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Running Head: Ovenbird response to seismic lines.

Title: Functional and numerical responses of Ovenbirds (*Seiurus aurocapilla*) to changing seismic exploration practices in Alberta's boreal forest.

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ABSTRACT: Rapid development of energy reserves in the boreal forest of western Canada has raised concerns about the potential impacts of forest fragmentation caused by seismic lines. Seismic lines are narrow linear corridors cut by the energy sector to access remote areas. Traditionally, seismic lines were cut using a bulldozer and averaged about 8m in width. In response to concerns about conventional seismic line impacts, some energy companies have turned to new "best practices" that use lower-impact techniques to reduce their footprint (2 to 3m wide lines). Crucial to assessing the efficacy of this change in seismic policy for maintenance of biodiversity is determining how conventional and low-impact seismic lines are perceived by wildlife. We assessed the functional and numerical response of male Ovenbirds (Seiurus aurocapilla) to conventional and low-impact seismic lines in mature aspen forest in northeastern Alberta. Based on radio-telemetry, Ovenbirds perceived conventional seismic lines as creating a gap in the forest and used it as a territory boundary. In contrast, Ovenbirds incorporated low-impact seismic lines within their territories. Spot-mapping data suggested no differences in Ovenbird density in stands with a single conventional seismic line, multiple low-impact lines, or reference plots with no seismic lines. Despite the lack of numerical response to any seismic practice, we believe it is prudent to recommend energy companies consider using new low-impact approaches in their seismic operations to minimize the ecological risks of energy sector activity for forest birds.

KEYWORDS: Ovenbird, seismic lines, forest fragmentation, territorial behaviour, energy sector exploration

INTRODUCTION: Increasing human access into previously remote forested areas has raised concerns about the impacts of narrow linear features such as roads and trails on biodiversity (Rich et al., 1994). While the area of forest lost to linear features is relatively small, the resulting fragmentation effects caused by changes in patch size, isolation, and edge habitat can be considerable (Fahrig, 2003). In the boreal forest of Alberta - Canada, energy sector development has resulted in an extensive level of fragmentation with an average of 1.8 km per km^2 of anthropogenic edge per township (Schneider et al., 2003). In some areas of Alberta, the density of linear edge reaches as high as 6 to 7 km per km^2. Seismic lines are the major source of anthropogenic fragmentation created by the energy sector. Conventional seismic lines are traditionally created by a bulldozer that creates a series of 8m wide linear features on a loose grid system with a typical spacing of 300 to 500m between seismic lines (Government of Alberta, 1998). Although conventional seismic lines are intended to be temporary, all-terrain vehicle traffic, soil disturbance/compaction, and apical suppression prevent regeneration of trees on most lines. Vegetation suppression remains apparent for up to 20 years after clearing (Revel et al., 1984; MacFarlane 2003).

Concerns over regeneration rates, impacts on wildlife, and changes in economic policies that reduce the penalty paid by energy sector companies for timber damage, have resulted in some energy companies turning to new mulching technologies to create significantly narrower seismic lines (2 to 3m). These new "best" practices for seismic exploration have been touted as the ideal solution to the growing level of habitat loss occurring in Alberta's boreal forest due to energy sector activity. However, whether reducing seismic line width reduces fragmentation effects caused by edge is unknown. In addition, the number of low-impact lines being cut annually is increasing rapidly (Schneider et al., 2003). Part of this increase stems from a new extraction technology called Steam Assisted Gravity Drainage (SAGD) that requires detailed seismic information (3-D seismic grids) that can only be obtained using very tight line spacing (50 to 80m), often over very large areas (> 100km^2). Like conventional seismic lines, low-impact lines in SAGD areas tend to follow relatively straight linear paths in a systematic grid pattern. The shift from conventional natural gas and oil exploration to SAGD in several areas in Northeastern, Alberta has resulted in places where the total area disturbed by low-impact lines is similar to that created by conventional approaches but with significantly more edge habitat created per unit area of forest.

