J. Field Ornithol. 82(1):11–24, 2011 DOI: 10.1111/j.1557-9263.2010.00303.x

Reservoir water levels do not influence daily mass gain of warblers at a riparian stopover site

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Received 15 May 2010; accepted 7 September 2010

ABSTRACT. Hydroelectric dam operations that lead to fluctuations in the water levels of reservoirs can influence the amount of riparian habitat available for migrating songbirds and may impact the use and quality of remaining habitat. Our objective was to determine if use of riparian habitats and mass gain by five warbler species at the Columbia River-Revelstoke Migration Monitoring Station in British Columbia, Canada, were influenced by water levels in the surrounding Arrow Lakes Reservoir. We analyzed fall migration data collected from 1998 to 2006. Capture rates of American Redstarts (*Setophaga ruticilla*), Common Yellowthroats (*Geothlypis trichas*), Orange-crowned Warblers (*Vermivora celata*), Wilson's Warblers (*Wilsonia pusilla*), and Yellow Warblers (*Dendroica petechia*) varied between years and weeks of the migration period, but were not affected by annual or weekly variation in water levels. Annual variation in capture rates was driven by hatch-year birds (>80% of individuals captured were juveniles) and could reflect conditions on the breeding grounds that influence productivity. We found that mass gain by the five species of warblers varied between 0.32% and 0.98% of lean body mass/hour. Mass gain did not vary between years or across weeks of the migration period and was not influenced by annual or weekly variation in reservoir water levels. Although the amount of available riparian habitat was reduced when reservoir water levels were high, we found no evidence that this loss of habitat influenced either the number of warblers or the mass gain of warblers using the riparian habitat that remained. Body mass at the time of first capture varied between years and across weeks for all five species. For American Redstarts and Orange-crowned Warblers, body mass declined as average weekly water levels increased, a pattern that could arise if water levels influenced either their settling decisions or length of stay.

RESUMEN. Los niveles del agua en un embalse no influyen en el incremento del peso diario de parulidos en un sitio de parada migratorio ripario

Las operaciones de las represas hidroeléctricas que resultan en fluctuaciones en los niveles del agua de los embalses pueden influenciar la cantidad de hábitat ripario disponible para las aves migratorias y tener impacto en el uso y la calidad de hábitat remanente. Nuestro objetivo fue determinar si el uso de hábitats riparios y el incremento en el peso de cinco especies de parulidos en la estación de monitoreo migratorio del Rio Columbia-Revelstoke en British Columbia, Canada fueron influenciados por los niveles del agua en el embalse de Arrow Lakes. Analizamos datos de la migración de otoño colectados desde 1998 hasta 2006. Las tasas de captura de *Setophaga ruticilla*, *Geothlypis trichas*, *Vermivora celata*, *Wilsonia pusilla*, y *Dendroica petechia* variaron entre años y semanas durante el periodo migratorio pero no fueron afectados por la variación anual o semanal en el nivel del agua. La variación anual en las tasas de captura fue influenciada por aves del primer año (>80% de los individuos capturados fueron juveniles) y podría reflejar condiciones en las áreas de reproducción que influyen en la productividad. Encontramos que el incremento en el peso de cinco especies de parulidos varió 0.32–0.98% de la masa corporal magra/hr. El incremento en el peso no varió entre años o a través de semanas durante el periodo migratorio y no fue influenciado por la variación anual o semanal en los niveles del agua del embalse. Aunque la cantidad de hábitat ripario disponible fue reducido cuando los niveles del agua del embalse fueron altos, no encontramos evidencia de que esta perdida de hábitat influenciaba el numero de parulidos o el incremento del peso de los parulidos usando el hábitat ripario que permanecia. El peso corporal en el momento de la primera captura varió entre años y a través de semanas para las cinco especies. Para *S. ruticilla* y *V. celata*, el peso corporal disminuyó frecuentemente cuando el promedio semanal de los niveles del agua incrementaban, cuál podría existir si los niveles del agua influyen en su decisión de parar o no en el sitio, ó acto tiempo permanecer en el sitio.

Key words: *Dendroica petechia*, *Geothlypis trichas*, migration, Parulidae, refuelling rates, *Setophaga ruticilla*, *Vermivora celata*, *Wilsonia pusilla*

Songbirds face numerous challenges as they migrate between temperate and tropical areas. The high energetic cost of long-distance travel (Wikelski et al. 2003, McWilliams et al.

