Analysis of telemetry data from burbot on Moyie Lake

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1. Introduction

A telemetry study on the movement of burbot on Moyie Lake was run between fall 2013 and fall 2017. Sonic tags (Vemco depth sensor V13 tags which will be referred to by serial number) were applied to 30 fish (15 fish in fall 2013 and 15 in fall 2014). Five receivers were placed in the north basin, 1 receiver on the channel between basins, and two receivers in the south basin (Figure 1). Detailed descriptions of sampling, tag application and receiver (VR2W) array set up can be found in Stephenson and Evans 2014 and 2015.

Four of the tagged fish were known to have died (sonic tag numbers 1200234, 1200231, 1200229, 1200227) typically from being caught by an angler who returned the tag. A plot of the dates on which each fish was detected somewhere in the two lakes (Figure 2), shows two fish with an unusual detection pattern. The fish with sonic tag number 1168220 was detected after end of its battery life, and the fish with sonic tag number 120029 was detected more than a year after its last detection. All such detections (Appendix 1) were not used in the subsequent analyses.

2. Movement

Figures 3a, 3b, and 3c shows the movement of fish among all receivers for the entire period (late 2013 to late 2017). Most fish do appear to move between the basins but about 1/3 did not move from the N to the S basin over the entire study.

Figures 4a, 4b and 4c shows the movement of the fish during the spawning period of February 4 to February 25 (Julian date 35 to 56 of each year). It appears that there is good mixing among the spawning grounds (receivers 220067 and 220161) in the north basin within and among years even for fish tagged in the south basin. This is one of the assumptions made in the Jolly-Seber analysis in Schwarz (2018).

Table 1 computes the number of days each fish was detected at receivers 220067 (east shore of southern spawning area of north basin) and 220161 (top end of Cotton Creek spawning area in north basin) during the spawning season in each year (February 4 to February 25). The pattern of detection from Figure 2 was used to exclude fish that were known to be dead during the

spawning period or whose last detection was well before spawning periods (fish dead or transmitter inactive).

Fish tagged in the south basin in late 2013 were only infrequently detected in north basin spawning areas compared to fish tagged in late 2013 in the north basin (p=.004). But in subsequent years, fish appear to visit north basin spawning grounds a similar number of days (all p-values are >0.05). In particular, fish tagged in the south basin in late 2014 appear to visit the north basin spawning ground in 2015 with about the same intensity. The cause for the different behavior in the two years is unknown.

3. Behaviour of fish

Figure 4 plots the mean daily depth of fish over time. The maximum depth recorded by the tags (40 m or 60 m) is an artifact of changes in the tag programming over the study. All burbot were tagged with Vemco V13 depth sensor tags, but between years Vemco changed sensor types and so the maximum depth is set at approximately 50 m for tagging events in 2013 and 35m for tagging in 2014 (the approximate accuracy for all tags was ±1.7m with a resolution of 0.15m).

There are several tags where the mean daily depth is negative (i.e. fish is above water). A summary of the number of negative sensor readings over the entire study is presented in Table 2. The two batches of acoustic tags differ in the set of negative sensor values that are used. Table 3 shows that these negative readings typically occur from November to March and may be related to ice conditions on the lake, as well as an artifact of the accuracy of the tag (±1.7m at room temperature).

Detections occurring at depths less than 4.5 m during spawn timing (February 4-25) are taken as an indication of spawning behavior. Each day that the fish was detected where the proportions of detections for that fish on that day with depths < 4.5 m is more than .80 was classified as a day that the fish was engaged in spawning behavior.

Table 4 summarizes the number of days individuals were detected on the receivers in the spawning grounds in the north basin when the fish is engaging in spawning behavior – there was no evidence (all p-values >> 0.05) of a difference in mean number of days engaged in spawning behavior for fish originally tagged in the two basins in each year.

Table 5 is a comparison of the number of days detected on each of the two receivers in the spawning grounds in the north basin when the fish is engaging in spawning behavior, i.e. a comparison of the fidelity of each fish in each year to each of the two spawning areas. The data is sparse (few active fish in 2014 and 2017) and smallish counts (all years). There was no evidence of a difference in the number of days spent at each receiver in any year except 2015, where 15/20 fish spent more days around receiver 220067 (south end of north Basin) than around receiver 220161 (Cotton Creek north Basin).

References

Schwarz, C. J. (2018). Analysis of Burbot Mark-Recapture Dataset. Unpublished report. 2018-11-20.

Stephenson, S., and V. Evans. 2014. 2013-2014 Kootenay burbot summary: Moyie Lake and Kootenay Lake. Ministry of Forests Lands and Natural Resource Operations, Nelson B.C.

Stephenson, S., and V. Evans. 2015. 2014-2015 Kootenay burbot summary: Moyie Lake and Kootenay Lake. Ministry of Forests Lands and Natural Resource Operations, Nelson B.C.

Table 1. Summary of number of days detected on receivers 220067 and/or 220161 in north basin (on spawning grounds by individual fish. Prefix N/S indicates basin where the fish was sonic tagged. Suffix M indicates a fish with a known mortality. Blank cells indicate fish was dead, or that the sonic tag was inactive based on a review of observed telemetry values (Figure 2)

Transmitter	2014	2015	2016	2017
N.1168208..	21	18		
N.1168216..	11			
N.1168217..	11	10	21	
N.1168218..	0	18	10	
N.1168219..	21	7	18	
N.1168220..	17	18	5	
N.1168221..	13			
N.1200224..		16	22	21
N.1200225.M		12	1	3
N.1200226..		17	0	
N.1200227..		22		
N.1200228.M		15		
N.1200229..		10		
N.1200235..		11	6	0
N.1200236..		3		
N.1200238.M		21	22	22
S.1168209..	0	9	11	
S.1168210..	8	15	9	
S.1168211..	4			
S.1168212..	0			
S.1168213..	0	9	5	
S.1168214..	0	17	21	
S.1168215..	0	12	15	
S.1200230..		15	5	2
S.1200232..		15	12	12
S.1200233..		10	0	
S.1200234..		12		
S.1200237..		5	9	4
P-value to compare mean number of days visiting spawning areas between the basins of tag origin.	.004	.243	.594	.445

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Table 2 Summary of number of negative depth values.

