USGS
science for a changing world

In Cooperation with the U.S. Forest Service, Montana Fish Wildlife and Parks, and Montana Trout Unlimited

Timing and Location of Spawning by Non-native Lake Trout in Lindbergh and Holland Lakes, Montana

2013 Progress Report

Vincent S. D'Angelo[*1], Brady J. Miller[1], and Clint C. Muhlfeld[1]

[1] USGS Northern Rocky Mountain Science Center, Glacier Field Station, Glacier National Park, West Glacier, Montana USA 59936
*Corresponding author: *vdangelo@usgs.gov*

Introduction

Non-native species of fish threaten native fishes throughout North America, and in the Rocky Mountains, introduced populations of lake trout *Salvelinus namaycush* threaten native populations of bull trout *S. confluentus* (Donald and Alger 1993). Lake trout are large, long-lived, top-level predators native to deep, cold, oligotrophic lakes of Canada and northern parts of the United States, including the Great Lakes (Crossman 1995). During the late 19th and early 20th century, lake trout were widely introduced into lakes and reservoirs outside their native range. More recently, the species is expanding its range in the western United States through dispersal and unauthorized translocations (Martinez et al. 2009). While lake trout occupy an important ecological niche as a top-level predator in lakes where they are native, they have often become predators and competitors with native and recreational fishes in lakes where they have been introduced (Fredenberg 2002; Ruzycki et al. 2003; Koel et al. 2005; Martinez et al. 2009; Cox 2010), resulting in cascading impacts within and beyond the affected water bodies and terrestrial communities. Eradication or suppression of nonnative populations, therefore, may be required as an effective management strategy for reducing the spread of nonnative lake trout to protect and conserve native fish populations (D'Angelo et al. 2010; Downs et al. 2011; Rosenthal 2012).

Non-native lake trout were first discovered in the Swan Lake and River system in 1998 (Vernon 1998). Although a suppression program is currently underway in Swan Lake (Rosenthal 2012), lake trout have apparently dispersed upriver and colonized Holland and Lindbergh lakes, threatening native bull trout populations. The objective of this study is to determine the timing and location of lake trout spawning in Holland and Lindbergh Lakes by December, 2014. This progress report briefly summarizes lake trout capture and telemetry results during the summer and fall of 2013.

Methods

During July and September, sonic telemetry tags (Sonotronics CTT-83-3-I) were implanted in nine adult-sized lake trout (mean total length, 577 mm; range: 530 – 652 mm;

mean weight, 1370 g) captured in Lindbergh Lake, and three adult-sized lake trout (mean total length, 649 mm; range: 561 – 695; mean weight, 3023 g) captured in Holland Lake (Table 1). Fish were captured with the assistance of lake trout anglers from the Flathead Valley. Warm ambient (30^{o}C) and surface water (>15.0^{o}C) temperatures required quick implantation of tags, which precluded determining the sex and reproductive status of each tagged fish during surgery. Maturity was therefore estimated based on body length, with fish >550 mm in total length considered sexually mature. Tissue samples were taken from all lake trout captured for later genetic analyses and sub-adult-sized lake trout (<500 mm) were sacrificed to collect otoliths for future microchemistry analyses. When possible, tissue samples were also taken from bull trout and any *Oncorhynchus spp.* that were incidentally captured.

Telemetry was conducted on a systematic stratified schedule and focused on observing lake trout movements during the spawning period (broadly considered October – early November). Tagged fish were also opportunistically relocated immediately after tagging. Tagged lake trout in Lindbergh Lake were relocated in mid-July, mid-September, and then twice weekly from 14 October to 1 November for a total of 77 relocations (Table 2; Figure 1). Tagged lake trout in Holland Lake were relocated twice weekly from 14 October to 1 November (Table 3) for a total of 18 relocations. Lake trout are primarily nocturnal spawners (Gunn 1995; Esteve 2008) and fish were typically relocated between 18:00 and 01:00 hours during the spawning period. To graphically display telemetry results, kernel density plots were generated for each lake expressing relative density of relocations within a 100 m radius per 100 m^2 (Figures 2 and 3).

