Text S1.

Range Testing

The telemetry grid used in the present study was principally set up to enable the recording of presence/absence data of acoustically tagged fish, not to pinpoint exact fish locations (Fig S1). The goal of the range testing was therefore to establish the average detection range of the receivers in the grid rather than meticulously identifying blind spots within clusters. To that end a range test tag was deployed at numerous locations situated throughout our grid (Fig. S2), albeit not in every receiver location. The range test tag operated on 69 khz and was programmed to emit a signal with a fixed 10 seconds off time after every transmission. It had the same power output as the acoustic fish tags. Due to logical constraints range testing could only be done in October 2017 and June 2018, i.e. after the release of fish into the grid. Range testing was performed in two principally different ways (Fig. S2) termed fixed and drift range testing. Fixed range testing; the range tested tag was deployed in a, more or less, fixed position for a given period of time. Two different methods of fixed range testing were performed; a) the range test tag was lowered to 5 m and then kept at this depth for 5 min (usually) before being lowered to 25 meters and then kept at this depth for another 5 min before being hauled to the surface. The boat was not anchored whilst doing this, but if necessary, the engine was used briefly to keep boat movement to a minimum. The position of the boat was noted at the start and end of both the 5 m and 25 m depth intervals. When analyzing the data, the average of these positions was used for distance to logger calculations. For some range test positions only the 25 m depth was tested. b) in three locations the range test tag was fixed to a rope anchored to the bottom with a buoy at the surface for later retrieval. The range test tag was first fixed to the rope at 5 m depth for 30 min and then at 25 m depth for 30 min. Method a) has the advantage that many locations can be tested, but engine noise might interfere somewhat with detections rates and there still might be some movement during the testing period. For the second method (b) engine noise is not a problem and the positions are indeed fixed. However, given that method b) is more time consuming than method a) we were limited in the number of locations we used it. Data from these two methods (a and b) were in the end pooled in the range test analyses described below.

The second method we termed drift range testing. This entailed maneuvering the boat close to a logger (e.g. 50 m) before allowing the boat to drift with the current until the boat had drifted approximately 2 km from the starting point all the while towing the range test tag at approximately 25 m depth (Fig. S2). During this period boat position was noted every minute. In the range test analyses described below the average position during each 1- minute interval, i.e. the initial and final position averaged, was used as distance from the receivers at a given 1-minute time interval.

Range test analyses

We first filtered all logger data so that only the range test tag ID and, for the fixed range testing, only time periods when the range test was at the target depth of 5 or 25 m was included. For each range test position and the corresponding time interval, we calculated the Euclidian distance to every logger in the grid, i.e. 33 distances for each range test point, and the number of detections of the range test tag on each logger during this time interval. These values were then subsequently standardized to the number of detections per minute. Given that we *a priori* expected detections rates to decrease from an asymptotic value at zero distance, we employed the SSlogis function in the base library of R (R Core Team 2020) to fit models to the range test data.

In the analyses the different range test positions were weighted by the square root of the duration of the testing for each range testing position. For the point range testing, we performed three separate analyses, i) including all data points and only ii) 5 m or iii) 25 m depth positions. A separate analysis was done for the drift range testing. Distance was log – transformed in all these analyses. We interpreted the maximum number of recorded detections per minute, i.e. 4.17, as a 100 % detection rate to allow for further interpretation of the calculated asymptotic model fits.

The analyses yielded quite similar results (Table S3, Fig S3). The asymptotic value fitted varied between 70-80 % of the theoretical maximum and the distance where 50 % of the possible detections was detected was estimated to be 450 - 530 m from the loggers (Table S2). In sum, although there undoubtedly are blindspots within clusters, we conclude that any fish spending any significant amount of time within the focal clusters had a high probability of being detected. The same applies for fish spending time in the vicinity (< 500 m) of the net-pens at the salmon farms or at the Hitra spawning grounds.

System Performance

To evaluate the grid system performance and stability over time we used two principal means, i) reference tags deployed in each focal cluster and ii) the event logs of all receivers, which yields information on the number of pings and detections recorded daily.

Reference tags - temporal and spatial variance

One reference tag was deployed in each focal cluster in October 2017 (Fig S2). This was done by fixing the reference tag to the mooring line of one receiver in each cluster approximately one meter above the bottom. These reference tags (V13-1x-A69-9001) operated with the same power output as the tag used for the fish on 69 khz, but they lacked a depth sensor. They were programmed to transmit on average every 660 seconds with a minimum and maximum time between transmissions of 580 and 740 seconds. Reference tags were set to turn off after a period of 1830 days, i.e. after the end of the project. From the downloaded data we calculated the number of detections, the mean delay between detections (MD), the median delay between detections and the median daily average delay (DAD). The latter was done by first calculating the average daily delay of the experiment post deployment of the refence tag and then finding the median of these values. From the mean delay (MD) and median DAD, we calculated the percentage of detections which had been detected across the study period and on a typical day, respectively; by dividing 665 (~expected average if all signals are detected) with MD or Median DAD.

We then examined if DAD was related to the number of fish present in the vicinity of the logger where the reference tag was deployed by a linear model (lm) where DAD was the dependent variable using the base library of R (R Core team 2020). Number of fish present daily was included as a continuous independent variable and logger was treated as a categorical independent variable in this model. Given that we *a priori* expect signal collisions to only become a concern once the number of fish pass a critical threshold and thus have a more exponential than strictly linear effect on the delays between detections, DAD values were log – transformed in the analysis.

