Additional file 1 for

Turning the tide: Understanding estuarine detection range variability via structural equation models

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Methodology specifics

Time-stamped transmissions. Since the transmission of a signal was time-stamped by the built-in tag of each receiver, we knew exactly how many transmissions were sent per tag per specific hourly bin. Using this value instead of the theoretical average of the random burst intervals to estimate the number of transmissions per hour is more accurate and avoids unrealistic detectability values of more than 100 % (given there is no over or under-counting of detections due to reflection (see further)). The shorter the chosen time bin interval and the longer the burst interval between transmissions, the more severe this inaccuracy is going to be.

Loess simulations for noise. The loess model used to predict noise values had a minimal span, meaning that it approximates a simple line drawn between two subsequent noise measurements and interpolates between those two for all time points in between. It might have been that passing boats caused an increasingly loud noise, however we did not detect any outliers in the noise measurements. Additionally, although a more complicated noise model that considers tidal frequencies could make sure that the effect of passing boats was accounted for, it would also mean that some tidal pattern in the noise measurements is implied and may as such bias the results. We tried to determine at which time boats would pass by using sluice data (i.e. knowing when the sluice would open and close for specific boats upstream), but we did lack the data to validate when boats passed making it very difficult to predict. We looked at different time intervals after boats left the sluice but could not find any patterns in the noise or any other measured environmental variable. A stationary camera determining when a certain boat passed might be a good addition to future range tests, especially if it could be used to validate a model that aims to predict boat passage based on sluice data. The time span in the data was so small (i.e. the minimal possible time span was selected) that interpolation was practically always happening between two (in time) neighboring data points without having any contributing effect of neighboring data points. This way any effect of an anomalous noise measurement would be constrained to only a few measurements. In addition, the temporal trend of noise showed a pronounced predictable tidal pattern without any outliers (1.5-IQR-rule). Hence, biases due to short spikes in noise were expected to be very limited.

Additional figures

Time series of environmental variables.