Preliminary Results

Two clusters of relocations were observed in Lindbergh Lake during the spawning period (October 14 – November 1; Figure 2). Fifteen relocations consisting of five different fish were observed near the inlet and seven relocations consisting of three individuals were observed near the east shore about half-way between the inlet and outlet (Figure 2). Of these fish, two individuals were relocated in both areas. The cluster near the inlet may represent a spawning location as fish were not relocated there prior to 14 October 2013. The cluster near the east

shore consisted of fewer individual fish, but was located near a shallow (~10 m) cobble/boulder deposit that may provide ideal spawning habitat. Summer relocations indicated a high use foraging area at mid-lake at depths of 7 to 15 m (Figure 2).

Discerning lake trout spawning behavior and locations was more difficult in Holland Lake because only three fish were tagged and monitored during the spawning period. Two fish were primarily observed in the same southeast cove where they were initially captured, and one fish was captured in the same cove and subsequently located further west along the south shore (Figure 3). The southeast cove is relatively deep (20–30 m) and is comprised of cobble to boulder sized substrates. This area may provide suitable spawning and foraging habitat for lake trout in Holland Lake. Much of the western half of the lake is relatively shallow and no relocations were observed in those areas. A larger sample size is needed to more accurately describe patterns of lake trout movement and spawning behavior in Holland Lake.

Twenty sub-adult lake trout, nine bull trout, one rainbow trout *O. mykiss* and one northern pikeminnow *Ptychocheilus oregonensis* were captured in Lindbergh Lake in addition to tagged fish (Table 4). Twenty-nine bull trout, one rainbow trout and one northern pikeminnow were captured in Holland Lake in addition to tagged fish (Table 4). No sub-adult lake trout were captured in Holland Lake. Angling was typically performed by trolling at 1.0 – 2.0 miles per hour using a combination of downrigger and lead-core lines. On average, five rods were active and catch rates were calculated based on this level of effort. The mean daily angling catch rate for lake trout was much higher in Lindbergh Lake (0.54 fish/hr. vs. 0.10 fish/hr.), while the mean daily angling catch rate for bull trout was much higher in Holland Lake (0.78 fish/hr. vs. 0.27 fish/hr.; Table 4).

Based on the size of the captured fish and our movement results, it is likely that there are reproducing populations of lake trout in both Holland and Lindbergh lakes. Further, it appears that lake trout are likely more abundant and established in Lindbergh Lake compared to Holland Lake (as of 2013) because daily catch rates were much higher in Lindbergh Lake and a number of sub-adults were captured. Only adult lake trout were captured in Holland Lake suggesting that invasion may be relatively recent. The observation of two clusters of fish in

Lindbergh Lake during the spawning period indicates that these areas are likely used for spawning. However, additional data are needed to determine the exact timing and location of spawning in both lakes. Capturing additional fish in each lake and dedicating more time before, during, and after the spawning period would enhance our understanding of lake trout spawning (telemetry was precluded October 1-14, 2013 due to the government shutdown). Updating the bathymetry profiles of each lake is also necessary and would contribute greatly to the discovery and exploitation of spawning locations in Lindbergh and Holland lakes.

Acknowledgements

We would like to thank the U.S. Forest Service, Montana Trout Unlimited, the Montana Department of Natural Resources and Conservation and the Lindbergh Lake Homeowners Association for providing funding for this project. We specifically thank Craig Kendall and Beth Gardner (USFS), Bruce Farling (MTTU), Jim Bower (MTDNRC), Leo Rosenthal (MTFWP) and Judd Binley for their commitments and logistical support. All fish were captured with the invaluable angling expertise provided by Mike Howe and Tim Johnson.

References

Cox B. 2010. Assessment of an invasive lake trout population in Swan Lake, Montana. M.S. Thesis. Montana State University, Bozeman, Montana.

Crossman E. 1995. Introduction of the lake trout in areas outside its native distribution: a review. Journal of Great Lakes Research 21 (Supplement 1): 17-29.

D'Angelo V., Muhlfeld C., Miller B., and Fredenberg C. 2010. Preservation of bull trout in Glacier National Park: Continued suppression of non-native lake trout in Quartz Lake, Glacier National Park.

Donald D.B., Alger D.J. 1993. Geographic distribution, species displacement, and niche overlap for lake trout and bull trout in mountain lakes. Canadian Journal of Zoology 71:238-247.

Downs C.C., Stafford C., Langner H., and Muhlfeld C. 2011. Glacier National Park fisheries

inventory and monitoring bi-annual report, 2009-2010. National Park Service, Glacier National Park, West Glacier, Montana.

Esteve M., McLennan D.A., Gunn J.M. 2008. Lake trout (*Salvelinus namyacush*) spawning behavior: the evolution of a new female strategy. Environmental Biology of Fish 83:69-76.

