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BRIEF COMMUNICATIONS

Nocturnal density patterns of Atlantic salmon parr in the Sainte-Marguerite River, Québec, relative to the time of night

M.-E. Bédard, I. Imre* and D. Boisclair

Département de Sciences Biologiques, Université de Montréal, C.P. 6128, Succursale Centre-Ville, Montréal, Québec H3C 3J7, Canada

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The number of visible Atlantic salmon *Salmo salar* parr in the Sainte-Marguerite River, Québec, increased between 2030 and 2230 hours then remained relatively stable until 0230 hours. Moon phase did not appear to influence the number of visible parr. There were more fish closer to the shore than to the middle of the stream.

Key words: juvenile; nocturnal density; population assessment; *Salmo salar*.

The abundance of Atlantic salmon *Salmo salar* L., a fish species with a global economic and social importance, has been declining over the past century (Nislow *et al*., 1999). The decline in stock sizes has been attributed, in part, to the destruction of freshwater habitats (Dodson *et al*., 1998). As the time spent in fresh water is considered a critical phase of the *S. salar* life cycle, understanding the influence of physical factors on the freshwater production of *S. salar* is vital in the conservation and management of this species (Poff LeRoy & Huryn, 1998). Accordingly, a great deal of research has been directed at identifying freshwater conditions used and avoided by fish and developing models that predict the effect of natural and anthropogenic perturbations on fish habitat quality (Nislow *et al*., 1999; Guay *et al*., 2000). These studies are based on juvenile *S. salar* observed during the day because, in the summer, stream-dwelling juvenile salmonids are typically considered to be actively feeding during dawn, daylight and dusk (Elliott, 1970). More recently, however, it became increasingly evident that in order to get a comprehensive understanding of the habitat requirements of Atlantic salmon parr, in addition to daytime observations, fish should be observed at night, because they become more nocturnally active as they grow older (Gries *et al*., 1997). Samples from a range of sites

*Author to whom correspondence should be addressed at present address: Redpath Museum & Department of Biology, McGill University, 859 Sherbrooke St W., Montréal, Québec H3A 2K6, Canada. Tel.: +1 514 398 4086 ext. 00808; fax: +1 514 398 3185; email: istvan.imre@umontreal.ca

characterized by different environmental conditions suggest that, on average, twice as many parr may be observed above the substratum at night than during the day (Imre & Boisclair, 2004). This means that habitat models developed during the night may provide information that is important and complementary to models developed during the day.

Relative fish abundance obtained at night may depend on the time at which observations are performed. Contor & Griffith (1995) found that the number of visible juvenile rainbow trout *Oncorhynchus mykiss* (Walbaum) in February increased after sunset; during the night, the density of visible fish decreased with increasing moonlight or artificial light. While this winter study may not be applicable to summer, its findings suggest that assessing the stability of juvenile salmonid abundance during the night may be essential to develop robust nocturnal habitat models.

The objective of this study was to examine whether the number of visible Atlantic salmon parr changes overnight. Nocturnal underwater observations were conducted in a natural stream and all visible Atlantic salmon parr were counted at 2 h intervals from dusk to dawn. These observations were carried out during a full moon and a new moon period.

Sampling was conducted at two sites located on the main branch of the Sainte-Marguerite River, a tributary of the Saguenay River, Québec, Canada. The lower site (48°23′58″ N, 70°15′37″ W) was a 'run' habitat (Cunjak *et al.*, 1993; Gibson *et al.*, 1993) (mean $\pm$ S.D. water depth $= 0{\cdot}6 \pm 0{\cdot}2$ m; mean $\pm$ S.D. water velocity $= 0{\cdot}6 \pm 0{\cdot}3$ m $\cdot$s^{-1}), with a substratum composed of mostly boulder (59·5%), cobble (23·3%), gravel and pebble (11·1%), and some sand (6·1%). The upper site was also a 'run' habitat (mean $\pm$ S.D. water depth $= 0{\cdot}4 \pm 0{\cdot}1$ m; mean $\pm$ S.D. water velocity $= 0{\cdot}6 \pm 0{\cdot}3$ m s^{-1}) located 400 m upstream. The substratum of the upper site was composed of cobble (44·4%), boulder (15·1%), gravel and pebble (31·6%), with some sand (8·9%).

Sampling was conducted over a new moon (30 June 2003) and a full moon night (13 July 2003). The fraction of the moon illuminated at midnight was not more than 10%, and not less than 90% at new moon and full moon, respectively. To quantify the relative abundance of *S. salar* parr each night, underwater visual surveys were conducted at both sites at 2 h intervals, starting from 2030 until 0430 hours (2030, 2230, 0030, 0230 and 0430 hours). In order to minimize any potential differences between sites due to the order of sampling, the sampling order was rotated between the two sites for each sampling time and night. Each survey at a certain sampling time was completed within 30 min.