While 3-D seismic grids are perceived by humans as creating more edge than a conventional seismic plan, a key uncertainty is whether animals view such landscapes as fragmented. For birds that are forest specialists, linear features such as seismic lines may act as territory boundaries (Rail et al., 1997: Figure 1). If this is the case, then birds in 3-D seismic grids with "circular" territories greater than about 0.2 ha either have to radically modify the shape of their territories to fit between these lines or simply will not be able to use these areas (Figure 1). Alternatively, the low-impact lines we considered (2 to 3m) may be sufficiently narrow that birds do not recognize them as gaps and incorporate them within their home range. Inclusion of seismic lines within a bird's home range should result in no loss of habitat, meaning that no changes in home range attributes would be expected relative to contiguous forest. However, low-impact seismic lines have the potential to alter other ecological processes (i.e. reduce food supply with a territory). This could result in birds requiring larger home ranges to support their basic daily requirements (Smith and Shugart, 1986), which could reduce the number of birds capable of using an area due to territorial behavior (Burke and Nol, 1998).

The objective of this study was to compare the relative impact of habitat fragmentation caused by conventional and low-impact seismic lines as factors influencing the behavior and abundance of Ovenbirds (Seiurus aurocapilla). Using a combination of radio-telemetry and detailed spot-mapping, we tested whether dissecting forest stands with a single conventional seismic line resulted in different functional or numerical responses than 4 or 5 low-impact lines disturbing an equivalent area of habitat but creating 4-5X as much edge.

METHODS: Detailed information on the territorial behavior of 24 male Ovenbirds around seismic lines was collected using radio-telemetry (12 near conventional lines cut in 1993 and 12 near low-impact lines cut in 1998). To ensure we selected birds that held territories adjacent to seismic lines (i.e. there was no other territory holder between the focal individual and the seismic line) we: 1) used our first round of spot-mapping (see below) to determine which individuals were closest to the line; 2) located these birds using unsolicited singing behavior prior to capture; and 3) only captured individuals singing within 10m of the edge of the line. Individuals were also captured as close as possible to the center of the plot. Birds were fitted with 0.62g transmitters (Model BD2A – Holohil Corp.) using methods outlined in Bayne and Hobson (2001a). Tracking was done in 2002 near Lac La Biche, AB (54° 46' N - 111° 58' W) around conventional seismic lines and in 2003 near Engstrom Lake, AB (56° 11' N - 110° 54' W) around low-impact lines. One day after handling, birds were located 4 to 6 times daily for 23 ± 4 days (mean ± 1 SD). We observed birds 85 ± 15 times between 4:30 am and 8:00pm MST. An observer using a hand-held receiver and 3-element Yagi antennae located birds on foot, recording whether the bird was heard singing, was observed with a female or young, and general descriptions of habitat use and behavior. To minimize bias caused by birds responding to the observer, we approached from different directions each tracking session. Once we visually confirmed the bird’s location we left the area in the opposite direction from which we approached to avoid creating disturbance trails to the bird’s location. All locations of the same bird were separated by a minimum of 20 minutes. Locations were recorded on paper maps by pacing distances to flagged grid corners. No explicit measure of spatial accuracy was done. However, our grid spacing was 50m so that observers only had to pace a maximum of 25m to approximate the location of a bird. We believe our points were accurate to within about 5m. Points were entered into Arcview using on-screen digitizing. When birds moved off the flagged area, a Global Positioning System was used to record their location.

The Arcview extension Animal Movement (Hooge and Eichenlaub, 1997) was used to derive minimum convex polygons (hereafter MCP) for each individual. To derive estimates of the size of each bird's home range, we used a jack-knife estimator to randomly select 50, 60, or 70 points to determine what effect sample size had on the estimated home range size. A series of overlap analyses were then done in ArcView 3.2 to determine the area of the MCP for each bird that occurred on either side of seismic lines. The predominantly used side of the line was defined as the side with the greatest proportion of the MCP and hereafter is described the percentage on the most used side of the line (i.e. all percentages are reported as > 50%). In 3-D seismic grids, the "main" seismic line was the one closest to the centroid of the bird's home range.