Fredenberg W. 2002. Further evidence that lake trout displace bull trout in mountain lakes. Intermountain Journal of Sciences 8**:**143-152.

Gunn J. 1995. Spawning behavior of lake trout: Effects on colonization ability. Journal of Great Lakes Research 21 (Supplement 1):323-329

Koel T.M., Bigelow P.E., Doepke P.D., Ertel, B.D., Mahony D.L. 2005. Nonnative lake trout result in Yellowstone cutthroat trout decline and impacts to bears and anglers. Fisheries 30: 10-19.

Martinez P.J., Bigelow P.E., Deleray M.A., Fredenberg W.A., Hansen B.S., Horner N.J., Lehr S.K., Schneidervin R.W., Tolentino S.A., Viola A.E. 2009. Western lake trout woes. Fisheries 34:424-442.

Rosenthal L. 2012. Experimental removal of lake trout in Swan Lake, MT: 2012 Annual report. http://fwpiis.mt.gov/content/getItem.aspx?id=59248

Ruzycki, J.R., Beauchamp D.A., Yule D.L. 2003. Effects of introduced lake trout on native cutthroat trout in Yellowstone Lake. Ecological Applications 31**:**23-37.

Vernon S. 1998. Lake trout caught in Swan River. Seeley Swan Pathfinder. July, 1998.

Table 1: Descriptive data for lake trout tagged in Lindbergh and Holland lakes, Montana 2013.

Waterbody	Tag Date	Tag ID	Length (mm)	Weight (g)	Sex
Lindbergh Lake	7/15/13	78.4668	531	1120	Unknown
Lindbergh Lake	7/15/13	76.4557	604	1570	Unknown
Lindbergh Lake	7/15/13	73.4556	540	1385	Unknown
Lindbergh Lake	7/15/13	71.3748	615	1575	Unknown
Lindbergh Lake	7/15/13	75.4556	556	1425	Unknown
Lindbergh Lake	7/16/13	79.5558	652	1600	Unknown
Lindbergh Lake	7/16/13	72.3757	591	1361	Unknown
Lindbergh Lake	7/25/13	77.4667	570	1275	Unknown
Lindbergh Lake	9/17/13	74.4457	530	1025	Unknown
Holland Lake	9/18/13	75.3667	690	3175	Unknown
Holland Lake	9/18/13	74.3666	695	3402	Unknown
Holland Lake	9/23/13	73.3584	561	2493	Unknown

Table 2: Relocation data for telemetered lake trout in Lindbergh Lake, Montana, during the summer and fall of 2013.

Date	Time	Tag ID	Total Depth (m)	UTM12x	UTM12y
7/23/13	21:14	76.4557	12.6	293129	5250978
7/23/13	21:04	71.3748	11.4	293108	5251357
7/23/13	21:27	79.5558	30.0	293098	5250552
7/23/13	21:30	73.4556	14.9	293331	5250750
7/23/13	21:43	72.3757	18.3	293343	5249681
7/23/13	21:36	78.4668	20.0	293358	5249260
7/24/13	14:52	75.4556	14.9	293894	5251905
7/24/13	15:03	79.5558	33.2	293388	5251294
7/24/13	15:09	73.4556	17.4	293264	5250993
7/24/13	15:13	76.4557	12.9	293126	5250998
7/24/13	15:21	71.3748	16.1	293257	5251033
7/24/13	15:48	78.4668	21.6	293198	5250057
7/24/13	15:53	72.3757	17.4	293345	5249900
7/24/13	19:55	79.5558	13.7	293255	5251203
7/24/13	19:56	73.4556	13.7	293251	5251192
9/17/13	15:45	73.4556	17.2	293300	5250943
9/17/13	18:20	77.4667	17.7	293985	5252501
9/17/13	17:59	78.4668	27.4	293445	5252027
9/17/13	18:02	79.5558	24.4	293745	5251980
9/17/13	17:59	74.4457	17.2	293289	5250158
9/17/13	17:47	75.4556	23.3	293426	5249368
9/17/13	18:10	72.3757	13.3	293494	5248719
9/17/13	17:40	71.3748	14.2	293521	5248587
9/17/13	18:05	76.4557	28.3	293074	5250319
10/14/13	22:41	71.3748	11.8	293321	5247875
10/14/13	22:52	72.3757	7.6	293171	5247677