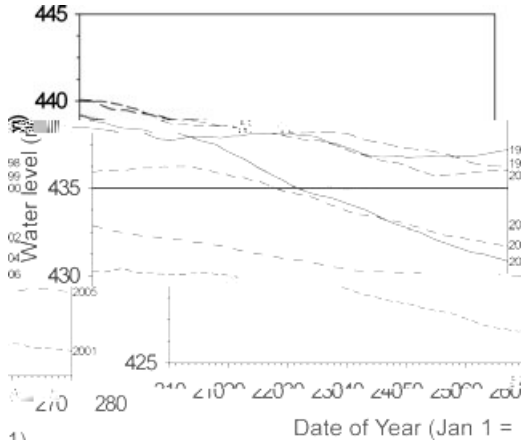

Fig. 1. Seasonal variation in the water levels in Arrow Lakes Reservoir during fall migration from

Table 2. Mist-netting effort at the Columbia River-Revelstoke Migration Monitoring station from 1998 to 2006. The station did not operate in 2003. Nets were always opened at sunrise and remained open for 6 hr.

Year	Period	Max. no. nets	Total net hours
1998	8 Aug–30 Sept	12	2206
1999	3 Aug–29 Sept	11	1933
2000	1 Aug–27 Sept	13	2250
2001	1 Aug–30 Sept	15	3469
2002	1 Aug–30 Sept	12	3341
2004	1 Aug–30 Sept	12	3129
2005	1 Aug–30 Sept	12	2681
2006	1 Aug–30 Sept	12	3299

migration season, weather permitting. Speci c operational details for each year are provided in Table 2. Nets were checked every 30 min and all birds were banded with USGS aluminum bands.

Data collected on the focal species included the date and time of capture, body mass, wing chord (closed wing length), and, where possible, age and sex. Body mass was measured using a digital scale (± 0.1 g). Wing chord was measured (± 0.5 mm) using a stainless-steel wing rule. Age and sex were determined using skull ossi cation and plumage characteristics (Pyle 1997). For analyses, we assigned birds into three classes: after-hatch-year (AHY) females, AHY males, and hatch-year (HY) birds. We did not distinguish between HY females and males because many cannot be sexed by plumage characteristics.

For analyses examining body mass gain, we included data from birds captured for the rst time in any given year where we had complete information on date and time of capture, body mass and wing chord, and sex and age class. We deleted records of individuals with mass or wing chord values falling below the 1st percentile or above the 99th percentile of all measurements to exclude possible errors in measurement or recording. We also excluded HY birds identi ed as local juveniles based on feather development and plumage (Pyle 1997). Our data set is nevertheless likely to include resident AHY and local HY birds as well as migrants because American Redstarts, Common Yellowthroats, and Yellow Warblers all breed in riparian habitat within the drawdown zone of Arrow Lakes Reservoir.

Reservoir water levels. Water levels in the Arrow Lakes Reservoir, a 240-km long reservoir system in the upper Columbia River valley, uctuate due to changes in in ow that are impacted by winter snow-pack, the timing of snowmelt, precipitation, and water release decisions at the downstream Hugh Keenleyside Dam. Willow/cottonwood habitat in the drawdown zone is found almost exclusively at elevations above 435 m so there is a marked difference in the impact 6(diff0(v)6(oir)60(,)-239.6(auctuateser)-1