The singing location of all males within 12.25 ha plots were also recorded using spot-mapping. Each plot was flagged into a series of 50m by 50m cells to facilitate accurate positioning of bird locations. Verner (1985) recommended a minimum of 8 and maximum of 14 visits per spot-mapping grid to derive the most precise estimates of bird density and territory distribution. We visited plots near Engstrom Lake on average 9.7 ± 0.5 times from June 1 to July 3, 2003. One of five observers systematically walked the entire grid in 2.5 hours. We recorded all birds heard and seen within the grid as well as all birds in the area 50m around the grid. In total, 12 plots were mapped with 4 having no seismic lines, 4 with a conventional seismic line, and 4 with approximately 5 low-impact seismic lines (2-3 m wide). All plots were located in 60 to 80 year old aspen (Populus tremuloides) forest (92 ± 8% of all trees were aspen). To determine the density of birds per plot, territorial clusters were identified by the senior author from the spot-mapping data using rules outlined in Bibby et al. (2000).

All data are reported as means ± 1 SD unless otherwise stated. We considered results significant at $P = 0.05$.

RESULTS

Home range/ territory overlap of seismic lines: In areas disturbed by conventional seismic lines, all individuals were observed on both sides of a line with the exception of a single individual. However, the average percentage of the MCP (hereafter home range) on the predominantly used side of conventional seismic lines was 78 ± 17% (Figure 2). A one-sample t-test demonstrated that the observed percentage of the home range on one side of conventional seismic lines was significantly different than what would be expected if the proportion was split 50/50. Given the variability in overlap of seismic lines between different Ovenbirds, the existence of 78% of the home range on one side of the line was not significantly different than if the mean home range split was 68/32%. The MCP based on singing locations (hereafter territories) were almost completely on one side of conventional seismic lines (92 ± 17%), which was not significantly different than if the mean territory split was 78/22%. Removing a single individual that was regularly seen singing on both sides of a conventional seismic line, we found that the observed split was not significantly different than a null model of 91/9%.

The MCP approach relies on the outermost points to define the area used by an individual. This can result in large areas being considered "used", despite no observations occurring in that area. Thus, we also examined the distribution of point locations. The average percentage of all point locations on the predominantly used side of the line was 91 ± 11%. Using a paired t-test, we found the percentage of all point locations occurring on one side of the line was greater than would be expected relative to the percentage of the total home range area on that side of the line ($t_{df=11}$ = -4.09, P = 0.002). In other words, despite a relatively large area of the home range occurring on the opposite side of the seismic line (22%), the proportion of points (9%) and presumably time spent by males in areas on the opposite side of conventional seismic lines was more limited than would have been expected based on area alone.

In 3-D seismic grids, male Ovenbirds included two to four low-impact seismic lines within their home range. They did not constrain home ranges to fit between low-impact seismic lines (Figure 2). The average percentage of the home range on the predominantly used side of the "main" low-impact seismic line was 58 ± 7%. This was significantly different than if the mean home range was split 50/50, but was no different than a 54/46 split. Similarly, Ovenbird territories extensively overlapped the main low-impact seismic line (61 ± 5% on one side). This was not significantly different than a 58/42 split. The average percentage of all point locations on the predominantly used side of the main line was 65 ± 18%. Relative to the area of the MCP on each side of low-impact lines, the number of points was not significantly different than expected ($t_{df=11}$ = -1.53, P = 0.16). This suggests no selection for a particular side of the line and similar time spent on both sides of the main low-impact line.

Overall, the mean percentage of the home range and territory on one side of conventional seismic lines was significantly greater than on low-impact lines assuming unequal variance ($t_{df=15.0}$ = -3.7, P = 0.002 and $t_{df=13.1}$ = -6.2, P < 0.001, respectively).