There were some differences in the mean detection delays for the different pingers and hence the number of detections. For the reference pingers deployed at Station 15 and 9, 51 % and 73 % of the possible detections, respectively, were detected on a median day, whereas between 85 % and 95 % of the possible detections were detected for the remaining reference pingers at their station of deployment (Table S4,Fig S4). Curiously, Station 31 situated ~450 m from the reference pinger at station 15 detected ~77 % of the possible detections. The low detection rate of the reference pinger at Station 15 was therefore likely at least partly related to specific hydrographical conditions at Station 15. Although there were clear differences in the number of detections of the different reference tags at stations where they were deployed, there was also distinct temporal patterns in DAD for each receiver (Fig. S3).

The lm - model indicated a highly significant effect of the number of fish present on DAD with longer delays with increasing number of fish (Table S3, $p < 0.001$). This is as expected given that more tag collisions and hence longer average delays between detections are expected with more fish present in the vicinity of the receiver. There were also strong significant differences between the different reference tags (Table S5). Importantly there was no indication that the reference tags were not heard during prolonged intervals as maximum delays between two consecutive detections during the entire study was typically a few hours (Table S5), i.e. the telemetry grid was functioning and, for all practical purposes, continuously logging detections.

Detections to pings -temporal and spatial variance

An acoustic transmission of a fish ID consists of 8-10 pulses of sound or pings (Vemco 2015). If two signals collide the number of pings will be registered, but no detection will be recorded because the combination of pulses, i.e. the "pulse train", is not recognized by the Vue software (Vue 2.6.2). Noteworthy, environmental and anthropogenic noise also can create pings (Fig S5). Regardless, the number of detections vs pings can be used to inform on system performance/signal collisions for the entire grid as increasing number of pings concurrent with decreasing number of detections is a clear indication of signal collisions (Vemco 2015). The event log created for each receiver sums up the number of daily detections and pings and can thus be used for this exact purpose.

Plotting the number of pings against detections recorded at the data loggers at each station, the number of detections increased roughly linearly with pings to about 1500 - 2000 daily detections then leveled off (Fig. S6). A plot of the number of fish present in the vicinity of the loggers vs detections indicated a roughly linear increase until ~20 fish. With more than 20 fish present the detections levelled off and even decreased if fish numbers increased further (Fig. S6). However, there were few days across the entire grid were the number of fish present at a given station was more than 20 (Fig. S7). Overall, we therefore conclude that the number of detections were not limited by the number of fish present.

References

R Core Team (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL. https://www.R-project.org/.

Vemco Range Test Manual (2015). www.vemco.com.

Wickham H (2016) ggplot2: elegant graphics for data analysis. Springer.

Table S1. Summary data for telemetry grid stations. Given is station number, type; Spawning Ground (SG) or Farm (F) and to which SG cluster the station belonged. If no cluster is given; single receiver deployed at Hitra. Latitude (lat) and longitude (Lon) for each station is given in decimal degrees. LD is the number of station logging days during the study period Feb 12 2017 to May 17 2020. Specific details pertaining to each station is given under Comment. No information given – data was logged at the station for the entire study period. *- stations not included in the present study. ** - receiver hung of feed barge at the salmon farm. For station 30, the receiver was originally hung of the feed barge, but redeployed on a rig anchored to the bottom in February 2018. Rdep – receiver depth (m). Bdep – bottom depth(m)

Station	Type	Cluster	Lat	Lon	RDep	BDep	LD	Comment
1	SG	Araneset	63.2620	8.3334	11	60	1188	
2	SG	Araneset	63.2632	8.3173	12	37	1188	
3	SG	Araneset	63.2680	8.3486	13	82	848	Lost Jan 2020. Last download June 2019.
4	SG	Araneset	63.2703	8.3225	12	61	1188	
5	SG	Araneset	63.2706	8.3054	13	44	1188	
6	SG	Åkvika	63.3342	8.4396	12	33	1049	Malfunctioned June 2017. Replaced Oct 2017.
7	SG	Åkvika	63.3385	8.4289	10	44	1188	
8	SG	Åkvika	63.3439	8.4423	13	30	949	Lost autumn 2019. Replaced Feb 2020.
9	SG	Åkvika	63.3402	8.4093	12	65	675	Lost autumn 2018. Replaced Nov 2019.
10	SG	Drom	63.3625	8.6930	8	27	1188	
11	SG	Drom	63.3667	8.6684	13	39	1188	
12	SG	Drom	63.3732	8.6617	11	64	1188	
13	SG	Drom	63.3808	8.6583	15	59	583	Lost autumn 2018. Replaced Feb 2020.
14	SG	Drom	63.3888	8.6416	13	37	848	Lost spring 2020. Last download June 2019.
15	SG	Glasøy	63.3522	8.2348	11	75	1188	
16	SG	Glasøy	63.3480	8.2162	11	28	1188	
17	SG	Glasøy	63.3472	8.1979	15	58	1188	
18	SG	Glasøy	63.3436	8.1826	12	41	1188	
19	SG	Lauvøy	63.3366	8.2312	12	26	1188	
20	SG	Lauvøy	63.3249	8.2355	15	52	1188	
21	SG	Lauvøy	63.3281	8.2030	15	40	1188	
22	SG	Lauvøy	63.3243	8.1889	14	30	1188	
23	SG	Lauvøy	63.3171	8.1785	14	35	1188	
24	SG	Lauvøy	63.3122	8.1682	15	36	1188	
25	SG	Lauvøy	63.3306	8.2183	15	37	1188	
26*	SG		63.4572	8.2995	12	80	477	Lost autumn 2018. Last download June 2018.
28	F		63.3102	8.1194	13	21	847	Lost autumn 2019. Last download June 2019.
29	F**		63.2972	8.4194	12	34	1188	
30	F**		63.3015	8.4177	12	114	1065	Taken up Oct 2017. Redeployed Feb 2018. Position until Oct 2017; 63.2691 (Lat) and 8.2310 (Lon).
31	F**		63.3559	8.2307	12	22	1188	
32	F**		63.3391	8.2684	12	42	816	Taken up Jan 11 2018, redeployed Feb 8 2018. Taken up March 8 2019, redeployed March 15 2019. Lost spring 2020. Last download June 2019.
33	F**		63.3947	8.2101	32	50	849	Lost autumn 2019. Last download June 2019.
34*	SG		63.4200	8.4939	12	50	247	Lost spring 2018. Last download June 2017.