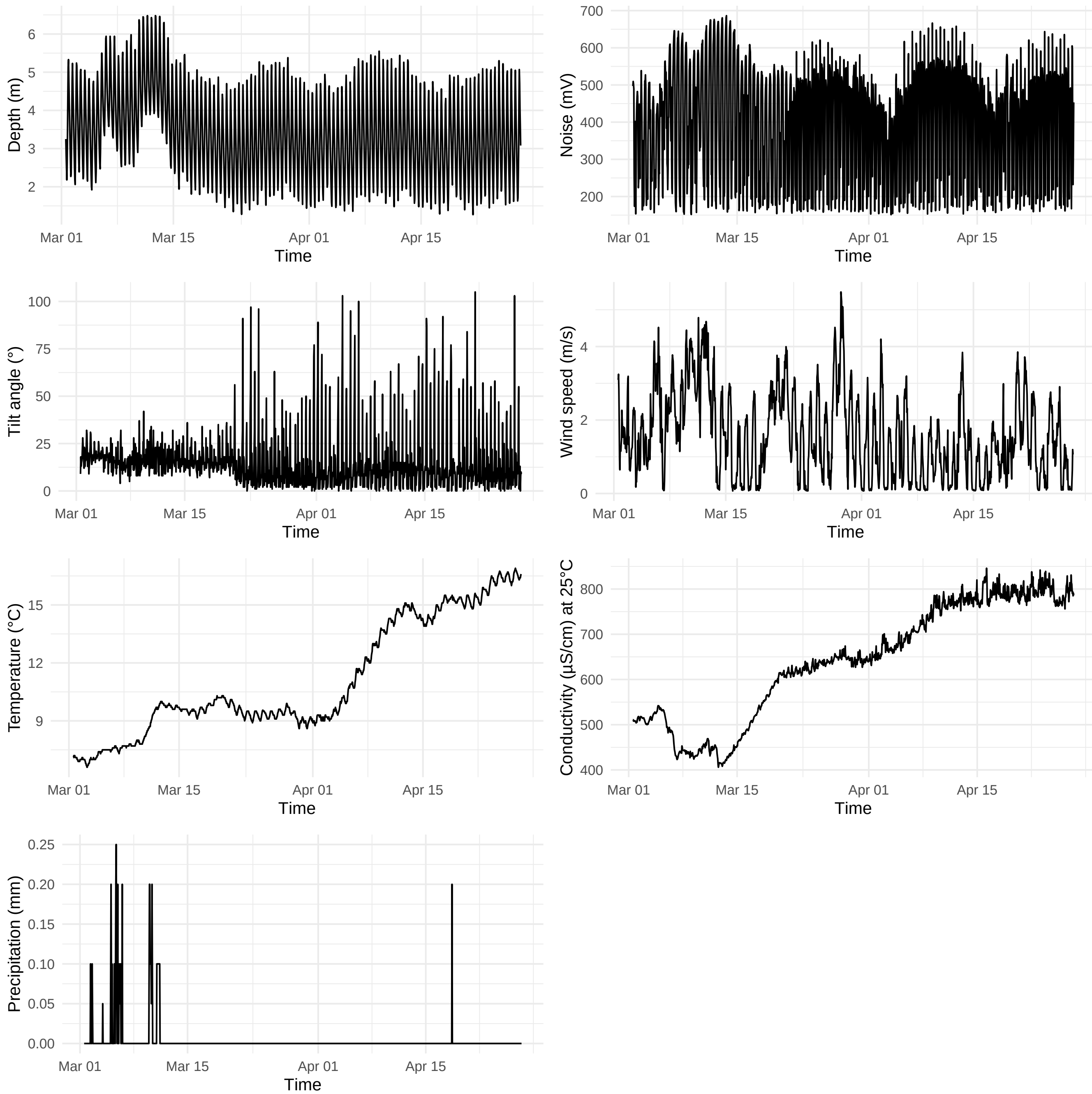

Fig. S1. Time series of the assessed explanatory variables during the study period. Time series are given for depth, noise, tilt angle of Rt1, wind speed, temperature, conductivity and precipitation