Sampling was performed by two snorkellers, who individually surveyed four count strips (2 m wide $\times$ 10 m long), for a total of eight count strips per site at a certain sampling time. Each count strip was always surveyed by the same snorkeller in order to reduce potential observational biases. The count strips were located along the right shore and the middle of the river. Snorkellers entered the river at the downstream end of the site and counted all *S. salar* parr visible above or on the substratum, while moving in an upstream direction. Both age 1+ and 2+ year juvenile Atlantic salmon were included in the counts per strip, because they could not be distinguished with confidence using only visual observations. The counts were performed by scanning the water column and the riverbed with a hand-held white dive light (Bremset, 2000). No behavioural observations were conducted, except that fish did not appear to be disturbed by the light. Water temperature (to the nearest 0·5° C) and cloud cover (to the nearest 5%) were recorded at the beginning and end of sampling at each sampling time. No rainfall occurred during sampling.

The numbers of visible Atlantic salmon parr in each count strip were analysed with a mixed model repeated measures ANOVA. The sites (lower and upper) and the snorkelling position (right shore and middle) were considered independent factors, while moon phase (new and full moon) and sampling time (2030, 2230, 0030, 0230 and 0430 hours) were included as repeated measures factors in the model. Only significant interactions were reported. To meet the assumptions of the repeated measures ANOVA, all data were transformed by $\ln(x+1)$. Transformed data were used for all statistical tests. The descriptive statistics shown in the figures are based on non-transformed data.

Correlation analysis was used to examine the potential effect of night-time cloud cover and water temperature on parr non-transformed strip counts over the sampling period. The statistical tests were performed using Statistica 5.0 (StatSoft, 1995). The level of significance was 0·05 for all statistical tests.

In total, 637 Atlantic salmon parrs were observed during the two sampling nights. The number of parr observed in individual count strips ranged between one and 13 (CV = 1·2, $n = 160$). While the number of visible fish did not differ significantly between the sites ($F_{1,\ 12}$, $P = 0{\cdot}237$), there were significant differences between the number of visible parr observed in the count strips located along the right shore and in the middle of the river ($F_{1,12}$, $P < 0{\cdot}001$). There were, on average, approximately five times more visible fish along the right shore (mean ± S.E. = 6·6 ± 0·3, range = 0–13, $n = 80$), than in the middle of the river (mean ± S.E. = 1·3 ± 0·1, range = 0–5, $n = 80$).

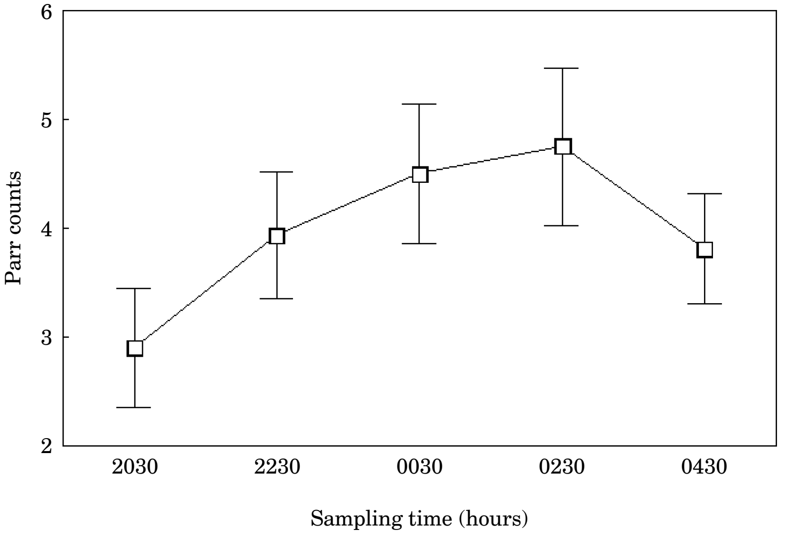

FIG. 1. Mean ± S.E. parr counts at consecutive sampling times. The descriptive statistics are based on all counting segments at each site over two sampling occasions ($n = 32$).

