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Wildlife Research

Supplementary Material

Increasing the accuracy and efficiency of wildlife census with unmanned aerial vehicles: a simulation study

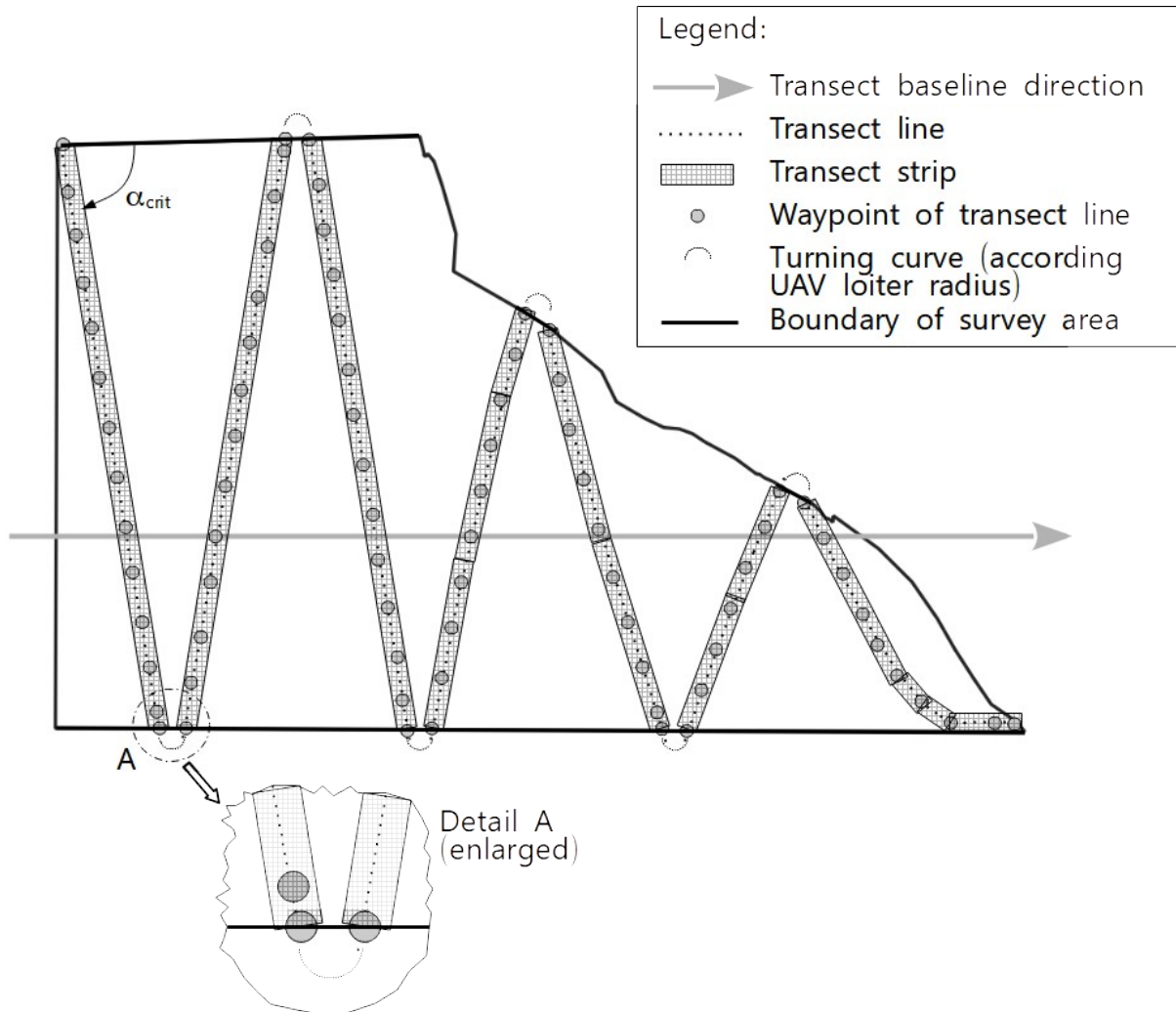
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Supplementary figure S1: Visualisation of the different components of the proposed survey design.



Supplementary Table S1: Comparison of modified zigzag and parallel survey approach applied on a survey area layout of four adjacent rectangular areas (area numbering according figure 2)

Rectangular shape 7.5 x 10km – surface area 75 km²								
<i>Flight speed UAV : 100 km/h</i>								
<i>Animal speed : 10 km/h</i>								
Rectangle n°	Survey design	Coverage	Survey direction	Flight time	Flight distance	Total transect length	Transect length / Flight distance	Benefit of zigzag
1	Parallel	16.0%	0°	50 min	81.4 km	60,000 m	74%	13.1%
	Modif. zigzag	16.0%	0°	45 min	72 km	60,138 m	84%	
2	Parallel	16.0%	0°	50 min	81.6 km	60,000 m	74%	12.7%
	Modif. zigzag	16.0%	0°	45 min	72.4 km	60,138 m	83%	
3 (=2)	Parallel	16.0%	0°	50 min	81.6 km	60,000 m	74%	12.7%
	Modif. zigzag	16.0%	0°	45 min	72.4 km	60,138 m	83%	
4 (=1)	Parallel	16.0%	0°	50 min	81.4 km	60,000 m	74%	13.1%
	Modif. zigzag	16.0%	0°	45 min	72 km	60,138 m	84%	