Edge use*:* Within the home ranges of radio-marked individuals, the mean percentage of the area within 10m of conventional seismic lines was 9 ± 6%. This was not significantly different from the percentage of points observed in that band (7 ± 7%) based on a paired t-test ($t_{df=23}$ = 1.43, P = 0.18). For low-impact seismic lines, the mean percentage of the home range within 10m of seismic lines was 33 ± 6%, while the observed percentage of points was 29 ± 9%, which was also not significantly different from expected ($t_{df=23}$ = 1.69, P = 0.12). Point locations where radio-marked birds were heard singing occurred the same distance from conventional (12 ± 15%) and low-impact seismic lines (35 ± 16%) than predicted based on area alone ($t_{df=23}$= -2.0, P = 0.07 & $t_{df=23}$ = -1.6, P = 0.13, respectively).

Territory/ home range size: Using repeated measures ANOVA with a single among-subjects and one within-subjects factor, we found that increasing the number of jackknifed points used to derive the MCP always resulted in a significantly larger home range size ($F_{df=2,44}$ = 18.9, P < 0.0001). Regardless of the number of points used to derive the MCP however, there was no difference in the mean home range size of male Ovenbirds near conventional (4.91 ± 2.56 ha) versus low-impact seismic lines (3.85 ± 0.92 ha for 70 jack-knifed points: F $_{df=1,22}$ = 0.1, P = 0.76). Breusch-Pagan heteroscedasticity tests indicated home ranges near conventional seismic lines were more variable in size than near low-impact lines however (All P < 0.02). Regardless, t-tests allowing for unequal variances supported the notion of no difference in mean MCP (All P > 0.1). In contrast, the territory size of Ovenbirds was significantly bigger near low-impact (1.49 ± 0.46 ha) than conventional lines based on a jack-knifed sample of 20 points (1.12 ± 0.42 ha: $F_{df=1,22}$ = 4.19, P = 0.05).

Overlap of individual's territory/ home range with each other: The two individuals captured at each site were neighbours in all cases (i.e. no other individual had a territory between the two radio-marked birds). The area of home range overlap between the two birds near conventional seismic lines was 6 ± 7%. This was not significantly different the 14 ± 8% overlap observed near low-impact lines ($t_{df=10}$ = -1.93, P = 0.08). Similarly, the overlap of territories near low-impact lines (3 ± 3%) was not significantly greater than near conventional lines (0.3 ± 0.4%: $t_{df=5.2}$ =-2.11, P = 0.09).

Ovenbird density: The density of Ovenbirds was not significantly different between treatments ($F_{df=2,9}$ = 0.06, P = 0.95). There were 9.0 ± 1.0 birds per 12.25 ha in reference plots with no seismic lines, 9.0 ± 1.2 in plots with a single seismic line, and 8.7 ± 1.9 birds in 3-D grids (Figure 3). Similar results were observed using a Generalized Linear Model with Poisson errors to compare the number of territories whose centroid was within the spot-mapping plot (z = -0.24, df = 1, P = 0.81).

DISCUSSION: Our results suggest no numerical impact on Ovenbird populations from either conventional or low-impact seismic lines relative to our reference areas with no seismic lines. However, Ovenbirds spent ~90% on one side of conventional seismic lines suggesting they perceive conventional seismic lines as fragmenting the forest. Ovenbirds did not avoid the edges created by conventional seismic lines, as they used areas within 10m of seismic lines just as would be expected based on availability. Together, these results suggest conventional seismic lines function as territory boundaries that effectively split stands in two but do not create zones of edge avoidance. In contrast, low-impact lines are not perceived as boundaries and are incorporated within both the home range and territory of Ovenbirds resulting in no loss of habitat.