Table 2 Continued:

Date	Time	Tag ID	Total Depth (m)	UTM12x	UTM12y
10/14/13	23:45	73.4556	17.7	293989	5252495
10/14/13	23:49	74.4457	11.9	294641	5253173
10/14/13	22:32	75.4556	11.4	293285	5247828
10/14/13	22:57	76.4557	11.0	293252	5247833
10/14/13	23:36	78.4668	16.8	293486	5251383
10/14/13	23:07	79.5558	9.4	293331	5248185
10/16/13	20:42	71.3748	7.6	293176	5247668
10/16/13	20:39	72.3757	7.7	293191	5247668
10/16/13	21:47	73.4556	14.0	293338	5250881
10/16/13	22:30	74.4457	9.1	294257	5253278
10/16/13	20:56	75.4556	11.1	293296	5248045
10/16/13	20:27	76.4557	11.3	293268	5247892
10/16/13	22:38	77.4667	15.3	294086	5252645
10/16/13	21:58	78.4668	23.6	293466	5251306
10/16/13	22:19	79.5558	26.0	293558	5252485
10/20/13	21:39	71.3748	7.1	293379	5248659
10/20/13	21:10	72.3757	7.0	293369	5247704
10/20/13	21:27	73.4556	16.1	293542	5249212
10/20/13	22:04	74.4457	4.9	293071	5250946
10/20/13	22:22	75.4556	5.6	293346	5250158
10/20/13	21:45	76.4557	13.2	293494	5248646
10/20/13	22:41	77.4667	12.5	293252	5250303
10/20/13	20:54	78.4668	16.3	294408	5253126
10/20/13	22:32	79.5558	15.5	293430	5251188
10/23/13	21:30	71.3748	14.0	293525	5248952
10/23/13	21:49	72.3757	4.7	293185	5247606
10/23/13	21:09	73.4556	11.8	293337	5250301
10/23/13	20:07	74.4457	3.7	294899	5253525
10/23/13	21:14	75.4556	11.1	293234	5250150
10/23/13	21:44	76.4557	10.3	293356	5247790
10/23/13	20:25	77.4667	8.4	294054	5252487
10/23/13	20:52	78.4668	13.0	293101	5251426
10/23/13	20:40	79.5558	20.7	293188	5251318
10/29/13	20:58	71.3748	7.1	293711	5248549
10/29/13	20:42	72.3757	10.1	293675	5248709
10/29/13	21:15	73.4556	9.7	293348	5250203
10/29/13	21:56	74.4457	3.4	294829	5253584
10/29/13	21:21	75.4556	11.7	293344	5250549
10/29/13	20:20	76.4557	12.6	293399	5247806
10/29/13	21:43	77.4667	7.9	294053	5252514
10/29/13	21:33	78.4668	14.1	293494	5251310
10/29/13	20:31	79.5558	12.6	293395	5247869
11/1/13	19:31	71.3748	9.0	293607	5248237
11/1/13	19:49	72.3757	7.8	293333	5247700
11/1/13	20:08	73.4556	8.9	293368	5250220
11/1/13	19:35	74.4457	9.7	293605	5248238

Table 2 Continued:

Date	Time	Tag ID	Total Depth (m)	UTM12x	UTM12y
11/1/13	20:11	75.4556	11.9	293289	5250251
11/1/13	19:55	76.4557	7.0	293225	5247635
11/1/13	20:38	77.4667	14.3	294142	5252660
11/1/13	20:25	78.4668	7.8	294040	5251862
11/1/13	19:44	79.5558	10.8	293431	5247932

Table 3: Relocation data for telemetered lake trout, Holland Lake, Montana during the fall of 2013.

Date	Time	Tag ID	Total Depth (m)	UTM12x	UTM12y
10/14/13	20:23	73.3584	7.0	305233	5258232
10/14/13	19:48	74.3666	10.0	305576	5258129
10/14/13	20:23	75.3667	40.0	305231	5258231
10/16/13	23:52	73.3584	7.5	303597	5257904
10/16/13	23:29	74.3666	8.7	305599	5258183
10/16/13	23:41	75.3667	5.9	305150	5258105
10/20/13	23:48	74.3666	11.0	305583	5258201
10/20/13	23:54	75.3667	18.1	305334	5258374
10/21/13	0:09	73.3584	2.3	303695	5257869
10/23/13	23:33	73.3584	2.6	303700	5257878
10/23/13	23:10	74.3666	7.0	305599	5258147
10/23/13	23:23	75.3667	38.0	305203	5258228
10/29/13	19:06	73.3584	4.2	304058	5258062
10/29/13	18:38	74.3666	8.7	305585	5258140
10/29/13	18:54	75.3667	18.5	305307	5258392
11/1/13	18:37	73.3584	2.5	303768	5257906
11/1/13	18:11	74.3666	10.6	305589	5258166
11/1/13	18:17	75.3667	20.0	305275	5258342