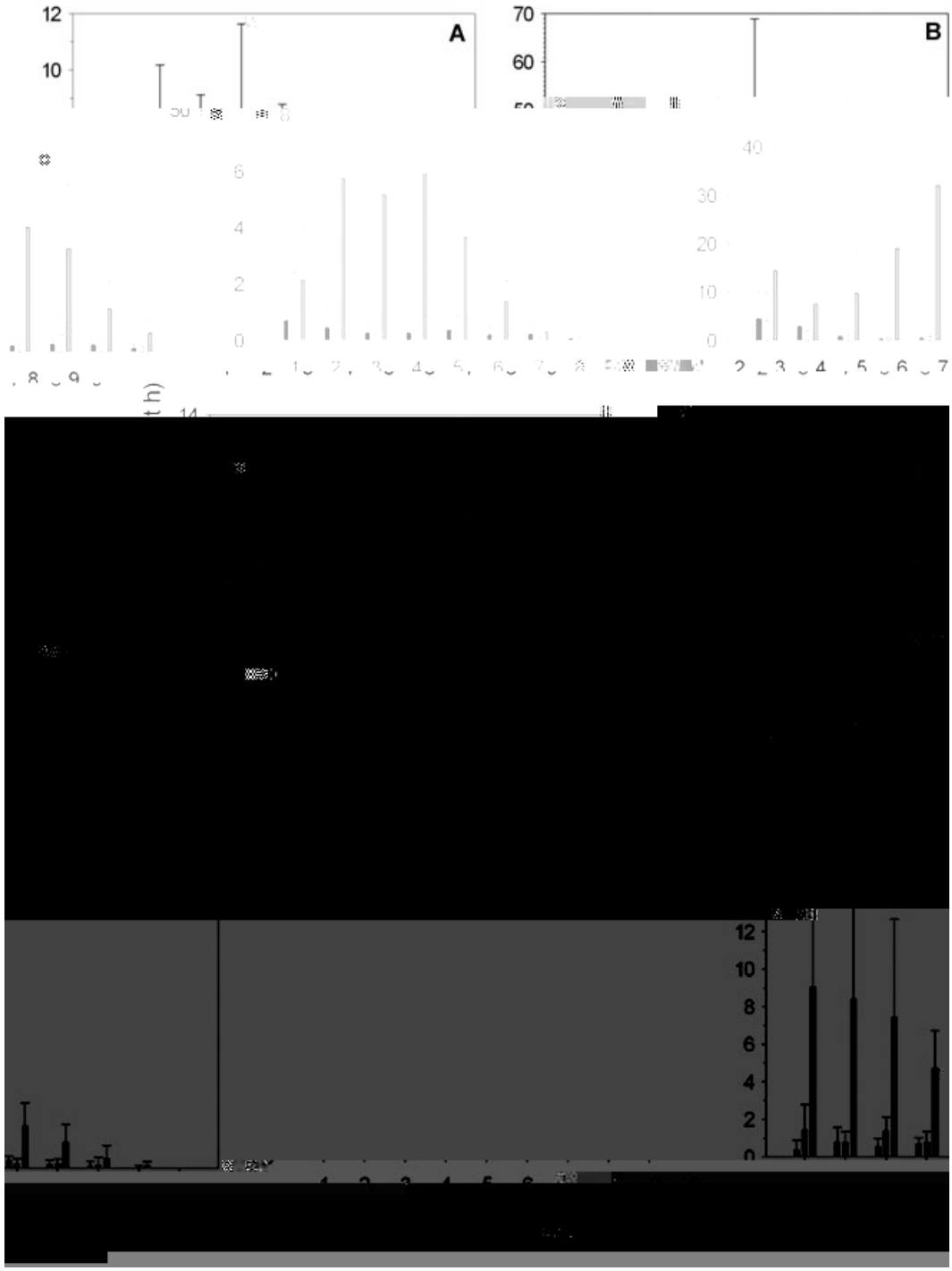

Fig. 2. Capture rates of (A) American Redstarts, (B) Common Yellowthroats, (C) Orange-crowned Warblers, (D) Wilson's Warblers, and (E) Yellow Warblers at the Columbia River-Revelstoke Migration Monitoring Station during fall migration. Capture rates (number/100 mist-net-hours) are averaged across the 8 yr of the study. Week 1 begins on 29 July. Bars denote AHY females (black), AHY males (light gray), and HY birds (dark gray).

Table 4. Model predictions ± SE from generalized linear models examining variation in the capture rates (numbers per 100 mist-net hours) of warblers at the Columbia River-Revelstoke Migration Monitoring Station from 1998 to 2006. Abbreviations, variable definitions, and significance of effects in models are presented in Tables 3.

		Species				
		AMRE	COYE	OCWA	WIWA	YWAR
Temporal and age/sex class model[a]						
Class	AHY F	0.29 ± 0.07	1.56 ± 0.21	0.29 ± 0.07	0.40 ± 0.08	0.35 ± 0.07
	AHY M	0.20 ± 0.05	1.86 ± 0.22	0.25 ± 0.06	0.26 ± 0.06	0.56 ± 0.09
	HY	2.63 ± 0.27	15.2 ± 1.25	3.40 ± 0.27	2.55 ± 0.24	3.60 ± 0.30
Reservoir water level model[b]						
Year type	Low	1.09 ± 0.28	4.68 ± 0.63	1.49 ± 0.21	0.87 ± 0.16	1.58 ± 0.24
	Intermed	1.27 ± 0.26	5.00 ± 0.56	1.83 ± 0.20	1.60 ± 0.20	1.58 ± 0.20
	High	0.71 ± 0.16	9.07 ± 0.97	0.66 ± 1.1	0.63 ± 0.10	1.38 ± 0.19

[a]

Table 5. Results from generalized linear models examining variation in mass of warblers captured at the Columbia River-Revelstoke Migration Monito Station from 1998 to 2006. Abbreviations and variables not de ned as footnotes are consistent with Table 3.