Given that Ovenbirds used conventional seismic lines as territory boundaries, we predicted a decline in Ovenbird density in areas with conventional seismic lines simply due to a shifting of territories relative to the seismic line. Based on a spatially explicit GIS model, Bayne et al. (in press) demonstrated that non-overlapping circular territories of sizes similar to those we observed, should have seen a decrease in Ovenbird density by ~15% in plots with a conventional seismic line relative to contiguous forest. This effect was not observed suggesting Ovenbirds were able to compensate for the loss of habitat by conventional seismic lines. One mechanism that might allow Ovenbirds to maintain a similar density in contiguous forest versus dissected stands would be for individuals to increase the amount by which their territory or home range overlaps that of other individuals. A small increase in the amount of overlap of territories (3 to 4%) is sufficient to maintain the density of birds in areas dissected by conventional seismic while maintaining constant territory size and shape. Admittedly, we did not observe that degree of overlap in territories of male Ovenbirds near conventional seismic lines but this was to be expected given that we captured individuals on opposite sides of the seismic line. Neighboring individuals living on the same side of the line might be more likely to show this overlap and would be the more appropriate comparison. We did observe this degree of overlap between neighbouring individuals in 3-D grids that lived across the low-impact lines, suggesting that intersecting territories are possible. Similarly, Mazerolle and Hobson (2005) found that adjacent Ovenbird home ranges overlapped anywhere from 15 to 60%.

Ovenbirds may also have reduced their territory size near conventional seismic lines. A ~10% compression in territory size near conventional seismic lines could maintain the density of individuals at levels similar to those in continuous forest. Territories based on a jack-knifed sample of 20 points were 33% smaller near conventional seismic lines than in the 3-D grids, which could be interpreted as supporting this hypothesis. However, it is also possible that individuals in areas with multiple low-impact seismic lines may require larger territories to compensate for the reduced availability of food resources caused by the low-impact lines. We do not have the appropriate data to support either hypothesis. To resolve how Ovenbirds compensate for the habitat lost by seismic exploration, more information from radio-marked individuals in continuous forest, areas with conventional seismic, and in 3-D low-impact grids needs to be collected simultaneously, possibly in conjunction with information on food supply. Ideally, radio-tagging all individuals within a plot would be particularly useful in understanding the degree of overlap, territory size, and spatial alignment of birds in areas disturbed by seismic exploration. Such an approach would provide important information on the biological factors that allow Ovenbirds to compensate for the loss of habitat created by seismic lines.

The use of radio-telemetry to document the behavioral response of Ovenbirds to seismic line exploration revealed that territories derived from singing locations are much smaller than the overall home range used by an animal during the breeding season (also see Mazerolle and Hobson, 2005). This suggests that the "all-purpose" or type-A territory (Hinde, 1956) traditionally ascribed to Ovenbirds may be an oversimplification. Similar off-territory movements have been observed using radio-telemetry for Ovenbirds in Saskatchewan, sometimes involving crossing of open agricultural habitat (Mazerolle and Hobson, 2003). Hooded Warblers in Ontario show similar behaviors (Norris and Stutchbury, 2002). In part, these movements reflect our increased ability to follow birds outside periods when they are typically observed (i.e. when they are singing). In particular, we were able to track males well into the afternoon, which our results suggest is when Ovenbirds move more extensively (Bayne unpub. data). We are unsure of the ecological significance of these off-territory movements. A myriad of explanations are possible including males seeking extra-pair copulations (Norris and Stutchbury 2002), movement to resource-rich foraging areas (Mazerolle and Hobson, 2003), information gathering on the status of other individuals (Tobler and Smith, 2004), or possibly going to water (Bayne unpub. data). More research into the ecological significance of off-territory movements is needed to determine what the mechanisms causing this behavior are and whether human disturbance might affect these movements.

