon speciosus* seasonal network diameter, monthly network diameter and network density, and *C. ignobilis* seasonal network density were transformed to normality using logarithmic transformation. *Caranx ignobilis* seasonal network diameter and network cluster, and monthly network diameter were transformed to normality using a square root transformation. Collinearity between biological (i.e. fish size) and environmental factors was assessed using variance inflation factors (VIF; R package '*car*'; Fox & Weisberg 2011). If a factor had a VIF value > 3 it would indicate collinearity with other factors so the factor was dropped from the analysis. Barometric pressure was not included in any of the year-season and year-month global models based on VIF values due to collinearity with water temperature. Rainfall accumulation, freshwater flow and light intensity were not included in any of the year-season global models based on VIF values due to collinearity with each other and water temperature. Light intensity was not included in the *G. speciosus* monthly APL global models based on VIF values due to collinearity with rainfall accumulation. Moon illumination was not included in the LMM monthly analysis as it was not informative at a monthly scale. Fixed factors that were included based on VIF values are noted for each network metrics and species in Table S1. Finally, fixed factors and interactions were examined using the residualPlots function (R package '*car*'; Fox & Weisberg 2011); interactions were only considered if the Tukey test (an output of the residualPlots function) was significant ($P < 0.05$; Zar 1999). Tukey's tests indicated no significant interactions, as such they were not considered in models.

Table S1: Variables used in the linear mixed effect model analyses of *Caranx ignobilis* (a) and *Gnathanodon speciosus* (b) seasonal and monthly networks. "FL" is fork length, "AW" is alongshore wind, "CW" is cross-shore wind, "WT" is water temperature, "WF" is water flow, and "L" is light intensity.

	Mixed effect model variable	
	Seasonal network	Monthly network
(a) *Caranx ignobilis*		
APL	FL+AW+CW+WT	FL+WF+AW+CW+L+WT
Network diameter	FL+AW+CW+WT	FL+WF+AW+CW+L+WT
Network density	FL+AW+CW+WT	FL+WF+AW+CW+L+WT
Network cluster	FL+AW+CW+WT	FL+WF+AW+CW+L+WT
(b) *Gnathanodon speciosus*		
APL	FL+AW+CW+M+WT	FL+RA+AW+CW+WT
Network diameter	FL+AW+CW+M+WT	FL+RA+AW+CW+L+WT
Network density	FL+AW+CW+M+WT	FL+RA+AW+CW+L+WT
Network cluster	FL+AW+CW+M+WT	FL+RA+AW+CW+L+WT

Statistical Models

First fixed factors were centred to simplify interpretation and facilitate comparison of their importance (Schielzeth, 2010). A variable (ID_YR) combining individual tag and year was included as a random factor to enable population-level prediction, account for the repeated-measures nature of the data and for unequal numbers of detections used to construct individual networks across years (Bolker et al. 2009). Linear models were implemented using the "lme" function from the 'nmle' package (Pinheiro et al. 2014) in the R statistical environment (R Development Core Team 2014). For each network metric (i.e. APL, network diameter, network density and network cluster), global models were fitted with different weight functions to account for heterogeneity of variance. The corrected Akaike information criterion (AICc) was calculated for each model. The models with the lowest AICc values, indicating greater support for the model, were selected (Burnham & Anderson 2004). Diagnostics plots (i.e. residuals plot and auto-correlation function plot) evaluated goodness of fit (Burnham & Anderson 2002, Zuur et al. 2010). If auto-correlation was present, global models were fitted with different correlation functions to account for temporal autocorrelation and heteroscedasticity. The corrected Akaike's information criterion was recalculated and final models with the lowest AIC_c values were selected for the analyses. The best model (lowest AIC_c) for all *C. ignobilis* year-season and year-month metrics, and *G. speciosus* year-season APL and network diameter and year-month network diameter and network density did not include weight functions. Then, for *G. speciosus* year-season network cluster and network density and year-month APL and network cluster global models, homogeneity of variance was accounted for using a constant variance structure (varIdent) weighting function. Auto-correlation was found for all year-season and year-month metrics so the global models were fitted with different correlation functions; the best fitted models (lowest AIC_c) included no correlation structure for *C. ignobilis* year-season APL, network density and network cluster and year-month APL and network cluster, and *G. speciosus* year-season APL and network diameter and year-month network diameter and network density. Then, for *G. speciosus* year-season network cluster and network density and year-month network cluster and *C. ignobilis* year-month network diameter and network density global models, auto-correlation was accounted for using a linear spatial correlation structure (corLin) whereas for *C. ignobilis* yearly-season network diameter and *G. speciosus* yearly-month APL, the best fitted models (lowest AIC_c) included a compound symmetry correlation structure (corCompSymm).