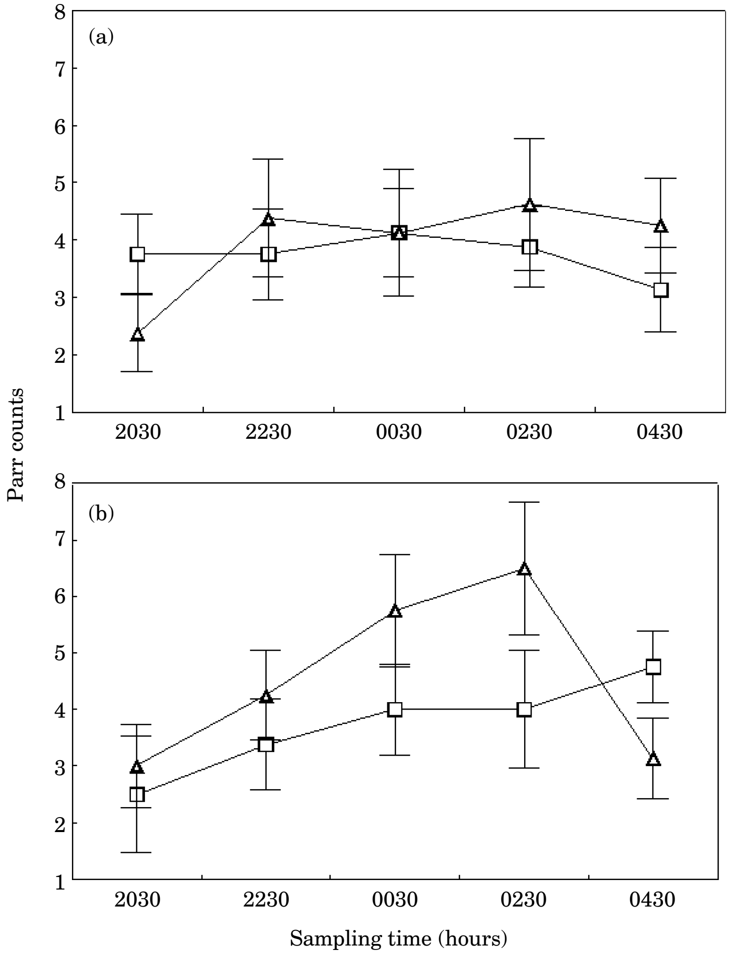

FIG. 2. Mean ± S.E. parr counts at the lower (□) and upper (△) sites at consecutive sampling times collected at night during the (a) new moon and (b) full moon ($n = 8$).

The number of visible *S. salar* parr differed significantly between sampling times ($F_{4,48}$, $P = 0{\cdot}008$). The parr counts observed at 2230 hours (Tukey HSD test, $P < 0{\cdot}047$), 0030 hours (Tukey HSD test, $P < 0{\cdot}012$) and 0230 hours (Tukey HSD test, $P < 0{\cdot}014$) were significantly higher than parr counts at 2030 hours (Fig. 1). Moon phase did not seem to influence the number of visible parr ($F_{1,12}$, $P = 0{\cdot}514$). The temporal pattern of the sampling sites, however, varied with sampling time and also with moon phase (interaction between sampling sites, sampling times and moon phase: $F_{4,48}$, $P = 0{\cdot}006$) (Fig. 2). During the sampling period, the water temperature and cloud cover recorded at the time of sampling varied between 14·0–16·0° C and 0–100%, respectively. The strip counts of Atlantic salmon parr were not related to water temperature or cloud cover measured at each site at the beginning (water temperature: $n = 160$, $r = 0{\cdot}05$, $P = 0{\cdot}495$; cloud cover: $n = 160$, $r = 0{\cdot}01$, $P = 0{\cdot}9$) or the end (water temperature:

$n = 160$, $r = 0{\cdot}05$, $P = 0{\cdot}495$; cloud cover: $n = 160$, $r = 0{\cdot}02$, $P = 0{\cdot}794$) of each sampling occasion.

This summer study found that the number of visible Atlantic salmon parr increased between 2030 and 2230 hours, remained stable until 0230 hours and then showed a non-significant decline between 0230 and 0430 hours (Fig. 1). Similarly the number of juvenile *O. mykiss* in the winter increased 30 to 80 min after sunset in a previous study (Contor & Griffith, 1995). The number of fish, however, decreased by *c.* 73 and *c.* 28% in the presence of moonlight and artificial light, respectively (Contor & Griffith, 1995). Light intensity was not measured during this study, but it is unlikely that moonlight had any effect on the number of visible fish because the fish counts were stable between 2230 and 0230 hours and the number of fish was not significantly different between the full moon and the new moon nights. This difference between the studies could be due to differences between species, or more probably, to seasonal differences in the light tolerance of fishes. Consistent with the latter speculation, Contor & Griffith (1995) found that rainbow trout started to emerge at significantly higher light intensities as water temperature increased gradually during the study period.

In the present study, moon phase did not appear to influence the number of visible fish. This finding should be interpreted with caution, because only two sites were compared over a single moon cycle. The potential implications of this preliminary finding for sampling designs and night-time population assessments highlight the need for a further, more rigorous investigation of the potential relationship between moon phase and nocturnal parr abundance, involving more sites and several moon cycles.

During the two night sampling occasions, there were five times more Atlantic salmon parr closer to shore than to the middle of the stream. This finding corroborates the results of a previous study on the same river indicating that there were 2·5 times more parr in the near-shore areas than in the middle of the river (I. Imre & D. Boisclair, unpubl. data). In addition, these results are consistent with previous observations of juvenile salmonids inhabiting slower water at night (Heggenes *et al.*, 1993; Metcalfe *et al.*, 1997). These findings suggest that a substantial part of the overall population can move in the slower flowing and near shore areas at night. Future sampling strategies for habitat use studies and population assessments should take into consideration this heterogeneity in the night-time spatial distribution of Atlantic salmon parr.

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