Table S2. Summary of the main field activities in the telemetry study.

Date	Task
November 2016	Deployment of grid of VR2W data loggers at each station.
Jan 27 – Feb 14 2017	Capture of fish in the 5 different focal clusters.
Feb 13 – Feb 16 2017	Fish tagging with VP tags (n = 194). Fish released in capture area.
June 2017	Data download (DD) and battery change (BC) in all data loggers.
Oct 2017, Nov 2017	DD and range testing. Reference tags deployed in each focal cluster.
Jan 30 - Feb 16 2018	Capture of fish in the 5 different focal clusters.
Feb 12 – Feb 16 2018	Fish tagging with VTP tags (n = 175). Fish released in capture area.
June 2018	DD and BC in all data loggers. Additional range testing.
November 2018	DD from all data loggers.
Jan 28 – Feb 12 2019	Capture of fish in the 5 different focal clusters.
Feb 11 – Feb 14 2019	Fish tagging with VP tags (n = 189). Fish released in capture area.
June 2019	DD and BC in all data loggers.
November 2019	DD from all data loggers
May 2020	DD and BC in all data loggers

Table S3. Summary data for the SSlogis - range test models. Given is the calculated percentage of possible detections detected at 0 m horizontal distance from the receiver (Asym (%)) and the estimated distance from the receiver where 50 % of transmissions were detected (p50 (m)).

Range test type/Area	Asym (%)	p50 (m)
Drift- test overall	71	532
Points-test overall	76	455
Points-test 25 m	80	450
Points-test 5 m	70	500

Table S4. Summary data for all reference pingers (logger ID written in italics). Given are all stations (#S) where signals were detected for each pinger with Euclidean horizontal distance in meters from the reference pinger to the station given in brackets. The summary data are the number of detections, mean delay between two consecutive transmissions, median delay between two consecutive signals, maximum delay between two consecutive signals, median daily average delay (Med DAD), the overall detection probability based on the mean delay across the study and the detection probability on the median day.

	Det (n)	Mean (sec)	Median (sec)	Max (hours)	Med DAD (sec)	Det prob mean delay (%)	Det prob Med DAD (%)
P - 65337							
S12 (0m)	113417	722	672	3.1	712	92.1	93.3
S11 (802m)	21770	3832	1231	1122	3637	17.4	18.3
S13 (863m)	1133	17436	1386	1781	11711	3.8	5.7
P – 65338							
S3 (0m)	65751	792	678	5.6	758	83.9	87.7
S1 (1015m)	2597	27273	2120	880	23436	2.4	2.8
P – 65339							
S9 (0m)	36870	962	687	5.7	914	69.1	72.7
P - 65340							
S20 (0m)	92622	714	670	4.6	700	93.1	95.0
S25 (1063m)	245	248984	33120	2437	-	0.3	-
P - 65341							
S15 (0m)	62857	1301	699	24.7	1296	51.1	51.3
S31 (464m)	92189	886	680	24.8	860	75.1	77.4
S16 (1043m)	441	141919	4110	6916	-	0.5	-

Table S5. Results of statistical model of explanatory variables for reference tag delay. Fish represent the number of fish present in the vicinity of the station (continuous variable), while Station[station number] represent the categorical variable of station. The treatment contrast of R was used with the intercept representing the value of Station 3 and the value for the other stations showing how they compare to this reference value.

	log(mean)			
Predictors	*Estimates*	*std. Error*	*Statistic*	*p*
Intercept	6.62	0.02	414.79	**<0.001**
Fish	0.03	0.00	12.00	**<0.001**
Station [9]	0.21	0.02	8.65	**<0.001**
Station [12]	-0.14	0.02	-7.44	**<0.001**
Station [15]	0.60	0.02	31.14	**<0.001**
Station [20]	-0.17	0.02	-8.34	**<0.001**
Observations	3591			
R^2 / R^2 adjusted	0.420 / 0.419			

Table S6. Explanatory variables included in final models of fish residence time (Res Time). Given predictors are the effect of the categorical variables Station type (StType) and Sex. Estimate is the parameter estimate of the predictor, CI is the 95 % confidence interval and p is the p – value. Significance (bold font) was assigned at $p < 0.05$. Only the fixed effects are shown. The treatment contrast of R was used with the intercept representing the value for females in Glasøysvaet.