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                          Sensor Value
Transmitter -0.87 -0.65 -0.6 -0.45 -0.43 -0.3 -0.22 -0.15 -.0002 -.0001.
   1168209     0     0    0     0     0    0     0     0    35     0
   1168210  3500     0    0     0     0    0     0     0    25     0
   1168211    11    21    0     0   220    0   141     0   943     0
   1168212     0     5    0     0   161    0   437     0  1275     0
   1168213     0     0    0     0     0    0     5     0    32     0
   1168214     0     0    0     0     0    0     0     0    60     0
   1168215     0     0    0     0     8    0     6     0   122     0
   1168216     0     0    0     0     0    0     4     0   167     0
   1168217     5   305    0     0   714    0   735     0  1890     0
   1168218     0     6    0     0    45    0   286     0  1228     0
   1168220    84    88    0     0   120    0   134     0   205     0
   1168221     0     0    0     0     0    0     0     0   321     0
   1168222     0     0    0     0     0    0     1     0    14     0
   1200224     0     0  651    69     0   81     0   117     0   176
   1200225     0     0   12    24     0   91     0   180     0  1199
   1200226     0     0 3132   387     0  358     0   518     0   822
   1200227     0     0  356   102     0  129     0   152     0   397
   1200228     0     0   95    30     0   41     0    54     0   179
   1200229     0     0  227    26     0   33     0    40     0   120
   1200230     0     0    0     6     0   74     0   196     0   682
   1200231     0     0  111     0     0    0     0     0     0     0
   1200232     0     0   79   117     0  187     0   161     0   479
   1200233     0     0  190   211     0  290     0   301     0   564
   1200234     0     0   67   239     0  103     0   127     0   222
   1200235     0     0 1901   391     0   90     0     8     0    90
   1200236     0     0  149    57     0   35     0    31     0    67
   1200237     0     0  652   168     0  179     0   194     0   465
   1200238     0     0   60    63     0   81     0   176     0   507
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Table 3. Tabulation of when negative sensor readings occur.

Sensor Value						Month						
	1	2	3	4	5	6	7	8	9	10	11	12
-0.87	3052	515	8	0	0	0	0	0	0	0	0	25
-0.65	59	228	138	0	0	0	0	0	0	0	0	0
-0.6	3303	1601	1726	28	3	1	6	11	119	38	141	705
-0.45	715	468	459	3	2	0	4	2	17	7	66	147
-0.43	169	796	301	0	0	0	0	0	0	0	2	0
-0.3	890	503	252	7	0	10	12	4	15	3	64	12
-0.22	422	786	539	0	1	0	0	0	0	0	0	1
-0.15	1173	609	203	15	2	22	14	1	12	4	157	43
-.0002	1803	2462	1879	13	85	0	0	0	0	3	0	72
-.0001	2760	1760	412	121	65	137	144	3	14	7	454	92

Table 4. Summary of the number of days detected on receivers 220067 and/or 220161 in north basin (on spawning grounds) by individual fish when the proportion of detections during a day at depths < 4.5m is .80 or higher. Prefix N/S indicates the basin where the fish was sonic tagged. Suffix M indicates a fish with a known mortality. Blank cells indicate the fish was dead, or sonic tag inactive based on a review of observed telemetry values (Figure 2)

Transmitter	2014	2015	2016	2017
N.1168208..	3	0		
N.1168216..	1			
N.1168217..	9	5	12	
N.1168218..	0	2	4	
N.1168219..	0	0	1	
N.1168220..	2	1	2	
N.1168221..	3			
N.1200224..		3	10	3
N.1200225.M		2	1	2
N.1200226..		11	0	
N.1200227..		11		
N.1200228.M		8		
N.1200229..		4		
N.1200235..		0	0	0
N.1200236..		0		
N.1200238.M		5	0	18
S.1168209..	0	2	6	
S.1168210..	8	0	0	
S.1168211..	3			
S.1168212..	0			
S.1168213..	0	2	5	
S.1168214..	0	11	8	
S.1168215..	0	8	12	
S.1200230..		2	3	2
S.1200232..		7	12	4
S.1200233..		5	0	
S.1200234..		11		
S.1200237..		1	3	3
P-value to compare mean number of days spawning between the basins of tag origin.	0.55	0.48	0.33	0.55

Table 5. Summary of the days on spawning grounds at receivers 220161 (Cotton Creek north basin) and 220067 (south end of north basin). A fish is "on the spawning ground" at this receiver if the proportion of depths at a receiver < 4.5 m (including negative values) is more than 0.80. Blank entries indicate that the fish was not detected at either receiver in that year. The sum of values over the two receivers may differ from that in Table 4 because of double counting, i.e. a fish could visit both receivers in a single day.

Transmitter	2014 220161	2014 220067	2015 220161	2015 220067	2016 220161	2016 220067	2017 220161	2017 220067
1168208	2	2						
1168209			0	2	3	5		
1168210	7	8			9	0		
1168211	0	4						
1168213			1	2	0	5		
1168214			0	11	5	4		
1168215			0	8	11	6		
1168216	1	0						
1168217	7	8	1	5	11	8		
1168218			2	0	3	4		
1168219					1	0		
1168220	2	2	1	0	0	3		
1168221	0	3						
1200224			2	1	4	8	3	0
1200225			0	2	1	0	0	2
1200226			6	8				
1200227			10	4				
1200228			4	7				
1200229			0	7				
1200230			1	1	3	1	0	2
1200232			1	6	9	9	2	3
1200233			1	4				
1200234			7	9				
1200235					6	0		
1200236			0	3				
1200237			0	2	2	7	1	3
1200238			0	5			15	15
Within year p-value from paired t-test for equal days spawning at two receivers	0.13		0.007		0.62		0.44	

Stn Number	Station Description	Easting	Northing	Serial Number	Basin
1	on east shore of southern spawn area on North basin (this stn is most southern on N basin)	585329	5464638	220067	North
2	on east shore of southern spawn area on North basin	585498	5465219	220140	North
3	on west shore, across from cotton creek spawn area	584210	5467239	220142	North
4	on east shore, lower end of cotton creek spawn area	585396	5467099	220144	North
5	in top end of Cotton Crk spawning area on east shore	585498	5467790	220161	North
6	N end of South Basin, on West shore in bay before channel	584065	5461746	220162	South
7	S end of South Basin on east shore	584815	5458993	220163	South
8	Piling in channel, closer to North Basin	584684	5463182	220164	Channel