Multi-model inference and model-averaging

Multi-model inference was used to improve estimation of the effects of fish size and environmental factors on *C. ignobilis* and *G. speciosus* APL, network density, network diameter and network cluster. First, a set of nested models with different combinations of the fixed variables were derived from the global models (Johnson & Omland 2004, Bolker et al. 2009) using the dredge function from the *"MuMIn"* package (Barton 2014). Using an information theoretic approach, nested models were ranked using AIC_c. Second, model averaging based on Akaike weight was applied to well-fitting nested models ($\Delta AIC < 2$). Best nested models were compared against the null model: y ~ 1 + (1 | ID_YR), where y is the response and ID_YR the random factor, and significant differences were evaluated with maximum likelihood ratio tests (χ^2, $p < 0.05$). Fixed variable estimates were calculated using the model.avg function from the *"MuMIn"* package (Barton 2014) to determine their relative importance and account for model selection uncertainty (Johnson & Omland 2004, Grueber et al. 2011). Finally, the full model-averaged coefficients (i.e. shrinkage estimates) were used to account for nested model selection bias (Burnham & Anderson 2002).

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Supplement 2

Table S2: Tagging data for *Caranx ignobilis* and *Gnathanodon speciosus* passively monitored in Cleveland Bay from 2011 to 2014.

Tag	Species	Year	FL (cm)	Bay region	Detection number	Days detected	Days at liberty	Residency index	Receiver number	Path	Movement	Network diameter	Network cluster	Average path length	Network density
63584	*C. ignobilis*	2013	36	W	3376	62	69	0.9	4	3	9	0.004	0.00	2.08	0.42
63585	*C. ignobilis*	2013	37	W	4015	87	92	0.95	7	12	103	0.009	0.63	1.57	0.45
63586	*C. ignobilis*	2013	39	W	15170	276	371	0.74	9	13	203	0.003	0.38	1.75	0.36
63587	*C. ignobilis*	2013	48	W	3264	73	75	0.97	7	12	262	0.004	0.67	2.38	0.45
63589	*C. ignobilis*	2013	37	W	12782	303	369	0.82	9	20	264	0.005	0.74	1.58	0.49
63597	*C. ignobilis*	2014	34	E	1084	134	234	0.57	6	9	69	0.041	0.50	1.63	0.43
63600	*C. ignobilis*	2014	38	E	444	73	188	0.39	5	6	44	0.035	0.55	1.40	0.60
63601	*C. ignobilis*	2014	34	E	164	30	160	0.19	5	5	16	0.167	0.43	1.80	0.40
63602	*C. ignobilis*	2014	35	E	448	60	186	0.32	6	12	36	0.045	0.73	1.57	0.50
63603	*C. ignobilis*	2014	33	E	442	50	186	0.27	8	10	30	0.054	0.41	2.13	0.29
53016	*G. speciosus*	2011	53	W	38915	363	421	0.86	12	35	1912	0.001	0.68	1.74	0.43
53017	*G. speciosus*	2011	59	W	15806	264	411	0.64	12	30	642	0.002	0.69	1.87	0.41
53020	*G. speciosus*	2011	36	W	20427	192	196	0.98	11	24	1004	0.001	0.58	1.88	0.34
53023	*G. speciosus*	2011	80	W	10974	394	421	0.94	26	93	1856	0.002	0.64	2.40	0.23
53024	*G. speciosus*	2011	61	W	4985	300	420	0.71	11	27	693	0.005	0.78	2.02	0.41
63581	*G. speciosus*	2013	56	W	569	98	290	0.34	8	21	128	0.018	0.81	1.41	0.59
63583	*G. speciosus*	2013	49	W	797	80	147	0.54	17	36	135	0.030	0.43	2.47	0.19
63592	*G. speciosus*	2013	59	W	4017	136	138	0.99	10	26	197	0.005	0.68	1.64	0.43
63593	*G. speciosus*	2013	56	W	2783	176	295	0.6	11	35	227	0.009	0.76	1.58	0.52

Information includes year of deployment (year), fork length (FL), western (W) and eastern (E) sides of Cleveland Bay where individual was captured; number of days present and absent in the study area, residency index, number of receivers it was detected on, and number of path and relative movement per individual.