	Duration (log secs)		
Predictors	*Estimates*	*CI*	*p*
Intercept (Glasøysvaet)	9.46	8.90 – 10.02	**<0.001**
Lauvøysvaet	0.27	-0.42 – 0.95	0.446
Araneset	-0.42	-1.16 – 0.32	0.262
Åkvika	-0.47	-1.24 – 0.30	0.232
Dromnessundet	0.41	-0.33 – 1.15	0.278
Farm	-0.08	-0.80 – 0.64	0.826
Sex [Male]	0.19	0.10 – 0.29	**<0.001**
Observations	28475		
Marginal R^2 / Conditional R^2	0.035 / 0.337		

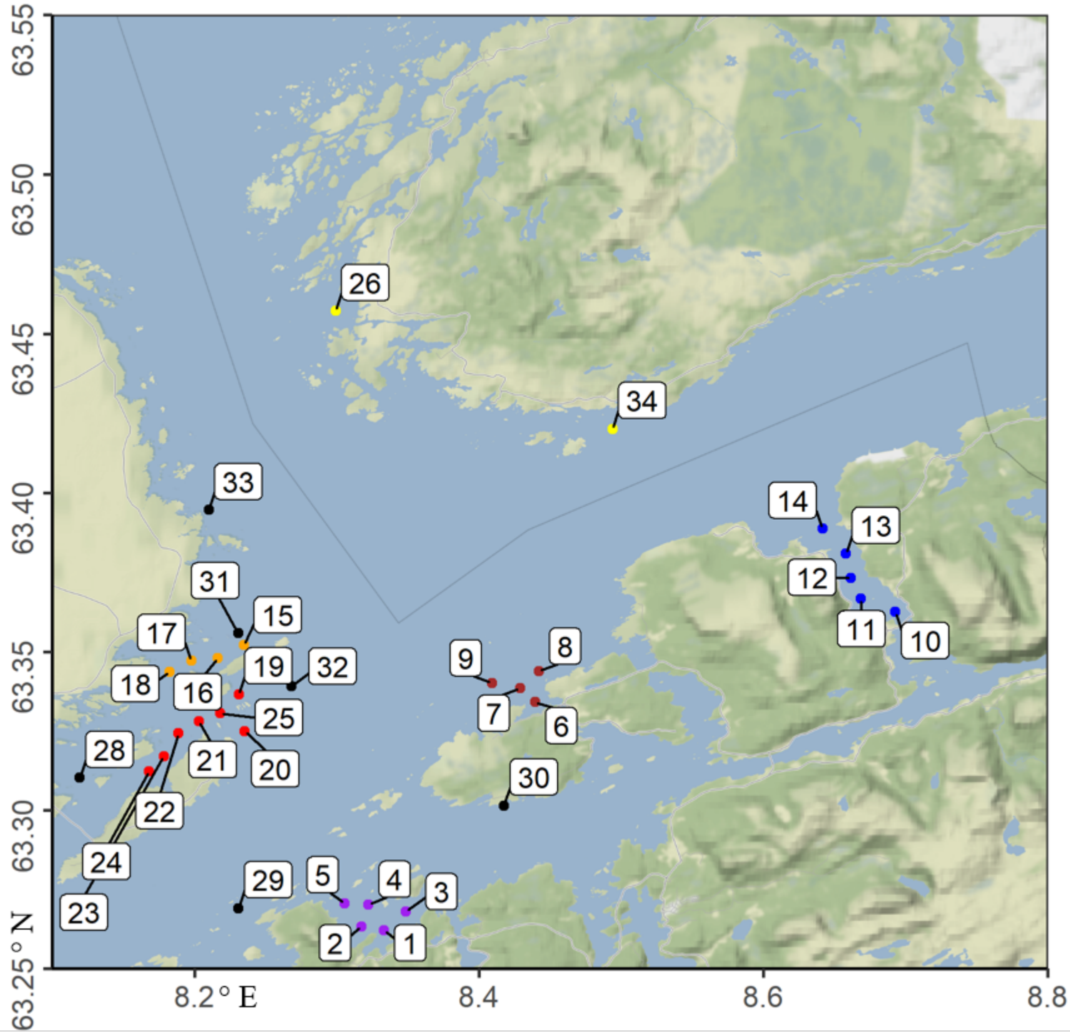

Fig. S1 Map showing the location of the study stations with their respective station numbers.