Figure 1. Location of receivers in Moyie Lake. An additional receiver was placed at the outlet of Moyie Lake (very southern point on the map); no detections were ever recorded on that receiver.
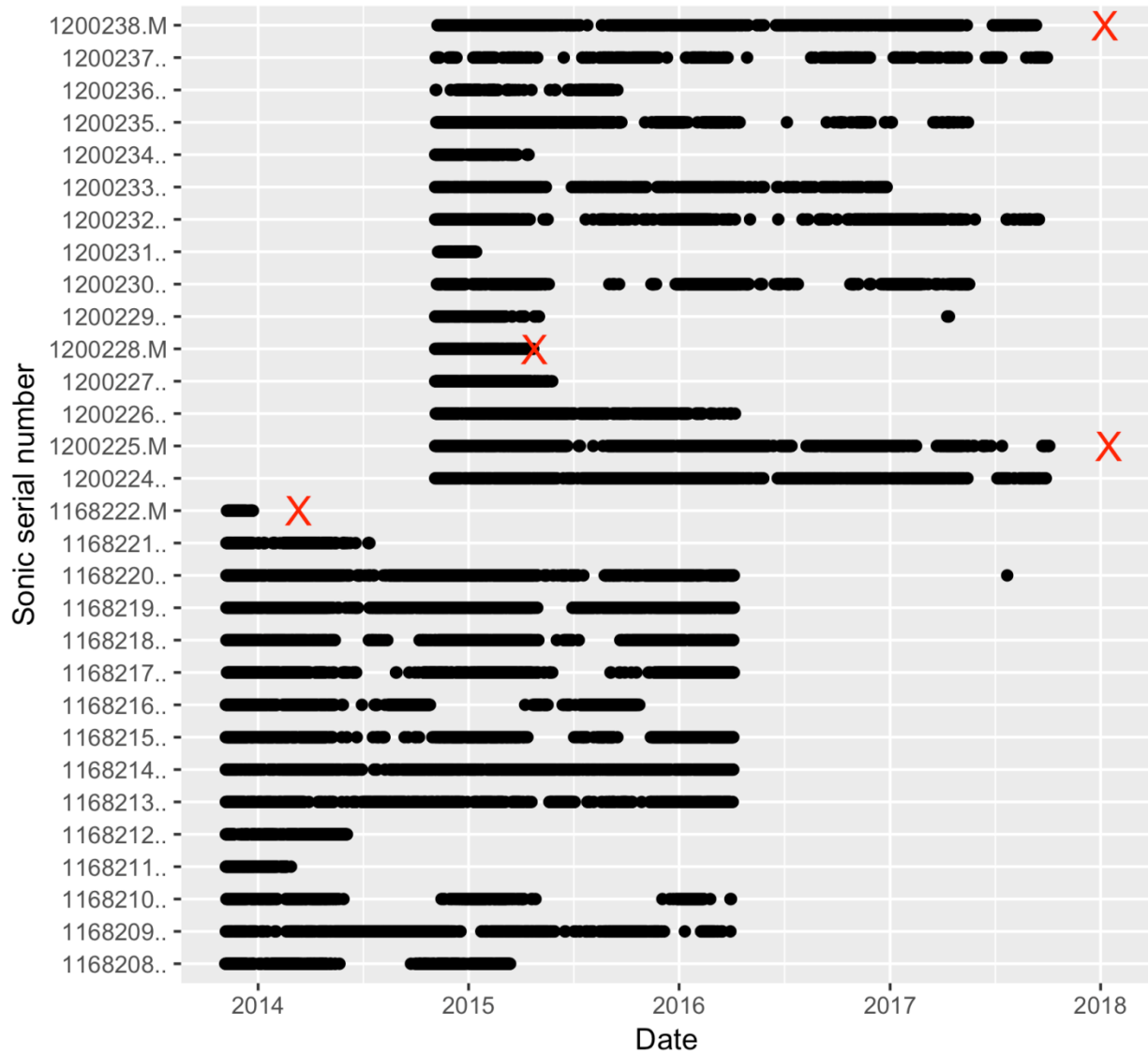
Figure 2. Detections of sonic tags. M suffix for tag number indicates known angler mortality at date indicated by X. There are two tags with obvious outliers.
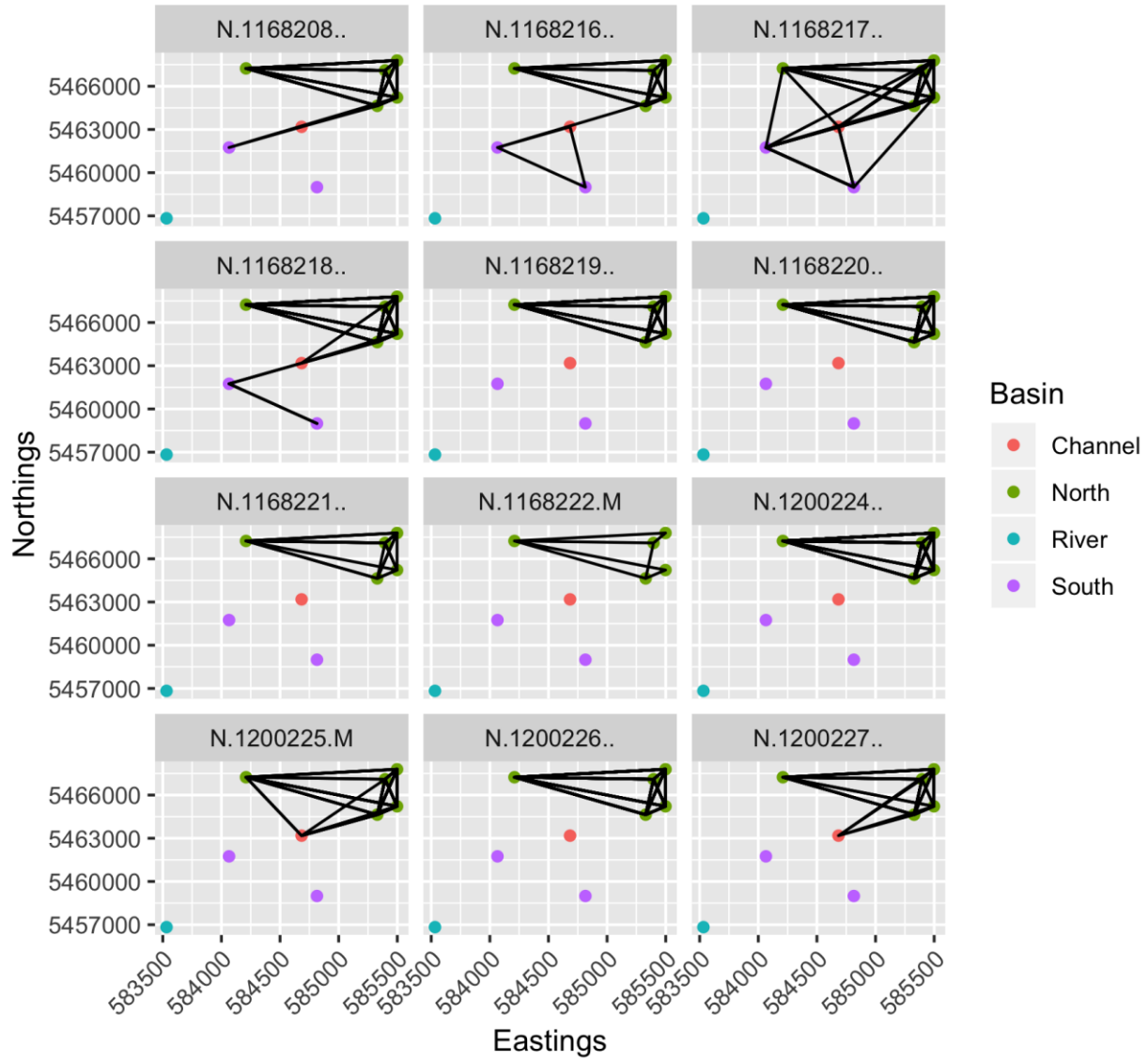