Table S3: Top nested mixed effect models from the model selection analysis examining the effect of fish size and environmental factors on *Caranx ignobilis* seasonal networks. All nested models included a random effect for individual fish and parameters were standardized. Only most relevant nested mixed effect models (Δ AIC_c < 2 – Akaike difference) are shown. W is Akaike weight. Asterisks indicate models that differed from null model ($p < 0.05$). "FL" is fork length, "AW" is alongshore wind, "CW" is cross-shore wind, and "WT" is water temperature.

Nested model	Formula	df	AIC_c	Weight
(a) Average Path Length (APL)				
M1	APL ~ FL	4	2.19*	0.30
M2	APL ~ FL+CW	5	3.70*	0.14
(b) Network density (Den)				
M1	log(Den) ~ FL	4	15.26*	0.25
M2	log(Den) ~ FL+AW	5	16.28	0.15
M3	log(Den) ~ FL+CW	5	16.76*	0.12
(c) Network diameter (Dia)				
M1	sqrt(Dia) ~ 1	4	-12.77	0.42
(d) Network cluster (Clus)				
M1	sqrt(Clus) ~ 1	3	30.39	0.18
M2	sqrt(Clus) ~ WT	4	30.76	0.15
M3	sqrt(Clus) ~ AW	4	30.96	0.14
M4	sqrt(Clus) ~ FL	4	31.76	0.09

AIC_c is the small-sample bias-corrected form of Akaike's information criterion. Network density was transformed to normality using logarithmic (log) transformation. Network diameter and network cluster were transformed to normality using square root (sqrt) transformation.

Table S4: Environmental and fish size effects on *Caranx ignobilis* seasonal network metrics from model-averaging analysis. Environmental parameters were standardised for comparison. Asterisks indicate significant effect ($p < 0.05$) on seasonal network metrics of *Caranx ignobilis* in Cleveland Bay.

	Estimate ±SE	z value	p-value	Relative importance
(a) Average path length				
(Intercept)	0.000 ±0.000	NA	NA	-
Fork length	-0.326 ±0.260	1.257	0.209	0.75
Cross-shore wind	-0.063 ±0.139	0.450	0.653	0.32
Water temperature	-0.046 ±0.121	0.378	0.705	0.28
Alongshore wind	-0.002 ±0.100	0.025	0.980	0.20
(b) Network density				
(Intercept)	0.000 ±0.000	NA	NA	-
Fork length	0.321 ±0.254	1.261	0.207	0.75
Water temperature	0.114 ±0.180	0.634	0.526	0.44
Cross-shore wind	0.072 ±0.150	0.480	0.631	0.34
Alongshore wind	0.004 ±0.113	0.039	0.969	0.21
(c) Network diameter				
(Intercept)	0.000 ±0.000	NA	NA	-
Water temperature	-0.019 ±0.105	0.183	0.854	0.20
Alongshore wind	0.012 ±0.097	0.120	0.904	0.19
Fork length	-0.008 ±0.092	0.085	0.933	0.18
Cross-shore wind	0.007 ±0.097	0.075	0.940	0.18
(d) Network cluster				
(Intercept)	0.000 ±0.000	NA	NA	-
Water temperature	0.098 ±0.176	0.556	0.578	0.39
Alongshore wind	-0.078 ±0.162	0.481	0.631	0.35
Fork length	0.053 ±0.137	0.384	0.701	0.29
Cross-shore wind	0.029 ±0.121	0.238	0.812	0.24

Table S5: Bay region effects on *Caranx ignobilis* seasonal (a) and monthly (b) average path length (APL), network density (Den), network diameter (Dia) and network cluster (Clus) in Cleveland Bay. Asterisks indicate significant effect ($p < 0.05$) via Wald Z test using Chi-squared test against Null model.

Model	χ^2	**df**	**p-value**
(a) Seasonal			
APL ~ Bay region	1.50	1	0.22
log(Den) ~ Bay region	1.61	1	0.20
sqrt(Dia) ~ Bay region	0.03	1	0.86
sqrt(Clus) ~ Bay region	1.27	1	0.26
(b) Monthly			
APL ~ Bay region	0.34	1	0.56
Network density ~ Bay region	0.50	1	0.48
sqrt(Dia) ~ Bay region	3.78	1	0.05
Network cluster ~ Bay region	0.08	1	0.78

Table S6: Top nested mixed effect models from the model selection analysis examining the effect of fish size and environmental factors on *Gnathanodon speciosus* seasonal networks. All nested models included a random effect for individual fish and parameters were standardized. Only most relevant nested mixed effect models (Δ $AIC_c < 2$ – Akaike difference) are shown. W is Akaike weight. Asterisks indicate models that differed from null model ($p < 0.05$). "FL" is fork length, "AW" is alongshore wind, "M" is moon illumination, "CW" is cross-shore wind, and "WT" is water temperature.