Table 4: Catch data by species, Lindbergh and Holland lakes, Montana, 2013. LKT = lake trout, BLT = bull trout, RBT = rainbow trout, NPM = northern pikeminnow.

Species	Total Captured	Length Range (mm)	Mean Daily CPUE (fish/hr)	*N* Genetics	*N* Otolith
Lindbergh Lake					
LKT	29	420-652	0.54	27	20
BLT	9	340-650	0.27	0	0
RBT	1	450	0.01	0	0
NPM	1	460	0.02	1	1
Holland Lake					
LKT	3	561-695	0.10	3	0
BLT	29	320-705	0.78	25	1
RBT	1	750	0.03	1	0
NPM	1	400	0.02	0	0

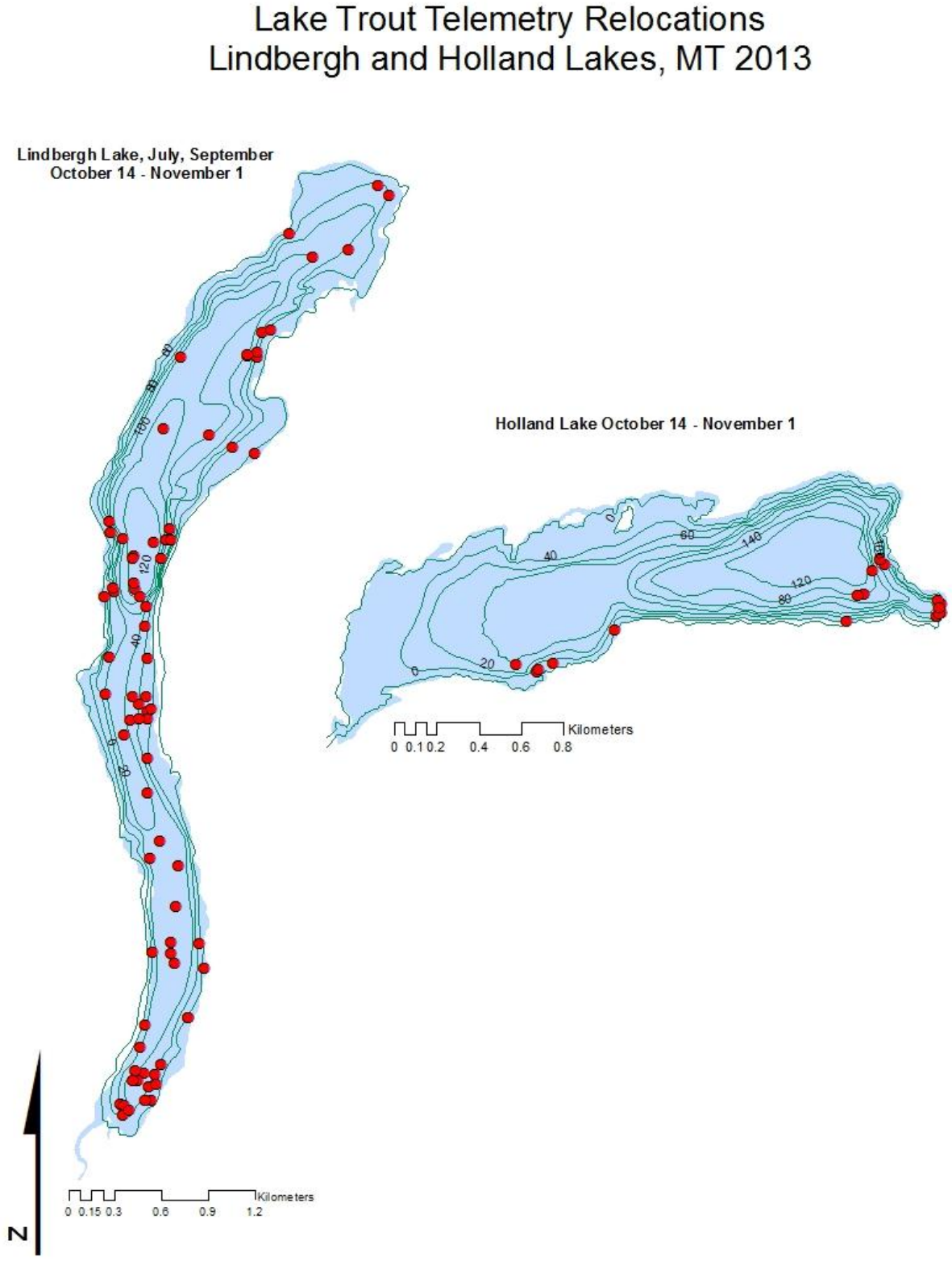

Figure 1: Relocations of tagged lake trout in Lindbergh and Holland lakes, Montana, 2013.

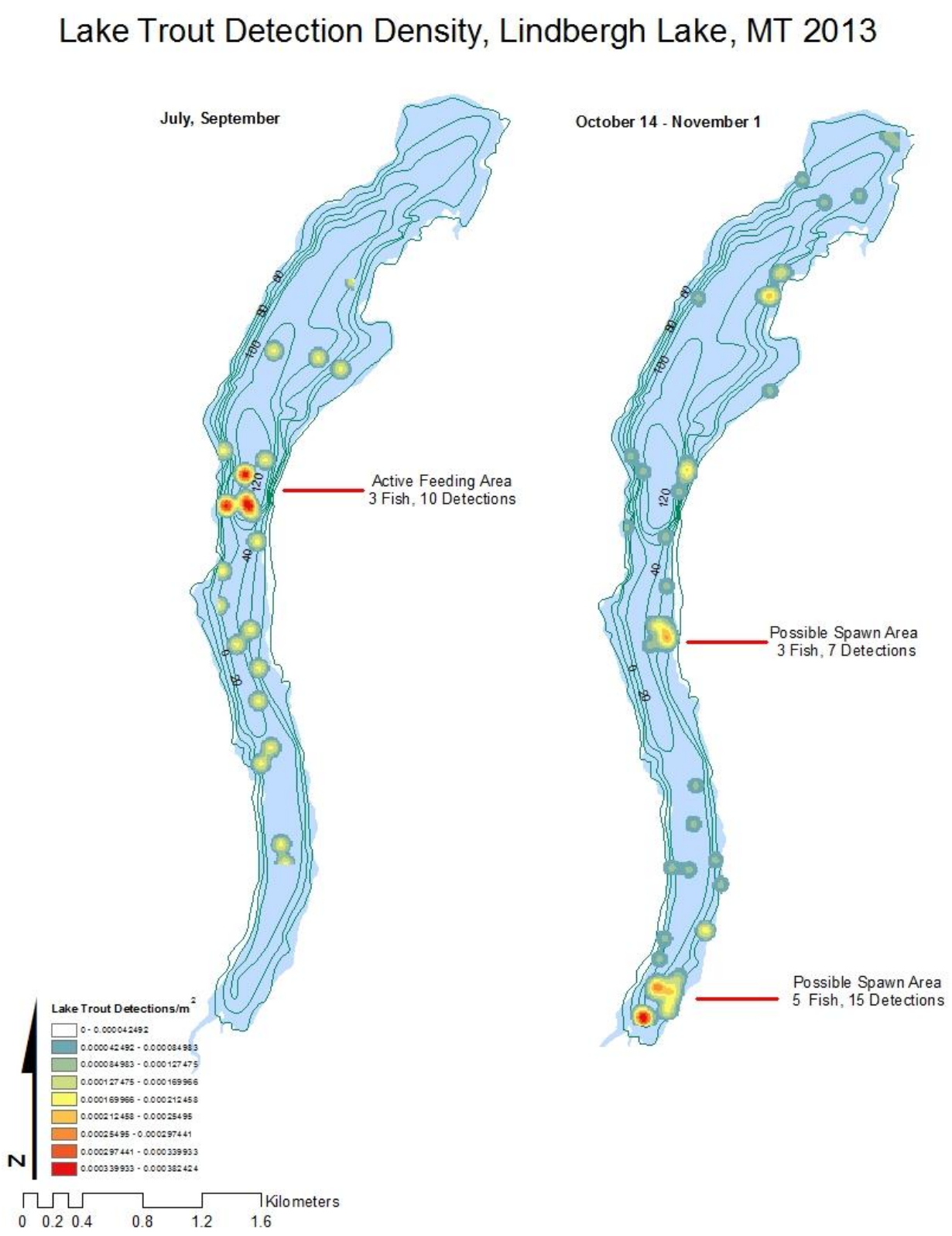

Figure 2: Kernel density plots for lake trout relocations in Lindbergh Lake, Montana, during the summer and fall 2013.