Supplementary Table S2: Comparison of modified zigzag and parallel survey approach using different survey directions applied on a survey area layout of four adjacent diamond shaped areas (area numbering according figure 2); greyed cells indicate the most efficient flight plans per area applied in the calculation of the respective benefits

Diamond shape 10 x 15km – surface area 75 km²								
<i>Flight speed UAV : 100 km/h</i>								
<i>Animal speed : 10 km/h</i>								
Diamond n°	Survey design	Coverage	Survey direction	Flight time	Flight distance	Total transect length	Transect length / Flight distance	Benefit of zigzag
1	Parallel	14.4%	304°	44 min	71.9 km	54,000 m	75.1%	11.1%
		15.1%	0°	51 min	82.4 km	56,600 m	68.7%	
	Modif. zigzag	15.1%	0°	47 min	77.0 km	56,500 m	73.4%	
		14.2%	303°	41 min	65.4 km	53,157 m	81.3%	
		14.3%	56°	40 min	64.7 km	53,771 m	83.1%	
2	Parallel	14.4%	304°	44 min	71.7 km	54,000 m	75.3%	10.0%
		15.1%	0°	55 min	90.6 km	56,600 m	62.5%	
	Modif. zigzag	15.1%	0°	53 min	77.3 km	56,500 m	73.1%	
		14.4%	303°	46 min	74.6 km	54,000 m	72.4%	
		14.2%	57°	40 min	65.2 km	53,771 m	82.5%	
3	Parallel	14.4%	304°	53 min	86.4 km	54,000 m	62.5%	33.5%
		15.1%	0°	55 min	90.1 km	56,600 m	62.8%	
	Modif. zigzag	15.0%	0°	47 min	74.1 km	56,500 m	76.4%	
		14.3%	57°	40 min	64.7 km	53,771 m	83.1%	
4	Parallel	14.4%	304°	43 min	70.2 km	54,000 m	76.9%	9.3%
	Modif. zigzag	15.0%	0°	46 min	75.2 km	56,000 m	74.5%	
		14.2%	57°	40 min	64.2 km	53,771 m	83.8%	

Supplementary Table S3: Comparison of modified zigzag and parallel survey approach using different survey directions applied on a survey area arrangement of seven adjacent hexagonal shaped areas (area numbering according figure 2); greyed cells indicate the most efficient flight plans per area applied in the calculation of the respective benefits

Hexagonal shape 9.2 x 9.2km – surface area 73.3 km ²								
<i>Flight speed UAV : 100 km/h</i>								
<i>Animal speed : 10 km/h</i>								
Hexagon n°	Survey design	Coverage	Survey direction	Flight time	Flight distance	Total transect length	Transect length / Flight distance	Benefit of zigzag
1	Parallel	15.0%	330°	47 min	75.9 km	55,700 m	73.4%	11.8%
	Modif. zigzag	15.0%	0°	42 min	67.9 km	55,000 m	81.0%	
2	Parallel	15.0%	330°	52 min	85.0 km	55,700 m	65.5%	11.7%
	Modif. zigzag	15.0%	0°	48 min	77.2 km	55,000 m	71.2%	
		15.0%	300°	47 min	76.1 km	55,000 m	72.3%	
3	Parallel	15.0%	330°	54 min	87.6 km	55,700 m	63.6%	14.1%
	Modif. zigzag	15.0%	0°	47 min	76.8 km	55,000 m	71.6%	
		15.0%	300°	47 min	76.8 km	55,000 m	71.6%	
4	Parallel	15.0%	330°	53 min	86.0 km	55,700 m	64.8%	12.0%
	Modif. zigzag	15.0%	0°	47 min	76.8 km	55,000 m	71.6%	
5	Parallel	15.0%	330°	53 min	85.4 km	55,700 m	65.2%	10.6%
	Modif. zigzag	15.0%	0°	49 min	77.2 km	55,000 m	71.2%	
6	Parallel	15.0%	330°	53 min	85.9 km	55,700 m	64.8%	12.7%
	Modif. zigzag	15.0%	0°	47 min	76.2 km	55,000 m	72.2%	
7 (=6)	Parallel	15.0%	330°	53 min	85.9 km	55,700 m	64.8%	12.7%

	Modif. zig-zag	15.0%	0°	47 min	76.2 km	55,000 m	72.2%	
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Supplementary Table S4: Deviations between programmed and realized contour following and flight height in UAV application at different elevations.

	Contour line				
	1,100m (N=6,647)	1,200m (N=5,737)	1,300m (N=5,666)	1,400m (N=5,936)	1,500m (N=5,469)
Distance from contour line (median, standard deviation)	15.7 ± 27.0 m	11.9 ± 21.5 m	10.8 ± 18.4 m	11.2 ± 21.9 m	11.2 ± 18.9 m
Maximum distance from contour line	187.9 m	152.3 m	122.3 m	143.2 m	107.4 m
Flight height (median, standard deviation)	100.4 ± 5.1 m	102.3 ± 10.9 m	103.8 ± 11.8 m	109.9 ± 20.3 m	101.9 ± 16.4 m
Minimum and maximum flight height	89.8 - 130.2 m	68.4 – 170.6m	76.1 – 175.8 m	40.5 – 199.8 m	55.9 - 196.5 m