Figure 3a. Movement of individual fish among the receiver stations.
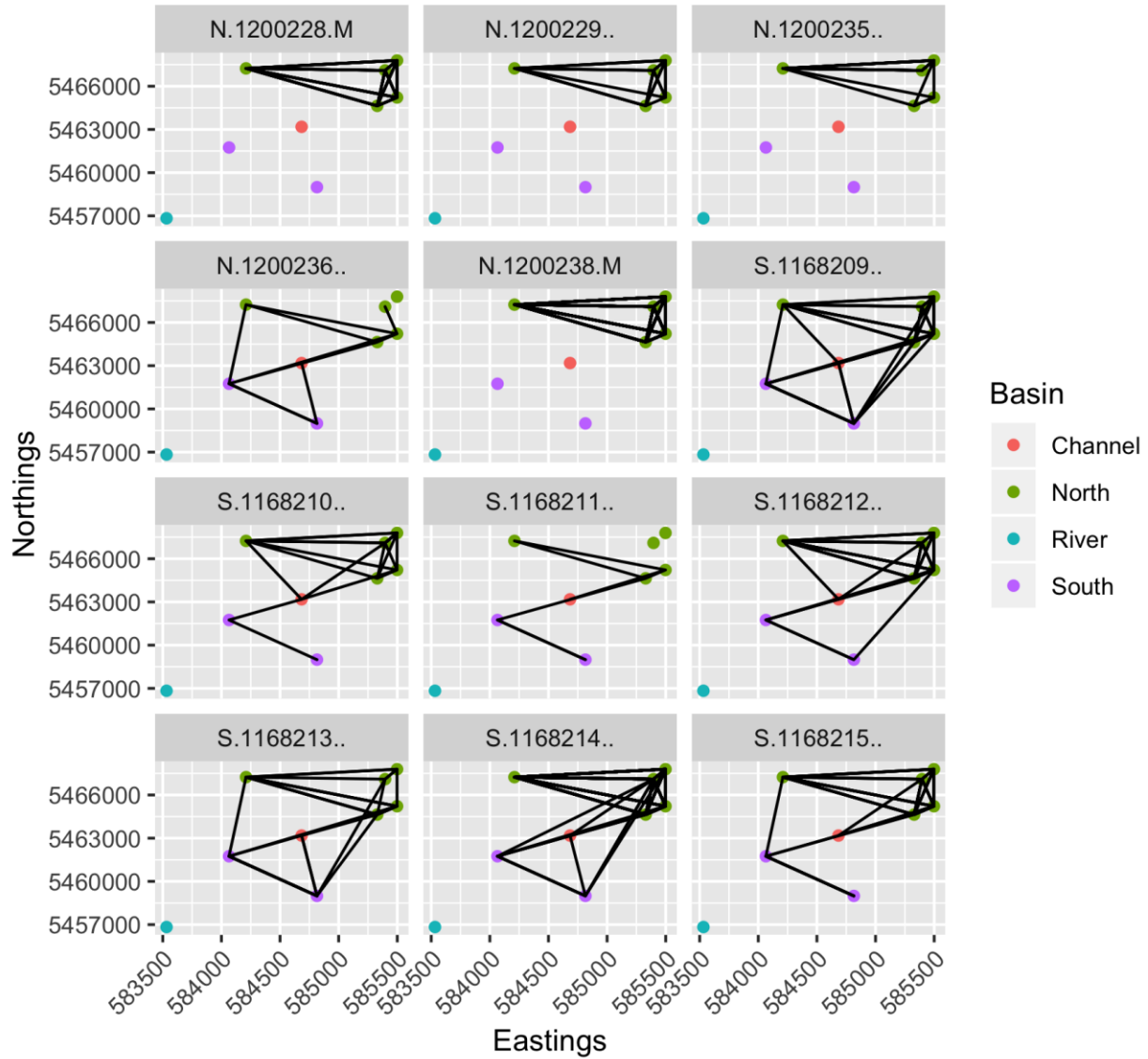
Figure 3b. Movement of individual fish among the receiver stations.