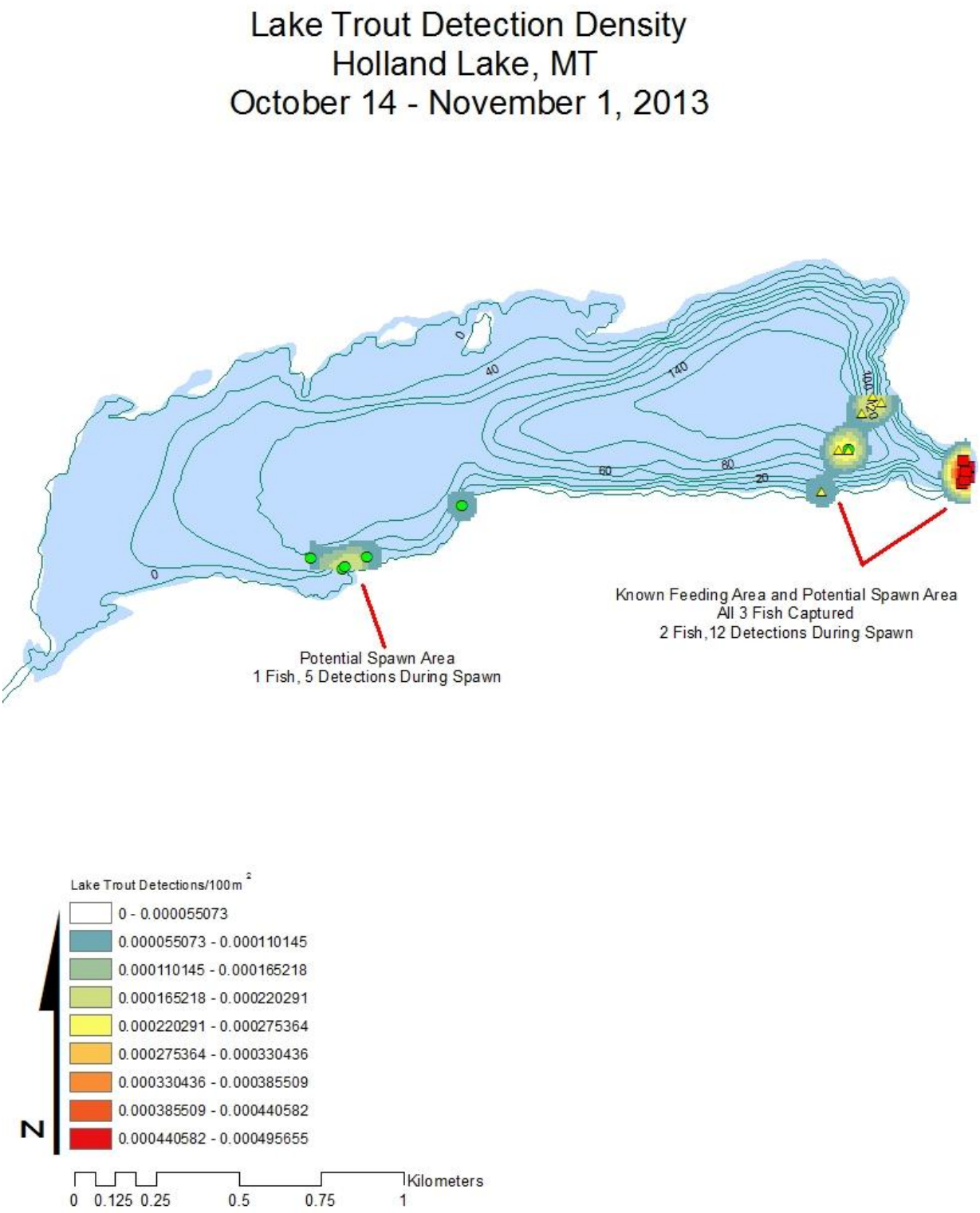

Figure 3: Kernel density plots and individual lake trout relocations, Holland Lake, Montana, fall 2013.