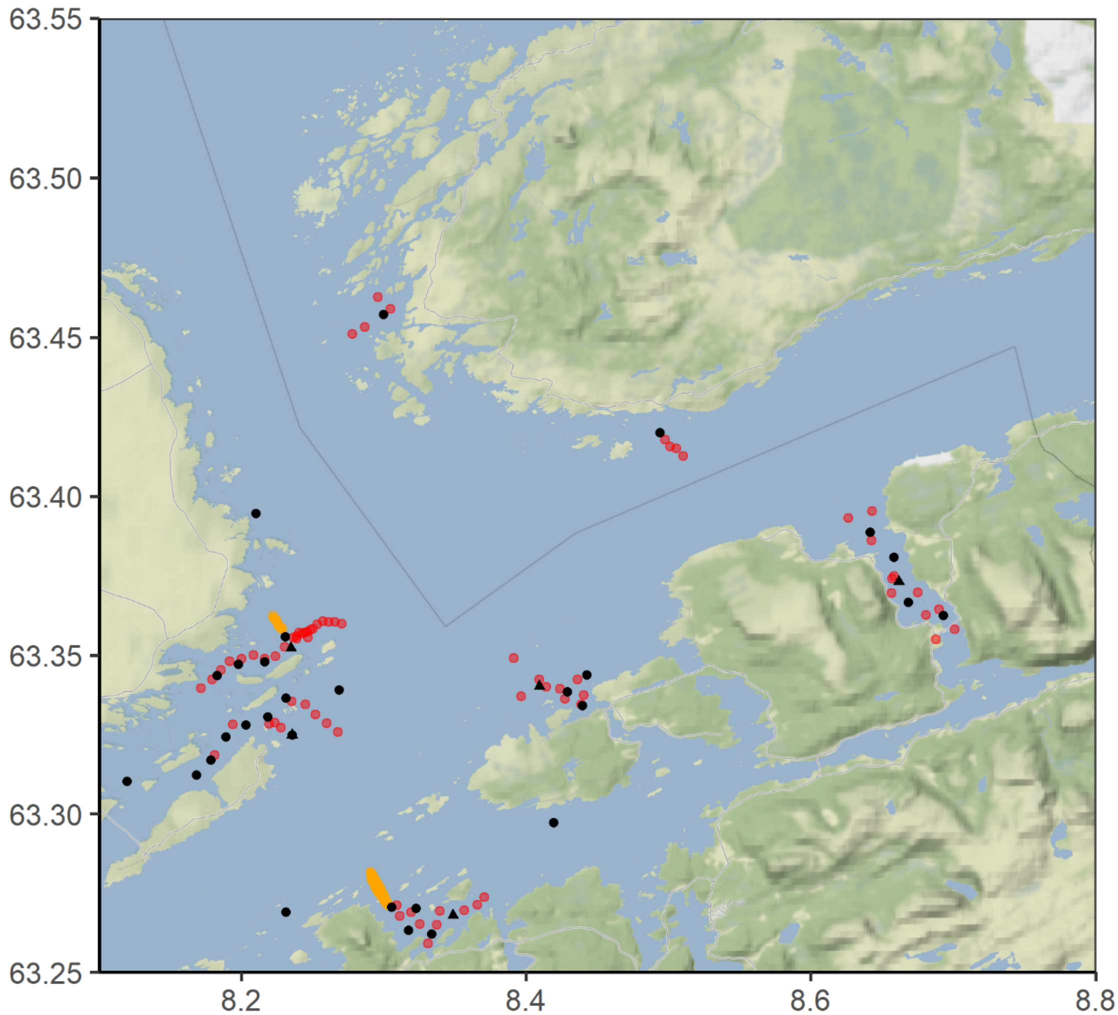

Fig. S2 Map depicting grid stations (black) and the positions used in the point - (red circle) and drift - (orange circles) range testing. Triangles represent a station where a reference pinger was also deployed.

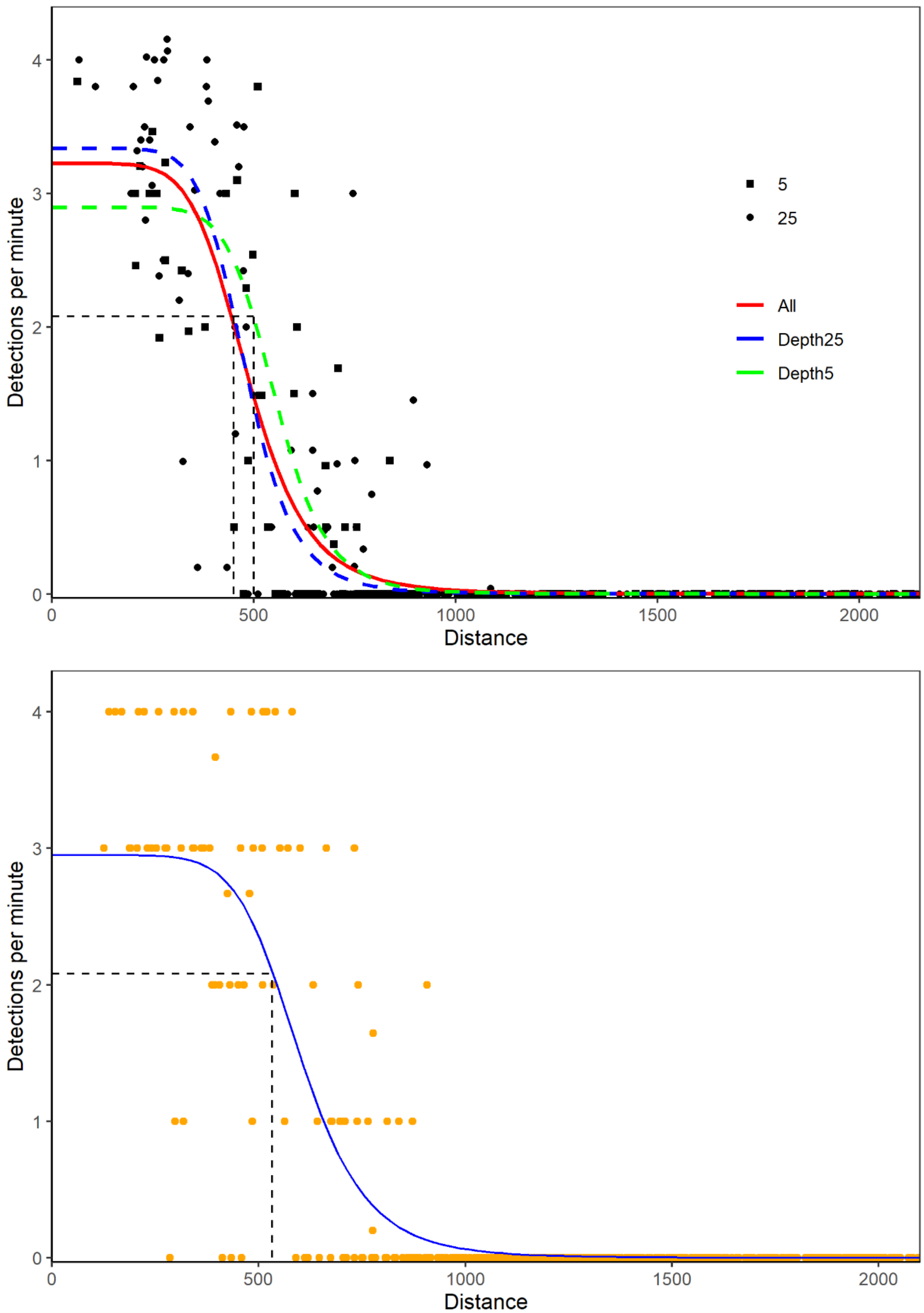

Fig. S3 Rangetest results. Coloured lines are the results of the logistic regressions whilst circles and squares represent the absolute values, i.e. the input data for the regressions. Dotted black lines represent the distance and value corresponding to a 50 % detection rate. Upper graph is the results of the point range testing, whereas lower graph depicts results of the drift range testing.