		Species									
		AMRE		COYE		OCWA		WIWA		YWAR	
	df	v.r.[a]	P	v.r.	P	v.r.	P	v.r.	P	v.r.	P
Temporal and class model[b]											
Time[c]	1	4.2	0.03	66.5	< 0.001	23.9	< 0.001	51.9	< 0.001	12.8	< 0.001
Time Year	7	0.7	1.0	0.0	1.0	2.4	0.94	6.5	0.48	0.7	1.0
Time Week	8	0.4	1.0	0.2	1.0	0.03	1.0	0.4	1.0	4.9	0.68
Time Class	2	1.1	0.58	0.0	1.0	0.5	0.80	0.0	1.0	0.1	0.96
Time Body size	1	2.3	0.12	0.6	0.32	0.04	0.84	0.01	0.93	3.2	0.07
Time Abundance	1	0.9	0.17	0.4	0.51	1.1	0.29	0.01	0.91	0.1	0.76
Year	7	22.9	0.002	28.1	0.002	21.4	0.004	27.3	< 0.001	76.8	< 0.001
Week	8	45.1	< 0.001	18.2	< 0.001	11.4	< 0.001	69.7	< 0.001	47.9	< 0.001
Class	2	3.1	0.22	13.3	0.001	1.6	0.38	2.7	0.26	17.4	< 0.001
Body size[d]	1	80.3	< 0.001	78.0	< 0.001	14.6	< 0.001	12.6	< 0.001	13.0	< 0.001
Abundance[e]	1	5.4	0.02	3.6	0.06	0.6	0.45	0.02	0.88	5.2	0.02
Reservoir water level model[f]											
Time Year type	2	0.03	0.99	0.02	0.99	1.4	0.50	0.0	1.0	0.0	1.0
Time Water level	1	0.9	0.35	0.1	0.90	0.3	0.58	0.7	0.68	0.5	0.50
Year type	2	5.1	0.08	5.5	0.06	1.5	0.23	7.5	0.02	54.6	< 0.001
Water level	1	0.6	0.01	0.9	0.35	4.1	0.04	0.01	0.93	0.2	0.67

[a]Change in variance ratio associated with dropping a term.
[b]Sample sizes were: AMRE, AHY-f = 57, AHY-m = 27, HY = 570; COYE, AHY-f = 234, AHY-m = 306, HY = 2899; OCWA, AHY-f = 60, AHY-m = 60, HY = 789; WIWA, AHY-f = 94, AHY-m = 52, HY = 625; YWAR, AHY-f = 64, AHY-m = 108, HY = 788.
[c]Time was measured in hours since sunrise.
[d]Body size was incorporated into models using wing chord.
[e]Warbler abundance at the migration station was estimated for each week using the combined capture rate of individuals from each sex/age class of each s
[f]Reservoir water level models control for any variation in body mass associated with the week of the migration period, size and class of individuals, an abundance of wood warblers at the migration station by including these terms in the models.

Table 6. Mass change of ve species of warblers at the Columbia River Revelstoke Migration Monitoring Station during fall migration expressed as grams/hour and percent of lean body mass/hour.

	Mass gain±	Mass gain

operations in uenced water levels in the Arrows Lake Reservoir, but did not affect mass gain in warblers from 1998 to 2006. This may change if the addition of extra turbines at the Revelstoke and Mica Dam upstream of the Arrow Lakes Reservoir, due to be completed in 2010 and 2014, extend the period when the reservoir is at full pool and prolonged ooding adversely impacts vegetation and leads to further loss of willow habitat.

The rate at which migratory songbirds gain mass during stopover might be expected to vary with age if young birds are less ef cient foragers (Wunderle 1991) or are excluded from more nutritious food sources by older birds. However, we found no evidence that rates of mass gain varied with age for any warbler species. This may be due to the relatively small number of older birds we captured (13–18% of individuals captured). However, Jones et al. (2002) also found that rates of mass gain of adults and immatures did not differ for most species captured during fall migration at Long Point, Ontario, including American Redstarts, Common Yellowthroats, Wilson's Warblers, and

birds with lighter birds being forced to settle at the stopover site, whereas heavier birds continue to migrate in search of better habitat. Fat scores are reported to in uence the habitat selection decisions and transience of migratory birds (Tietz and Johnson 2007, Ktitorov et al. 2010). Alternatively, birds may not remain at sites as long when less foraging habitat and

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