Nested model	Formula	df	AIC_c	Weight
(a) Average Path Length (APL)				
M1	APL ~ FL+CW	5	9.45*	0.13
M2	APL ~ FL+CW+WT	6	9.53*	0.12
M3	APL ~ FL+M+CW+WT	7	9.83*	0.11
M4	APL ~ FL+M+WT	6	10.37*	0.08
M5	APL ~ FL	4	10.67*	0.07
M6	APL ~ FL+WT	5	10.77*	0.07
M7	APL ~ FL+M+AW+WT	7	11.09*	0.06
M8	APL ~ FL+AW	5	11.25*	0.05
M9	APL ~ FL+CW+AW	6	11.39*	0.05
(b) Network density (Den)				
M1	Den ~ M+AW	9	-37.23*	0.38
M2	Den ~ AW	8	-35.80*	0.18
(c) Network diameter (Dia)				
M1	log(Dia) ~ FL+M+CW	6	119.22*	0.17
M2	log(Dia) ~ FL+M+CW+AW	7	119.52*	0.15
M3	log(Dia) ~ FL+CW	5	119.86*	0.12
M4	log(Dia) ~ FL+M+CW+WT	7	120.34*	0.10
M5	log(Dia) ~ FL+M+CW+AW+WT	8	120.93*	0.07
(d) Network cluster (Clus)				
M1	Clus ~ M+CW+AW	10	-25.75*	0.32
M2	Clus ~ M+CW	9	-24.44*	0.17

AIC_c is the small-sample bias-corrected form of Akaike's information criterion.
Network diameter was transformed to normality using logarithmic (log) transformation

Table S7: Top nested mixed effect models from the model selection analysis examining the effect of fish size and environmental factors on *Caranx ignobilis* monthly networks. All nested models included a random effect for individual fish and parameters were standardized. Only most relevant nested mixed effect models (Δ AIC_c < 2 – Akaike difference) are shown. W is Akaike weight. Asterisks indicate models that differed from null model ($p < 0.05$). "FL" is fork length, "AW" is alongshore wind, "L" is light intensity, "CW" is cross-shore wind, "WF" is water flow and "WT" is water temperature.

Nested model	Formula	df	AIC_c	Weight
(a) Average Path Length (APL)				
M1	APL ~ CW	4	14.02	0.10
M2	APL ~ 1	3	14.68	0.08
M3	APL ~ L+CW	5	15.24	0.06
M4	APL ~ CW+WF	5	15.49	0.05
M5	APL ~ FL+CW	5	15.57	0.05
M6	APL ~ FL	4	15.81	0.04
M7	APL ~ WF	4	15.84	0.04
M8	APL ~ CW+AW	5	16.01	0.04
(b) Network density (Den)				
M1	Den ~ CW	5	-3.88*	0.09
M2	Den ~ CW+WF	6	-3.73*	0.09
M3	Den ~ L+CW	6	-3.58*	0.08
M4	Den ~ CW+WF+AW+WT	8	-3.38*	0.07
M5	Den ~ CW+WF+WT	7	-3.31*	0.07
M6	Den ~ CW+AW+WT	7	-2.86*	0.06
M7	Den ~ CW+WT	6	-2.47	0.05
M8	Den ~ CW+AW	6	-2.30	0.04
M9	Den ~ 1	4	-1.90	0.04
(c) Network diameter (Dia)				
M1	sqrt(Dia) ~ FL	5	-14.45	0.11
M2	sqrt(Dia) ~ FL+CW	6	-13.88	0.08
M3	sqrt(Dia) ~ 1	4	-13.60	0.07
M4	sqrt(Dia) ~ CW	5	-12.74	0.05
M5	sqrt(Dia) ~ FL+AW	6	-12.60	0.04
(d) Network cluster (Clus)				
M1	Clus ~ CW	4	52.66	0.09
M2	Clus ~ CW+WF	5	52.96	0.08
M3	Clus ~ L+CW	5	53.09	0.08
M4	Clus ~ 1	3	53.65	0.06
M5	Clus ~ WF	4	53.80	0.05
M6	Clus ~ L+CW+WF	6	54.15	0.04

AIC_c is the small-sample bias-corrected form of Akaike's information criterion. Network diameter was transformed to normality using square root (sqrt) transformation

Table S8: Environmental and fish size effects on *Caranx ignobilis* monthly network metrics from model-averaging analysis. Environmental parameters were standardised for comparison. Asterisks indicate significant effect ($p < 0.05$) on monthly network metrics of *Caranx ignobilis* in Cleveland Bay.