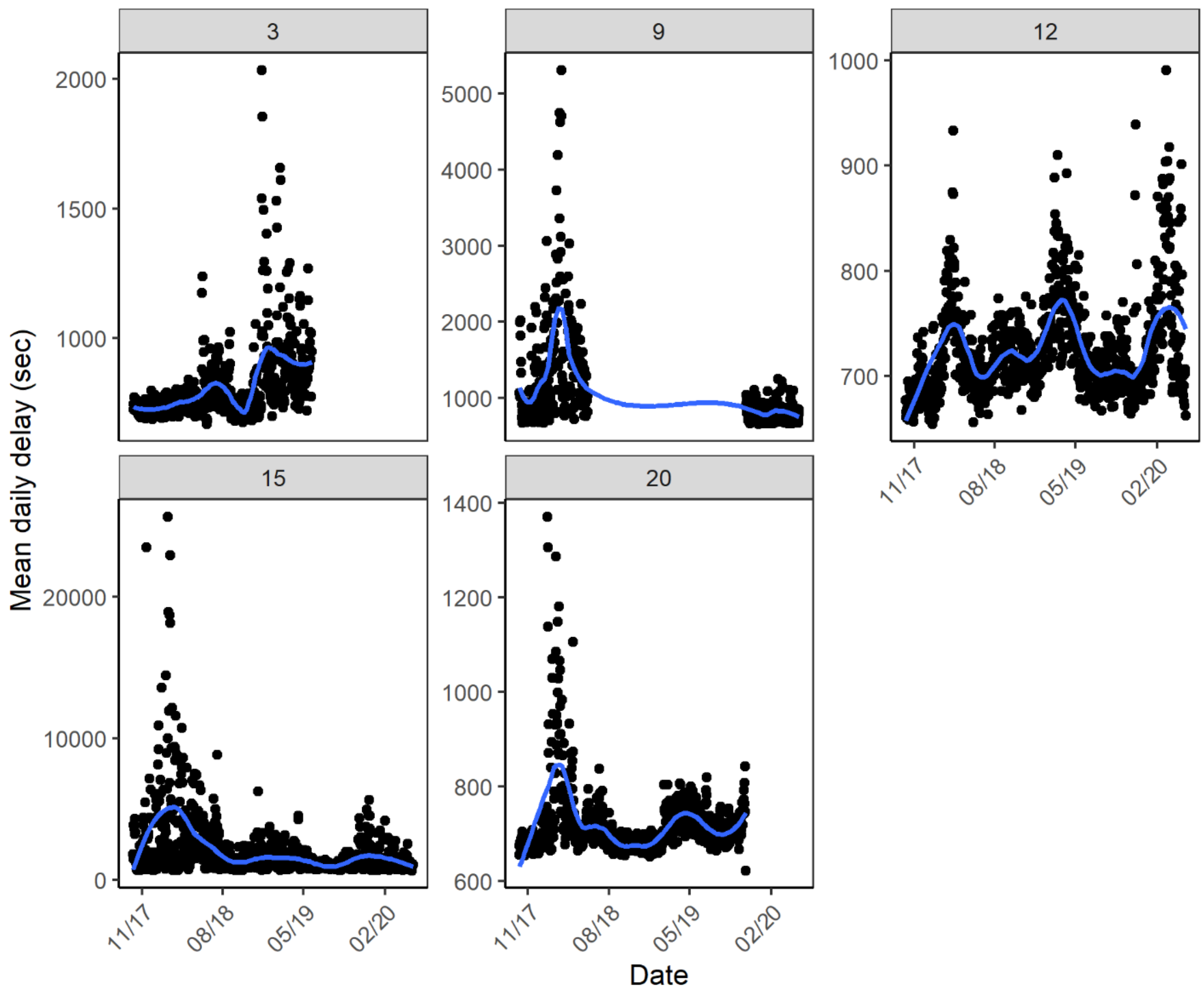

Fig. S4 Mean daily delays of the reference pingers at the station were the pinger was deployed. Notice the difference in the y scales. The pingers were deployed in October 2017. For station 3 and 9, daily data missing is due to the loss of the station loggers (see also Table S1), whereas for station 20 the reference pinger malfunctioned after handling associated with data downloading in November 2019. Lines are fitted loess smoothers obtained through the geom_smooth function of ggplot2 (Wickham 2016) with span set to 0.3.