Ovenbirds are often used as indicator species in boreal forest Environmental Impact Assessments and monitoring programs. The wide acceptance of the Ovenbird as a sensitive indicator species is based on data collected mainly from the eastern portion of the continent where the species is less abundant and typically avoids anthropogenic edges (Rich et al., 1994). Our data and that collected by collaborators in harvested and agricultural landscapes in the boreal forest of Saskatchewan, suggest that the designation of the Ovenbird as a species that avoids edges may not be warranted in the boreal forest (Mazerolle and Hobson, 2003). This is not to say that Ovenbirds are not affected by fragmentation of boreal landscapes, as we have found significant differences in nest success, pairing success, and apparent survival between agricultural and forested landscapes (Bayne and Hobson, 2001b; Bayne and Hobson 2002). Instead our results support the observation by Villard (1998) that edge use by birds and sensitivity to landscape-level fragmentation are not always linked. Why differences in Ovenbird sensitivity to edges exist between different parts of North America remains poorly understood. An intriguing possibility modeled by Bollinger and Switzer (2002) is that edge sensitivity is a density-dependent phenomenon whereby individuals prefer to settle in interior sites but some are forced to use edge habitats when despotic behavior of dominant individuals in the preferred interior habitat forces them to. The density of Ovenbirds in the western boreal forest is currently higher than anywhere else in North America, which seems to result in extreme competition for space as evidenced by the existence of floaters (Bayne and Hobson, 2001b). This "density-dependent" habitat selection may partially explain why Ovenbirds are less edge-sensitive than in other areas of their range. As human activity in the boreal forest increases over the next 50 years it is possible that Ovenbirds will suffer reduced reproductive success, consequently resulting in reduced population sizes and presumably less direct competition for space. If this happens, Ovenbirds may become "more sensitive" to edges over time (Donovan and Lamberson, 2001).

As with any study focused on a single species, the generality of the results and the applicability for other species must be considered. Ovenbirds nest and forage almost exclusively on the ground in stands with relatively open understories (Van Horn and Donovan, 1994). Other species relying on different structural elements such as a complex shrub or canopy layer may be differentially affected by seismic lines. Canopy nesting/ foraging species may be the least likely to be impacted by low-impact seismic as all of the lines we surveyed maintained canopy closure. In contrast, conventional seismic lines create a distinct break in the canopy that may be sufficient to act as a territory boundary for these species, although this effect will tend to be mitigated over time as aspen crowns grow over the line. Immediately after line clearing, shrub-nesting species may be the most sensitive to seismic lines as both conventional and low-impact lines clear considerable amounts of understory vegetation. However, the edges of 5-10 year old conventional seismic lines have increased shrub growth relative to forest interiors (MacFarlane 2003), which may partially offset the habitat lost by the seismic line itself. Similarly, where all-terrain vehicle traffic is minimized on lines, shrub growth can be considerable (Revel et al., 1984; MacFarlane, 2003).

While more information on the space-use patterns of birds like the Ovenbird are required around seismic lines, we believe it is prudent to recommend energy companies consider using new low-impact equipment in their seismic operations wherever possible. If SAGD companies were to use conventional seismic, the habitat lost and edges created would undoubtedly produce a situation where bird abundance would decline dramatically because, as our data suggests, birds would be constrained to fit their territories into the very narrow strips of remaining forest. The delayed regeneration of conventional seismic lines also means that the density of conventional lines is accumulating over time. As more and more conventional seismic lines occur on the landscape, there is an increasing risk that some threshold density of seismic lines may be reached whereby a numerical response by birds may be observed. Given that Ovenbirds do not perceive low-impact seismic lines as creating an edge, low-impact seismic lines seem to be an increasingly cost-effective and relatively simple way of reducing the risk that energy sector development will reach threshold levels where populations of forest songbirds are negatively affected.