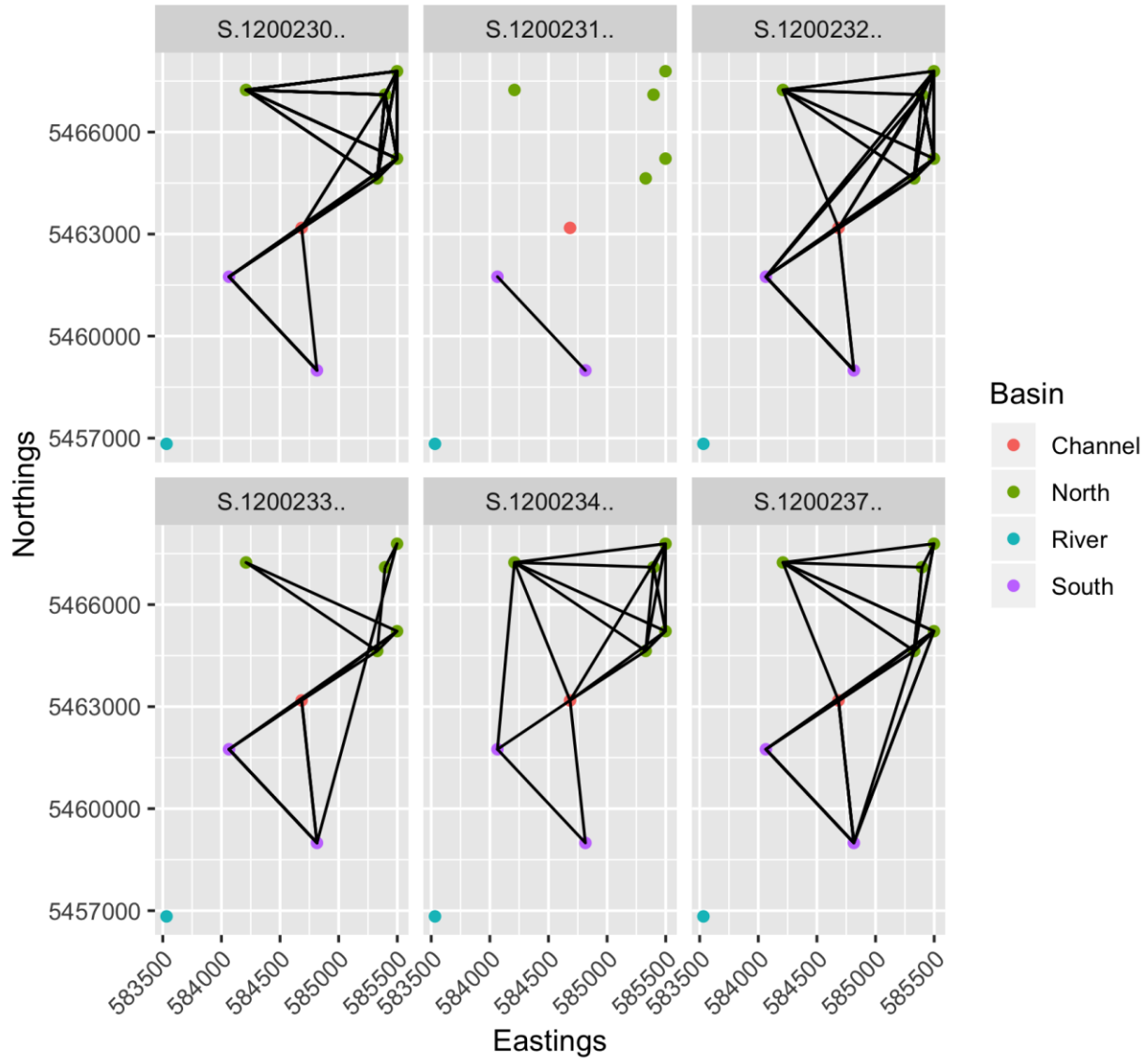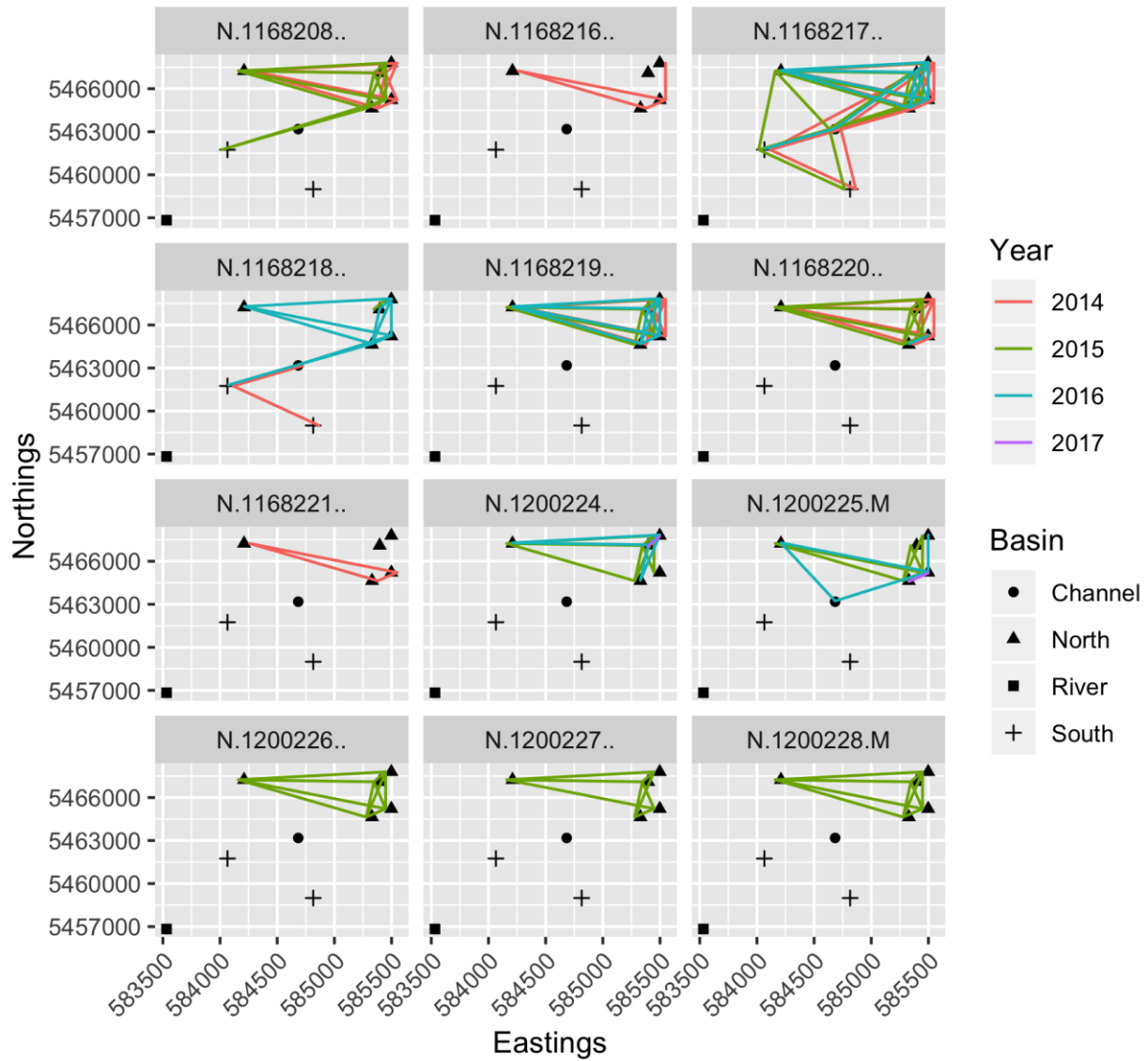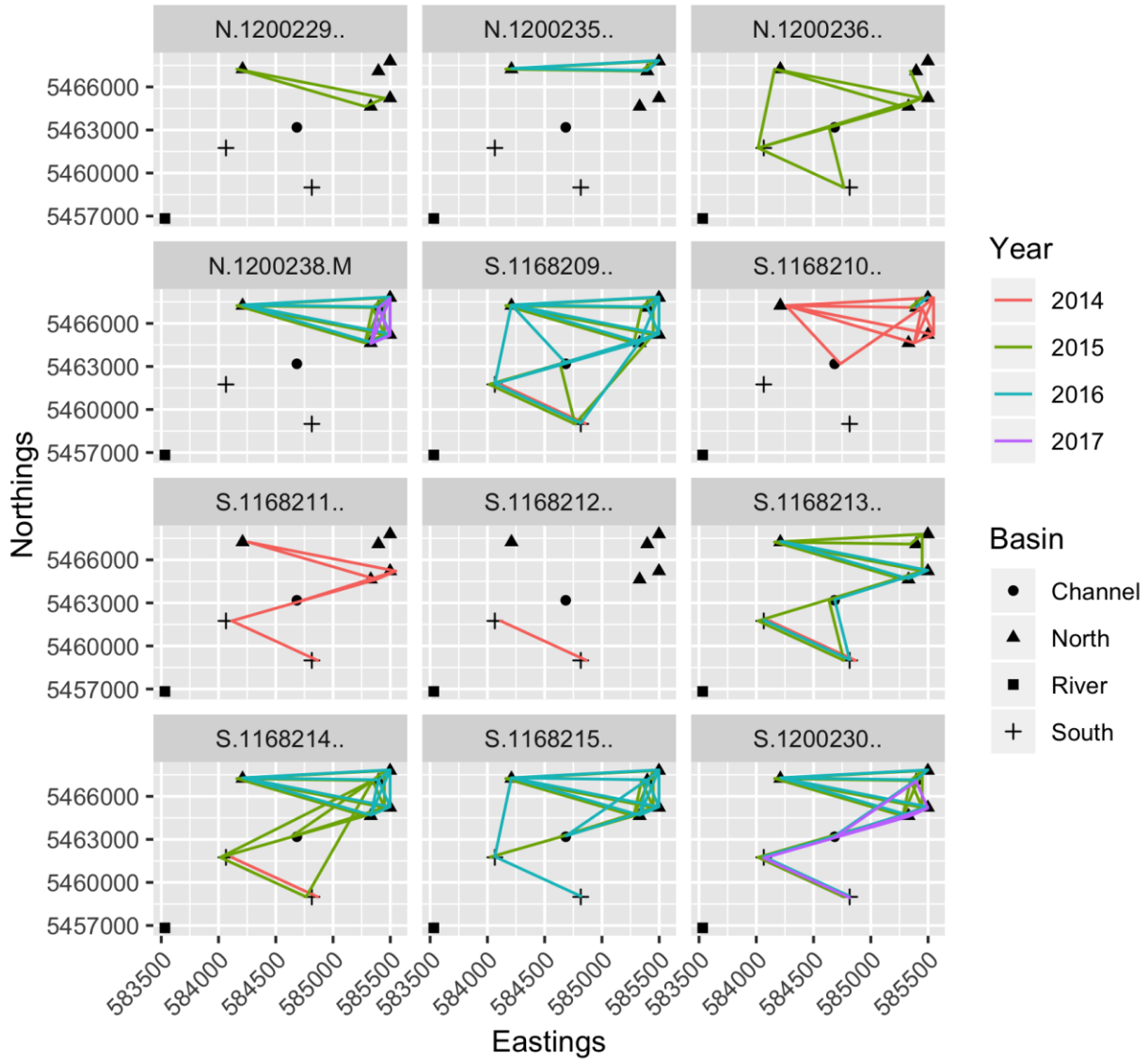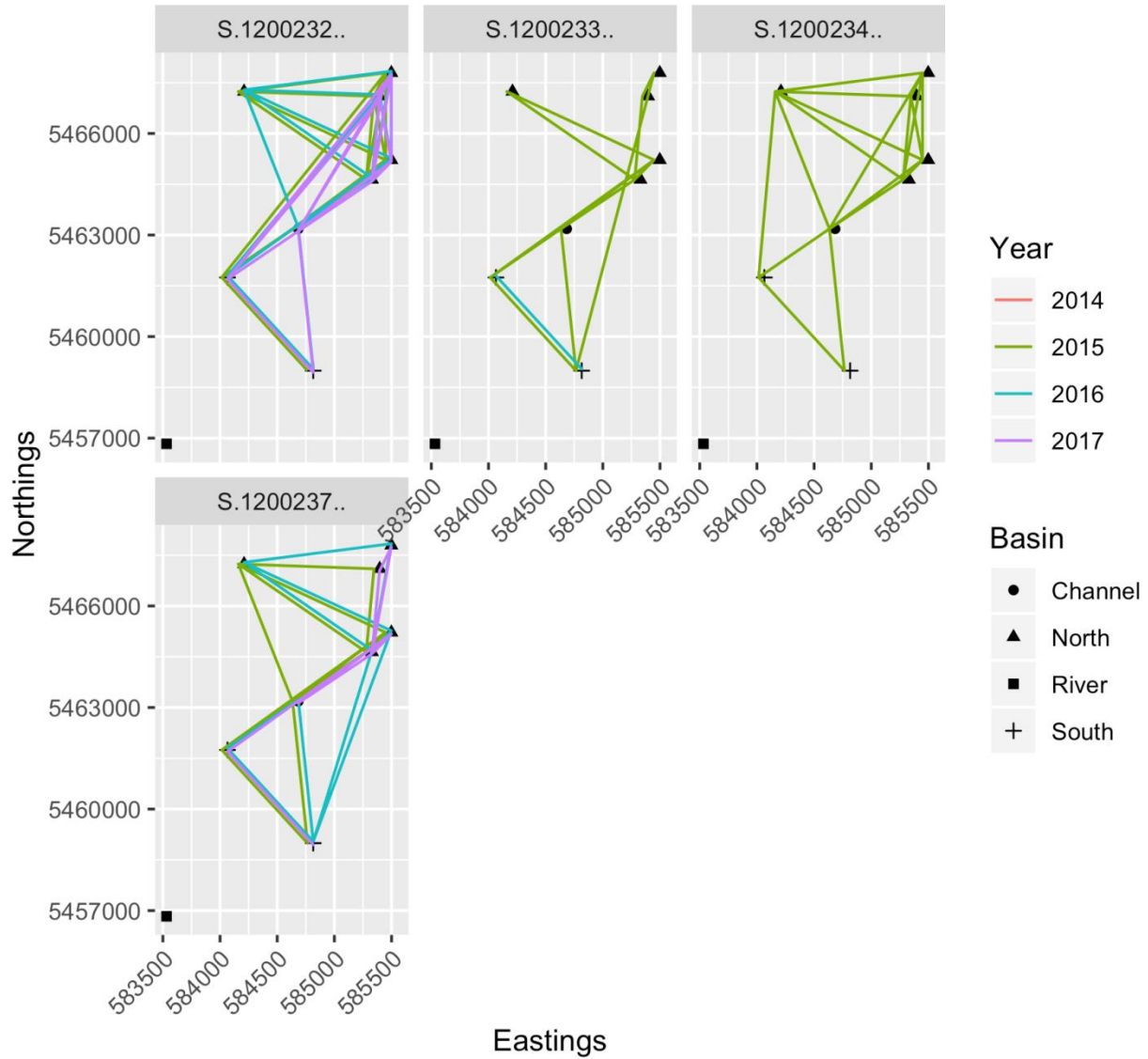
Figure 3c. Movement of individual fish among the receiver stations.