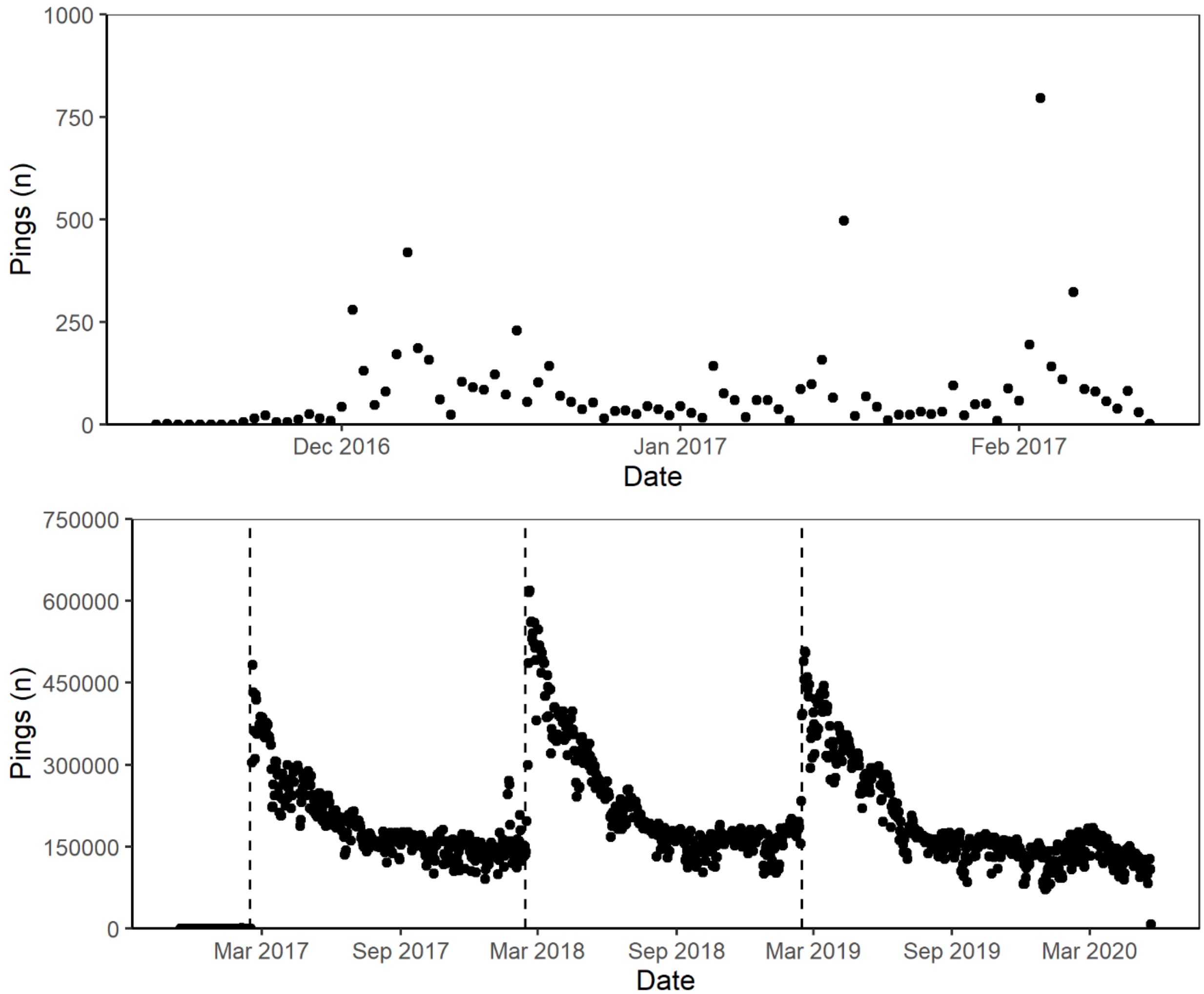

Fig. S5. Number of pings detected in the entire grid over time. Upper panel shows the pings detected before the release of fish into the grid. Lower panel shows the total amount of pings detected across the study, with dotted lines representing the annual release of fish in 2017-2019.