	Estimate ±SE	z value	p-value	Relative importance
(a) Average path length				
(Intercept)	0.000 ±0.000	NA	NA	-
Cross-shore wind	-0.189 ±0.209	0.903	0.367	0.61
Light intensity	0.047 ±0.144	0.326	0.744	0.29
Freshwater flow	-0.046 ±0.115	0.401	0.688	0.30
Fork length	-0.055 ±0.130	0.425	0.671	0.31
Alongshore wind	0.032 ±0.104	0.309	0.757	0.26
Water temperature	0.008 ±0.109	0.078	0.938	0.23
(b) Network density				
(Intercept)	0.000 ±0.000	NA	NA	-
Cross-shore wind	0.359 ±0.217	1.655	0.098	0.88
Freshwater flow	0.106 ±0.156	0.681	0.496	0.45
Light intensity	-0.058 ±0.152	0.380	0.704	0.26
Alongshore wind	-0.078 ±0.147	0.527	0.598	0.35
Water temperature	-0.127 ±0.210	0.605	0.545	0.45
Fork length	0.021 ±0.101	0.209	0.834	0.25
(c) Network diameter				
(Intercept)	0.000 ±0.000	NA	NA	-
Fork length	-0.180 ±0.199	0.907	0.365	0.61
Cross-shore wind	-0.082 ±0.151	0.547	0.584	0.38
Alongshore wind	-0.034 ±0.107	0.317	0.751	0.26
Freshwater flow	-0.036 ±0.105	0.345	0.730	0.27
Light intensity	-0.024 ±0.114	0.210	0.834	0.24
Water temperature	0.003 ±0.107	0.025	0.980	0.22
(d) Network cluster				
(Intercept)	0.000 ±0.000	NA	NA	-
Cross-shore wind	0.216 ±0.215	1.008	0.313	0.66
Freshwater flow	0.101 ±0.155	0.649	0.516	0.45
Light intensity	-0.066 ±0.161	0.410	0.682	0.33
Water temperature	-0.004 ±0.113	0.033	0.974	0.24
Alongshore wind	0.024 ±0.094	0.253	0.800	0.25
Fork length	0.020 ±0.096	0.210	0.834	0.23

Table S9: Top nested mixed effect models from the model selection analysis examining the effect of fish size and environmental factors on *Gnathanodon speciosus* monthly networks. All nested models included a random effect for individual fish and parameters were standardized. Only most relevant nested mixed effect models (Δ AIC_c < 2 – Akaike difference) are shown. W is Akaike weight. Asterisks indicate models that differed from null model ($p < 0.05$). "FL" is fork length, "AW" is alongshore wind, "L" is light intensity, "CW" is cross-shore wind, "RA" is rainfall and "WT" is water temperature.

Nested model	Formula	df	AIC_c	Weight
(a) Average Path Length (APL)				
M1	APL ~ AW+WT	8	24.80*	0.19
M2	APL ~ FL+AW+WT	9	25.47*	0.14
M3	APL ~ AW	7	25.81*	0.11
M4	APL ~ FL+AW	8	25.92*	0.11
(b) Network density (Den)				
M1	log(Den) ~ 1	3	22.72	0.10
M2	log(Den) ~ WT	4	23.34	0.07
M3	log(Den) ~ L	4	23.83	0.06
M4	log(Den) ~ AW+WT	5	24.23	0.05
M5	log(Den) ~ RA	4	24.47	0.04
(c) Network diameter (Dia)				
M1	log(Dia) ~ FL+L+RA	6	121.86*	0.24
M2	log(Dia) ~ FL+L+CW+WT	7	122.92*	0.14
M3	log(Dia) ~ FL+L+RA+AW	7	123.81*	0.09
(d) Network cluster (Clus)				
M1	Clus ~ L	6	-54.92*	0.11
M2	Clus ~ WT	6	-53.98*	0.07
M3	Clus ~ FL+L	7	-53.61*	0.06
M4	Clus ~ L+WT	7	-53.56*	0.06
M5	Clus ~ RA+WT	7	-53.27*	0.05

AIC_c is the small-sample bias-corrected form of Akaike's information criterion. Network density and network diameter were transformed to normality using logarithmic (log) transformation.