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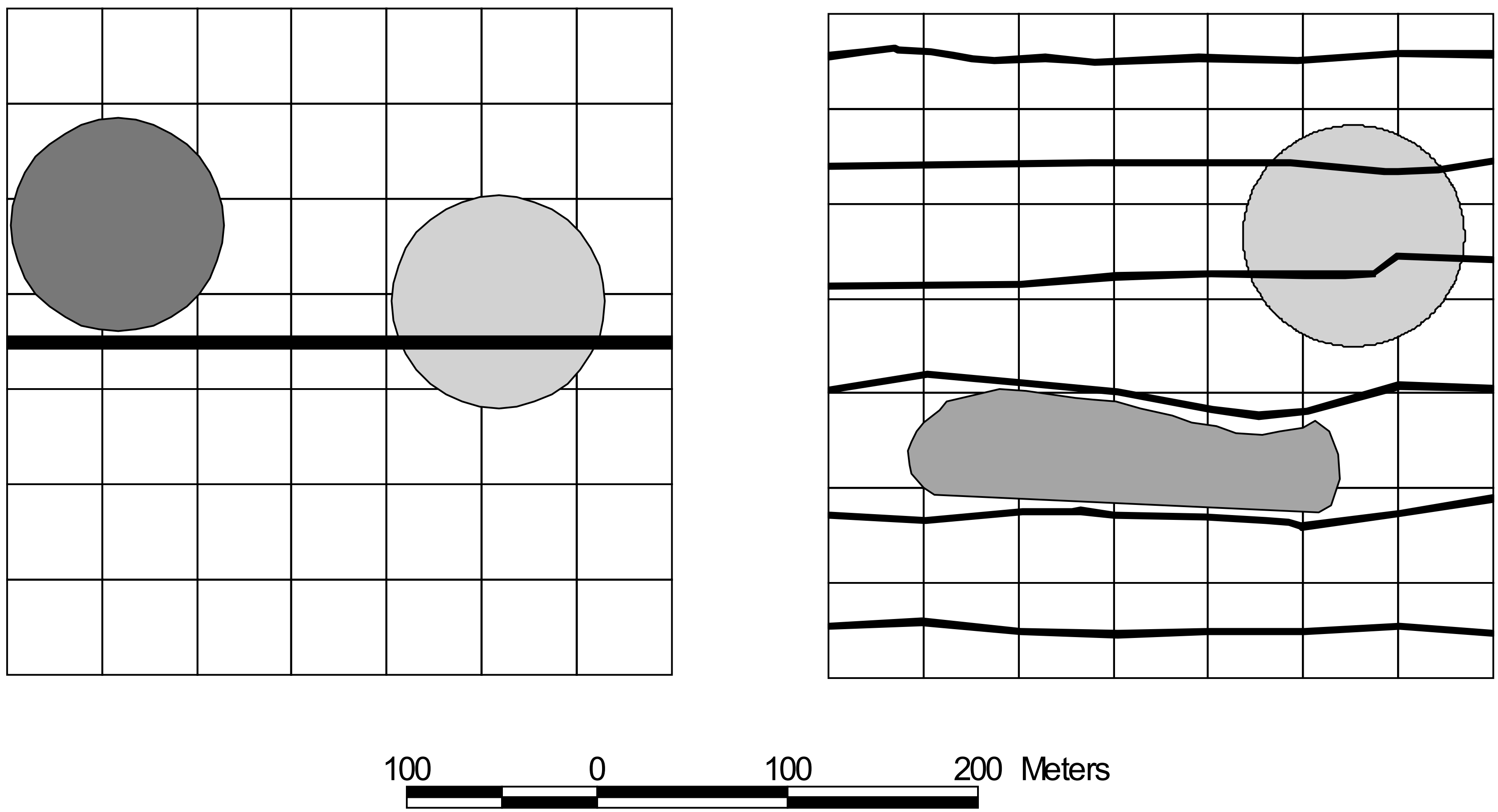
FIGURE LEGENDS

Figure 1 –Theoretical bird territories (1 ha) if individual incorporates conventional (8m wide) seismic lines within their territory vs. uses the seismic line as a territory boundary (left) and in a 3-D seismic grid with multiple low-impact lines (2 to 3m wide) where an individual incorporates lines or uses the seismic lines as a territory boundary (right). Dark black lines represent seismic lines. The grid represents a series of 50 X 50 m areas on a spot-mapping grid.

Figure 2 –Example of Ovenbird territories (light gray – 95% MCP based on singing locations) and home ranges (dark gray – 95% MCP based on all locations) derived from radio-marked individuals living near a conventional seismic line (left) and in a 3-D seismic grid with multiple low-impact lines (right). Point locations used to derive MCP for each individual are also shown. The grid represents a series of 50 X 50 m areas on a spot-mapping grid.