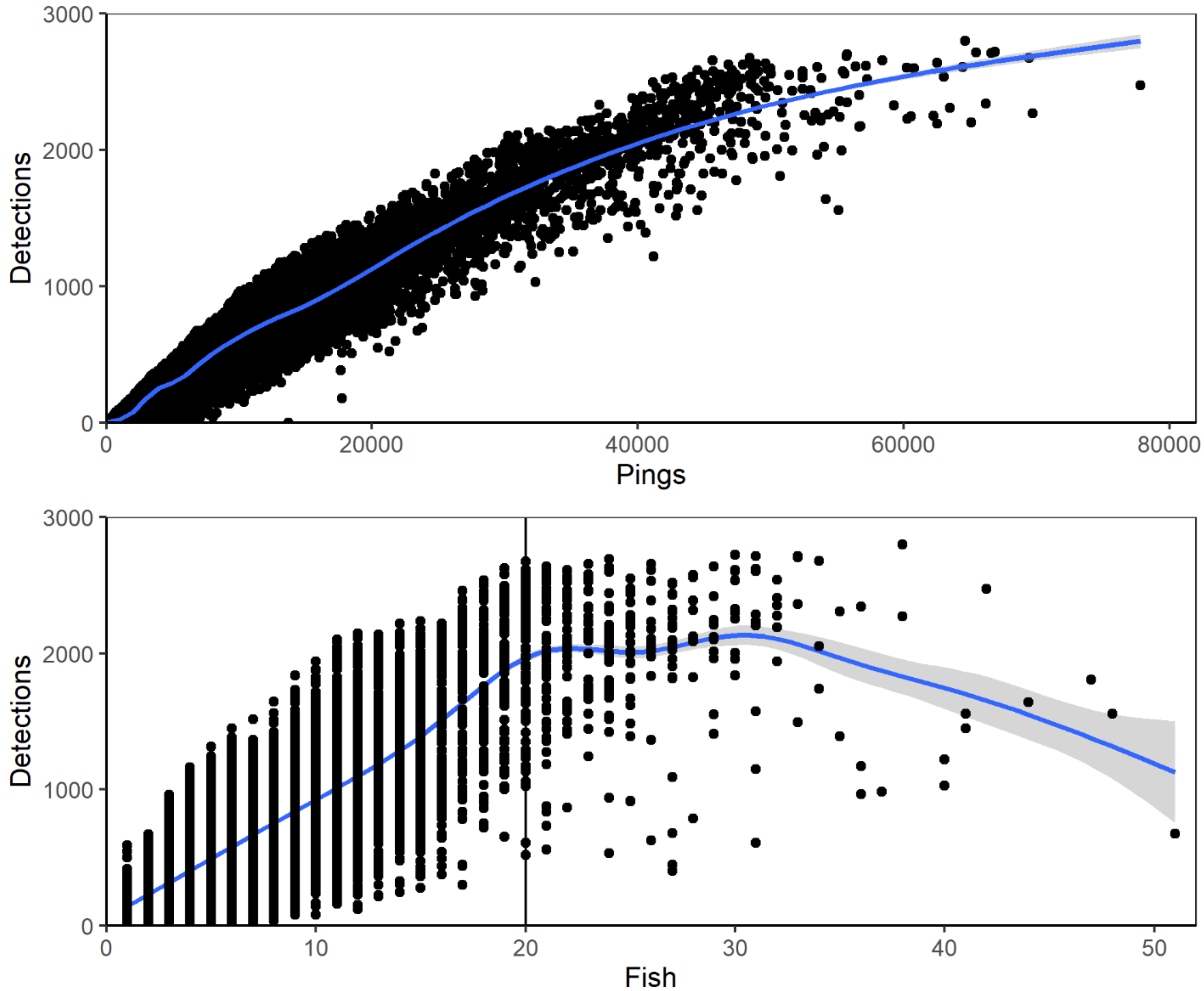

Fig. S6. Number of daily detections versus daily number of pings (upper panel) and daily number of detections vs daily number of fish detected (lower panel). Data pooled across stations.

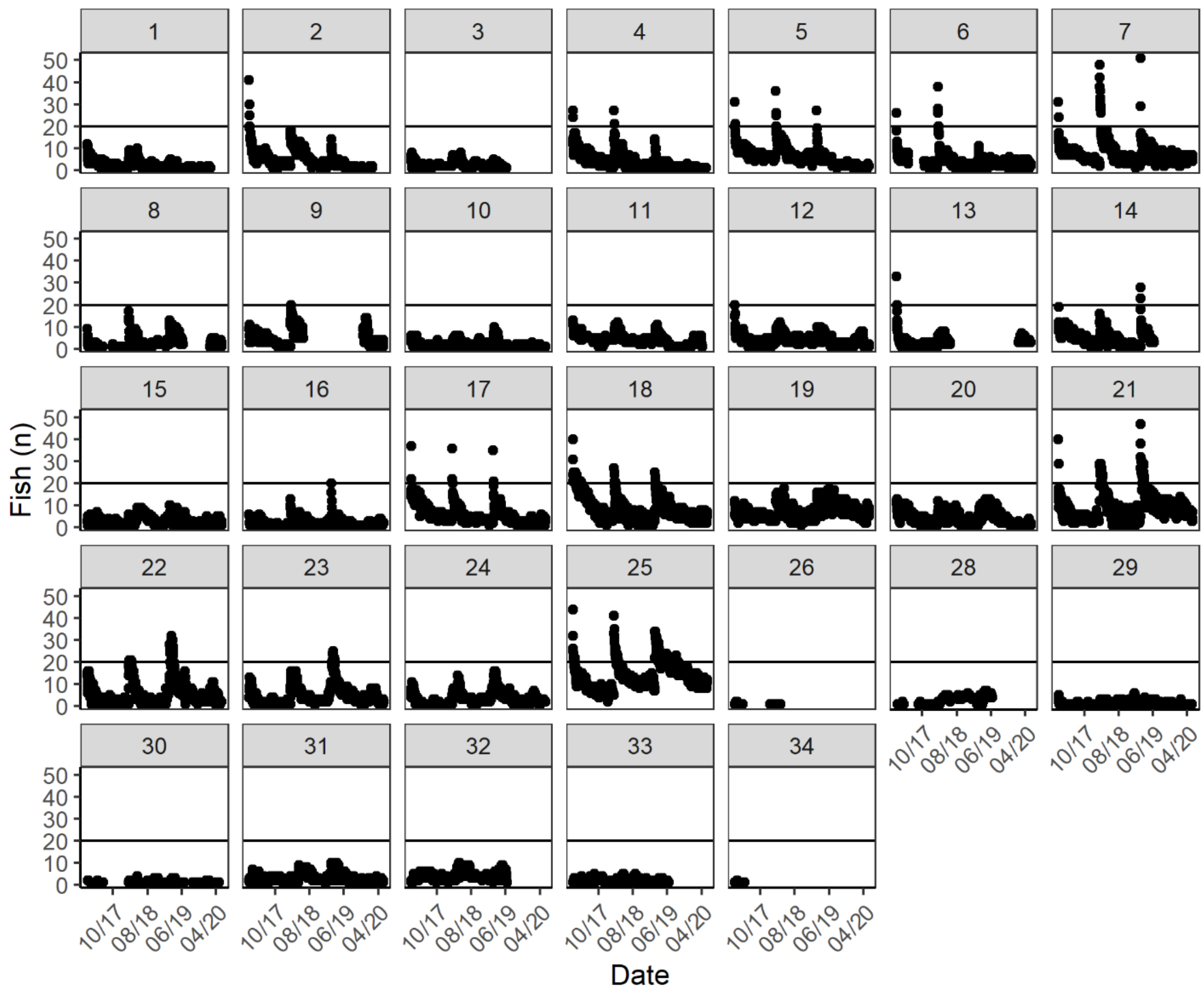

Fig. S7 Number of fish detected daily at each station. Horizontal line depicts a value of 20, i.e. the number of fish present when signal collisions looked to become more prevalent.