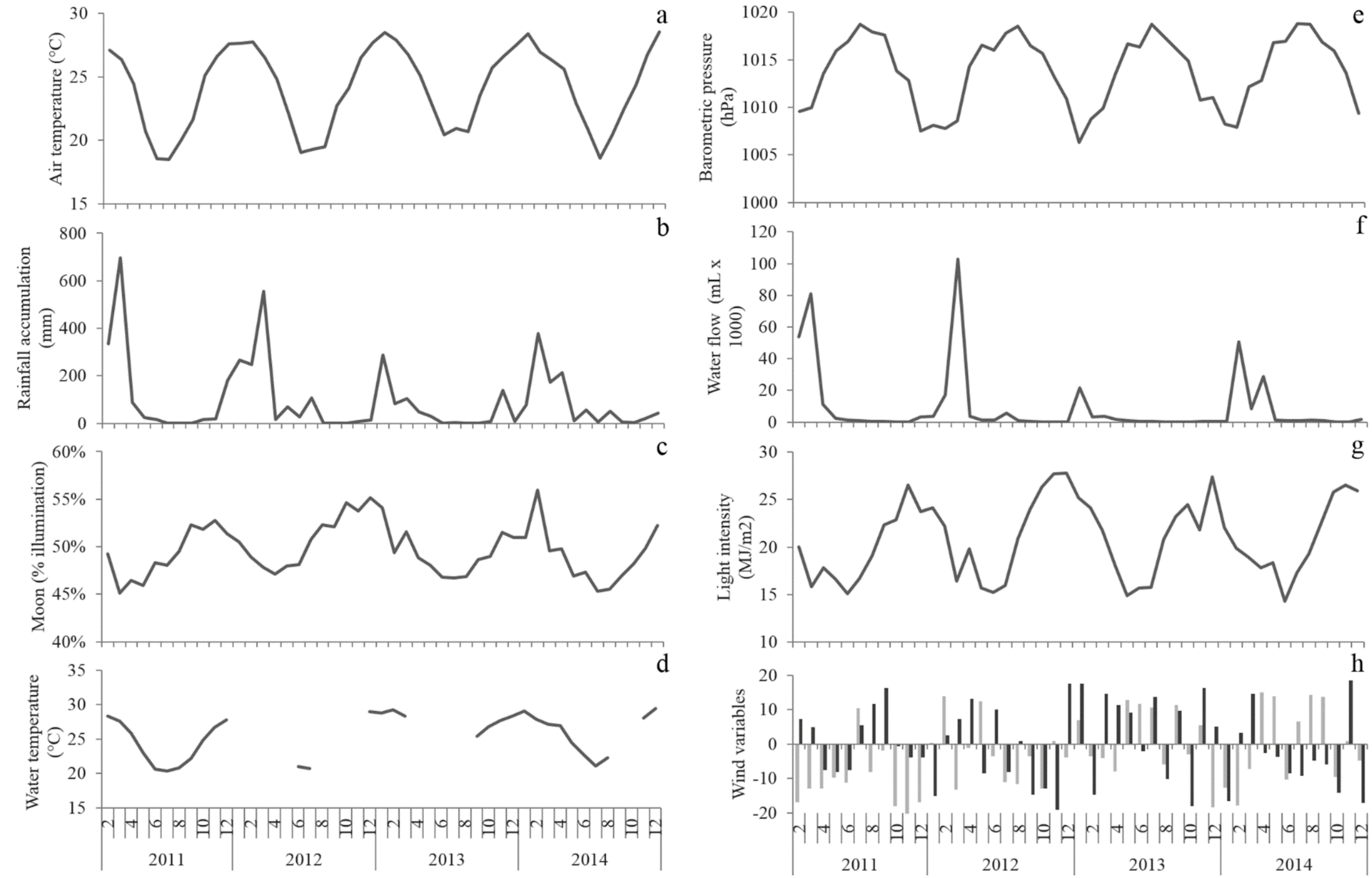

Figure S1: Monthly environmental values for Cleveland Bay, Australia: a) mean air temperature, b) mean rainfall, c) mean moon illumination, d) mean water temperature, e) mean barometric pressure, f) mean freshwater flow, g) mean light intensity and h) mean wind variables (Positive values represent winds from the east (dark grey) and north (light grey). Negative values represent winds from the west (dark grey) and south (light grey) - Begg et al. 2006). Source: generated from Bureau of Meteorology of Australia, Department of Natural Resources and Mines and United States Naval Observatory.