Figure 4a. Movement of individual fish among the receiver stations during the spawning period only (Julian day 35 to 56 of each year).

Figure 4b. Movement of individual fish among the receiver stations during the spawning period only (Julian day 35 to 56 of each year).

Figure 4c. Movement of individual fish among the receiver stations during the spawning period only (Julian day 35 to 56 of each year).
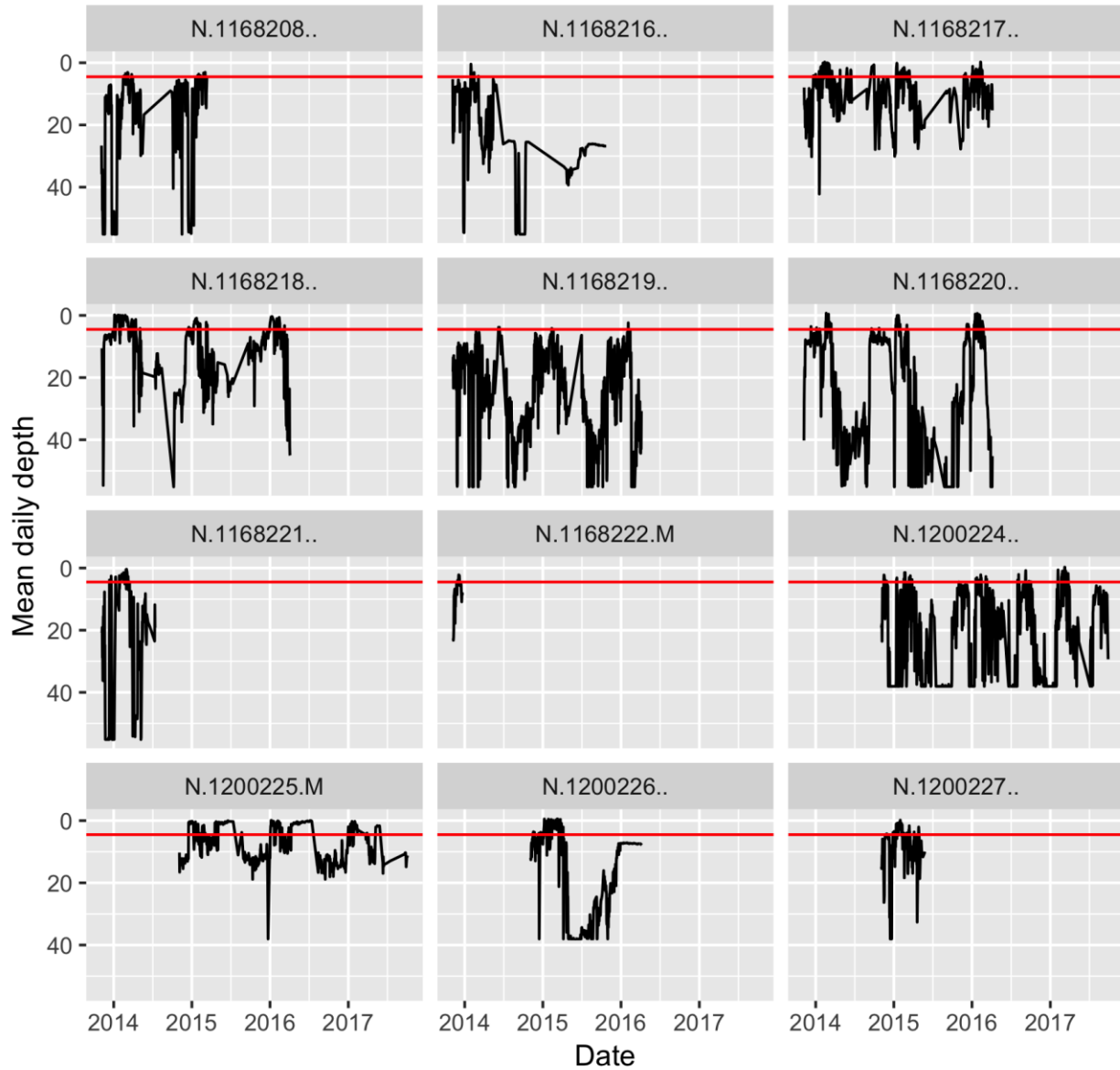
Figure 5a. Mean daily depth of individual fish. Changes in maximum depth recorded (40 m or 60 m) reflect changes in the programming of the tags over the study.
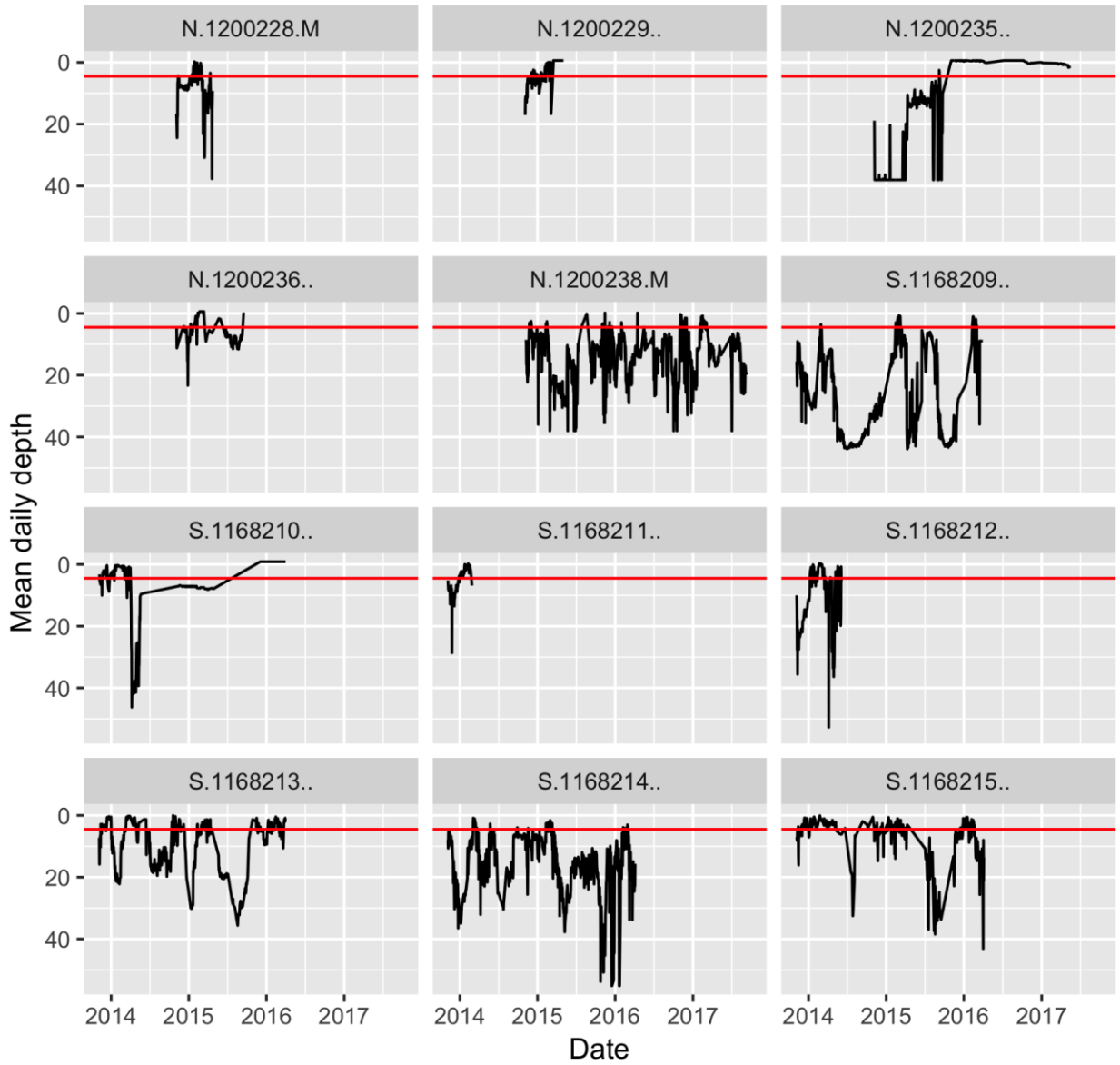
Figure 5b. Mean daily depth of individual fish. Changes in maximum depth recorded (40 m or 60 m) reflect changes in the programming of the tags over the study.
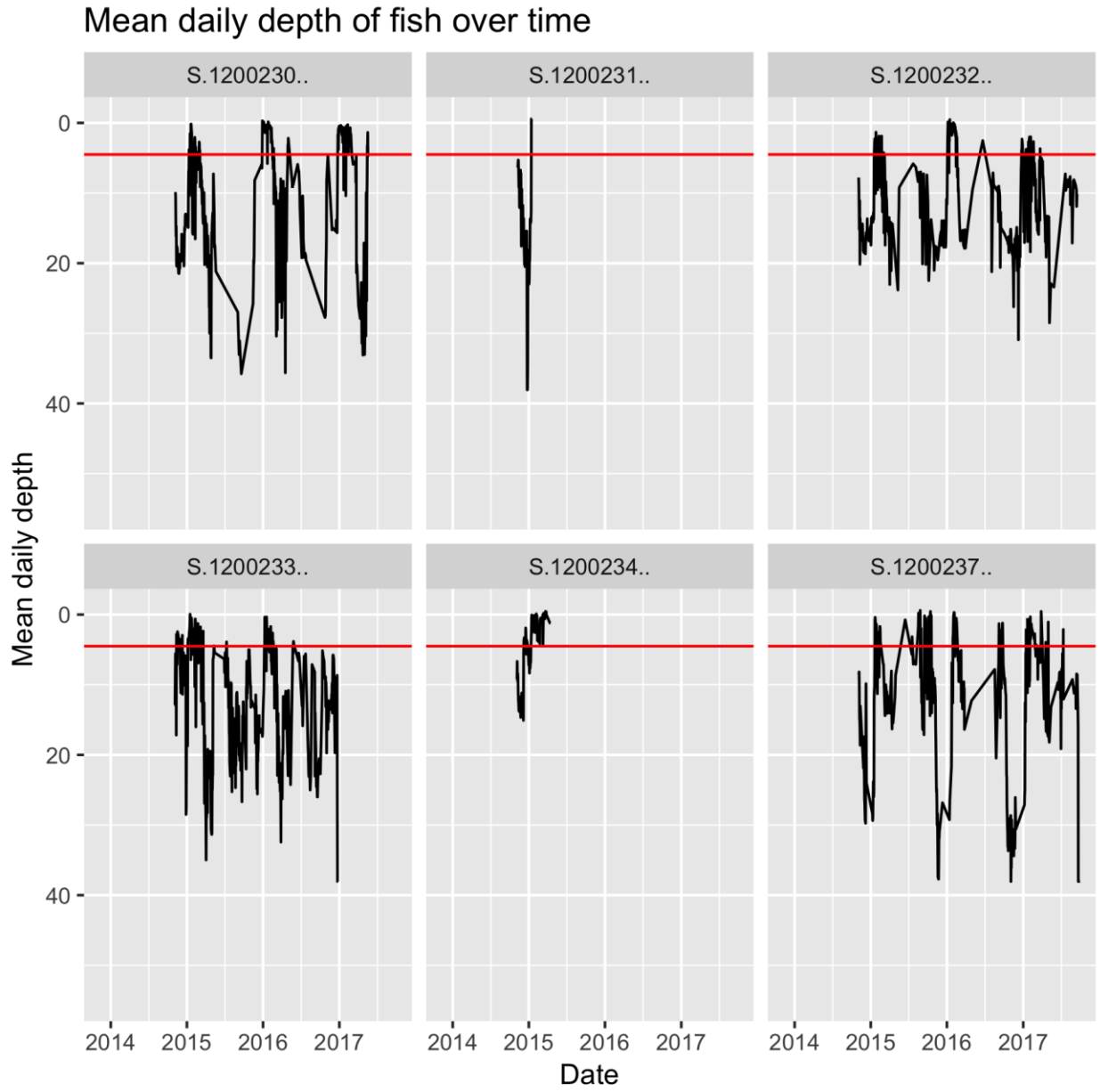