Figure 3 –Ovenbird territories (thick black line) determined by spot-mapping in stands with no lines (top), single conventional lines (middle), and 4 to 5 low-impact lines (bottom). Underlying image is a kernel estimator of Ovenbird activity based on all detections collected during spot-mapping. Darker areas indicate areas of greater Ovenbird activity. The grid represents a series of 50 X 50 m areas on a spot-mapping grid.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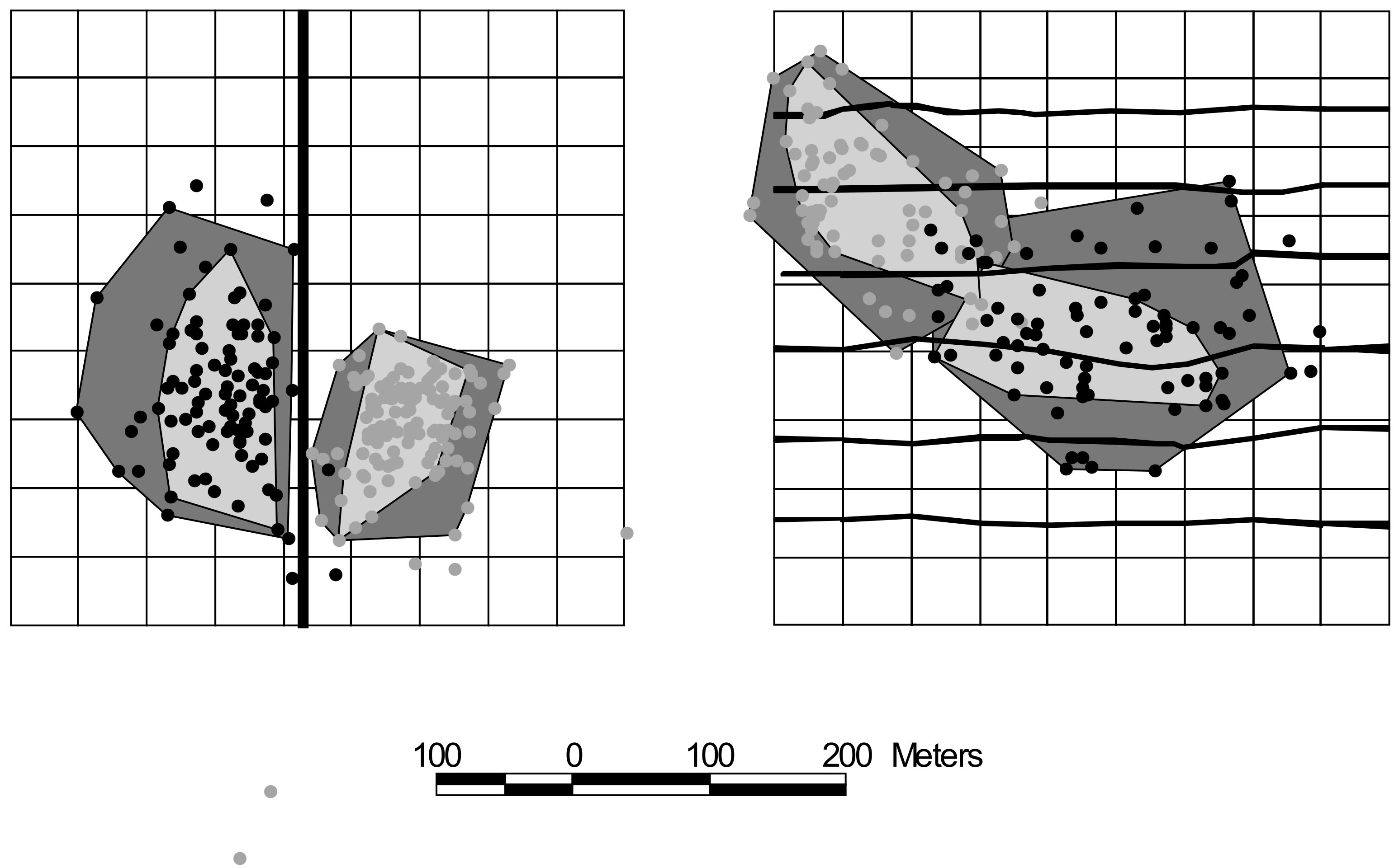
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