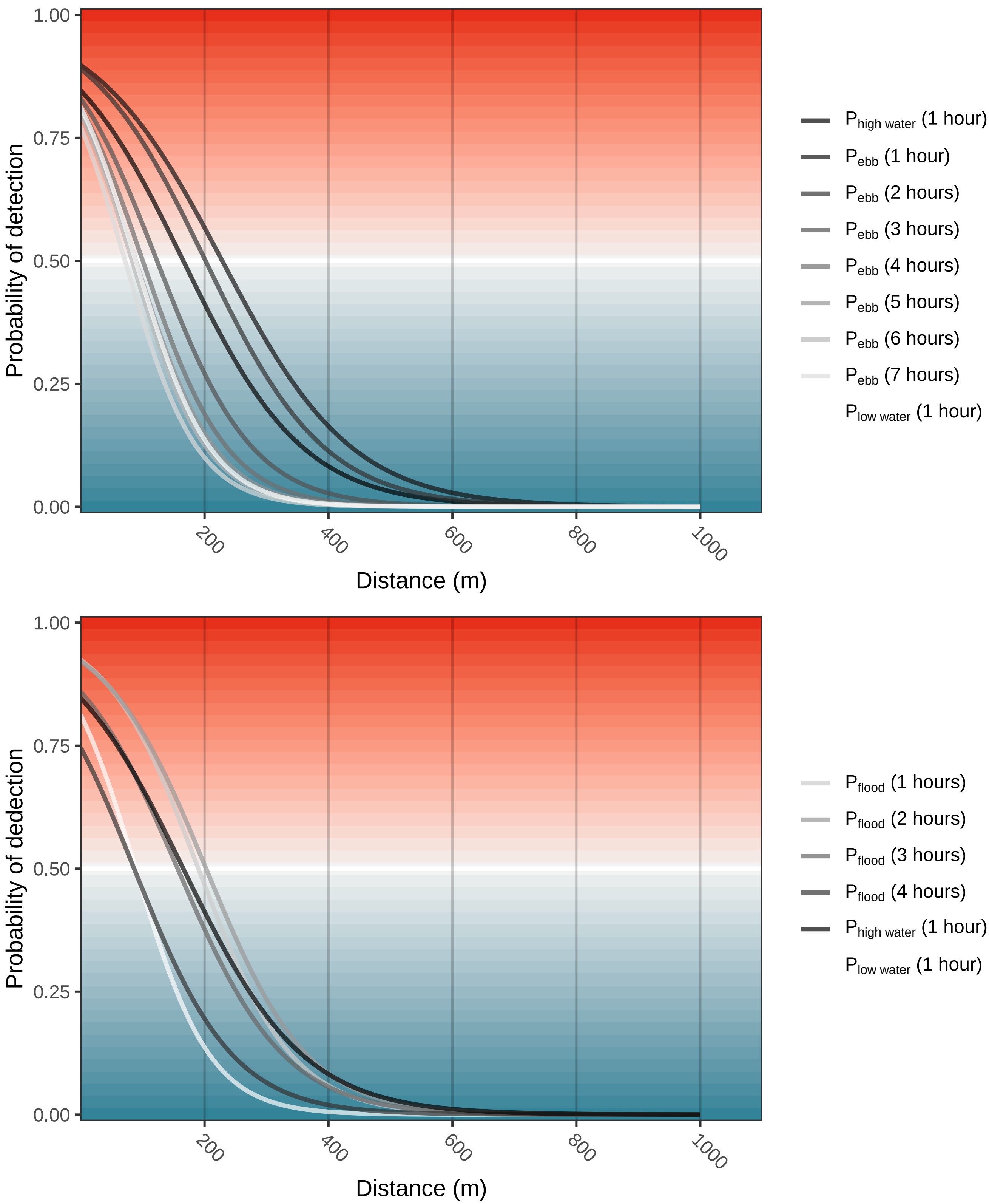

Fig. S2. Detection probability in function of the distance between receiver and transmitter for different tidal phases. The tidal cycle was subdivided in hourly tidal phases. Each curve represents the detection probability (P) for each subsequent hourly tidal phase. The top and bottom panel depict the detection probability during ebb and flood, respectively. No distinction was made between neap tide, spring tide or intermediate tide. The detection probability was estimated using the developed logistic submodel of the pSEM under median conditions of noise, water depth and tilt angle for all the considered tidal phases. A larger version of this figure is provided in the Supplementary Information.

Additional tables

pSEM with mixed performance model. The mixed model failed to converge and this is most likely the result of over-specification of the random structure given the fixed effects. As can be deduced from the sampling design, the random factor receiver id will compete with the fixed factor distance for information. In addition, the turning angle is very receiver-specific with most of the variation explained by the receiver itself (conditional R^2 of 0.71). Hence, both distance and tilt angle, both included as fixed factors in the model, seem to be receiver specific to some extent. Though the mixed model did not converge and despite issues regarding confounding fixed and random factors, it seems the model output of the mixed model and original model (no random effects and without Rt6) seem very similar (Table S1). The only notable difference, is the increasing importance of tilt angle. This is somewhat to be expected as some of the variation of the tilt angle tied up with the receiver id is accounted for by the random effect. The variation of the tilt angle that is not accounted for remains available to be assessed. Though limited, it seems that the tilt angle shows a tidal pattern and this tidal pattern is artificially inflated by the partial removal of the receiver-specific tilt angle variation. Since the real tidal variation cannot be perfectly approximated by the low-resolution ambient noise measurements and/or water speed simulations, it makes sense that some of the underlying, unmeasured, yet detection-range-affecting, tidal variation is captured by the inflated variation in tilt angle and as such increases its importance in the model. An additional explanation for the increased importance of the tilt angle is the inclusion of Rt6 which had an unexpectedly high detection probability (for which it was removed from the analysis of the original pSEM). The fact that distance does not seem to explain this high detection probability (that is why it is described as unexpected), would mean that by including Rt6 we would force the model to look for other spatially varying factors that might explain the observed detection probability. In this study, tilt angle was the variable with the second highest spatial variability (distance was the first) which forces the model in giving more weight to tilt angle. It might of course be that tilt angle is more important, though this one receiver with outlying values will have a very strong influence on the results. We do not know whether tilt angle is really behind this. That is why we also argue for a better distribution of the sampling effort over the spatial and temporal dimension. In this study, and most studies on detection range, the focus is on the temporal dimension. We argue that, given these results, a better distribution is advised.

Table S1. pSEM model output for aggregated data with Rt6. For the different sub-models (i.e. performance, noise and tilt angle), for each variable, the coefficient estimates (Est), standard error (SE), critical value (Crit.Value), p-value and standardized estimates (Std.Est) are given. The performance model is a mixed model with receiver id as random effect

Response	Predictor	Est	SE	Crit.Value	p-value	Std. Est
Performance	Noise	-1.5327	0.0334	-45.8459	$<$0.0001	-0.2615
	Distance	-3.5249	0.0403	-87.4246	$<$0.0001	-0.6015
	Water depth	0.8346	0.0232	35.9225	$<$0.0001	0.1424
	Tilt angle	-0.7926	0.0304	-26.1014	$<$0.0001	-0.1352
	Tilt angle (sub)	-0.8593	0.0175	-49.1561	$<$0.0001	-0.1466
	Wind speed	-0.1771	0.0131	-13.5327	$<$0.0001	-0.0302
	Distance * Noise	-0.4947	0.036	-13.7593	$<$0.0001	-0.0905
	Distance * Water depth	0.6472	0.0287	22.5765	$<$0.0001	0.1022
Noise	Water speed	0.7564	0.0022	348.0258	$<$0.0001	0.7564
	Water depth	-0.3124	0.0028	-110.5312	$<$0.0001	-0.3124
	Precipitation	0.1062	0.0021	50.4034	$<$0.0001	0.1062
	Wind speed	0.0230	0.0022	10.6502	$<$0.0001	0.0230
	Tilt angle	0.0551	0.0036	15.3348	$<$0.0001	0.0551
	Temperature	0.0242	0.0022	10.9156	$<$0.0001	0.0242
Tilt angle	Water speed	0.1627	0.0022	75.4625	$<$0.0001	0.1627
	Water depth	-0.0591	0.0029	-20.6102	$<$0.0001	-0.0591
	Wind speed	0.0362	0.0021	16.8678	$<$0.0001	0.0362

References