Figure 5c. Mean daily depth of individual fish. Changes in maximum depth recorded (40 m or 60 m) reflect changes in the programming of the tags over the study.

Appendix 1. Detections of sonic tags that were removed prior to subsequent analyses.

ID	Date Time	Transmitter	Receiver	Station
1217482	2017-04-10 05:38:19	1200229	220161	Moyie 5
1217483	2017-04-10 05:44:31	1200229	220161	Moyie 5
1217507	2017-04-10 08:58:54	1200229	220161	Moyie 5
1217508	2017-04-10 09:34:47	1200229	220161	Moyie 5
1217509	2017-04-10 09:38:51	1200229	220161	Moyie 5
1217512	2017-04-10 10:53:26	1200229	220161	Moyie 5
1217513	2017-04-10 10:57:18	1200229	220161	Moyie 5
1217518	2017-04-10 12:12:25	1200229	220161	Moyie 5
1217519	2017-04-10 12:15:46	1200229	220161	Moyie 5
1217520	2017-04-10 12:18:14	1200229	220161	Moyie 5
1217522	2017-04-10 12:21:17	1200229	220161	Moyie 5
1217629	2017-04-12 04:49:28	1200229	220161	Moyie 5
1217766	2017-04-13 10:35:53	1200229	220161	Moyie 5
1228319	2017-07-23 07:27:49	1168220	220144	Moyie 4