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ARTICLE

Improving Salmonid Monitoring by Nocturnal Counting in Rivers

Marius Kambestad*
Department of Biological Sciences, University of Bergen, Postboks 7803, N-5020 Bergen, Norway; and Rådgivende Biologer AS, Edvard Griegs vei 3, 5059 Bergen, Norway; and Norwegian Research Centre AS, Postboks 22 Nygårdstangen, 5838 Bergen, Norway

Bjart Are Hellen
Rådgivende Biologer AS, Edvard Griegs vei 3, 5059 Bergen, Norway

Knut Helge Midtbø Jensen
Department of Biological Sciences, University of Bergen, Postboks 7803, N-5020 Bergen, Norway

Harald Sægrov
Rådgivende Biologer AS, Edvard Griegs vei 3, 5059 Bergen, Norway

Abstract
Accurate abundance estimates are crucial for evidence-based fisheries management. In rivers, drift dive counting and electrofishing are commonly used for quantifying fish abundance. However, the likelihood that fish are detected by these counting methods is affected by a range of factors, with substantial potential implications for the outcomes. Fish behavior and distribution also differs with light intensity, yet diel variation in abundance estimates produced by common enumeration methods has received little attention. Here, we present a comparison of diurnal and nocturnal counts of the landlocked population of Atlantic Salmon *Salmo salar*, known as "småblank," and Brown Trout *Salmo trutta* in a Norwegian river. Six drift dive transects and 12 electrofishing sites were surveyed at day and night in early autumn. During drift dives, småblank were exclusively observed at night. Brown Trout were observed by snorkelers both day and night but in significantly higher numbers at night (six times more Brown Trout per 100 m at night versus in the day). Catch per unit effort of backpack electrofishing was significantly higher at night than at daytime for both småblank and Brown Trout older than age 0 (202% and 108% higher, respectively). We argue that differences in drift dive counts were mainly caused by fish hiding in the substrate during the day and being more active at night, resulting in diel differences in detection rate. Further studies are needed to determine whether differences in electrofishing catches were caused by diel fish migrations or higher catchability at night.

Quantifying abundance is fundamental in fisheries research and management. The most straightforward way of estimating population size is counting all individuals within their spatial distribution as is attempted for adults of some migratory fish populations (e.g., Orell and Erkinaro 2007; Skoglund et al. 2021). This is impractical for most species, and population monitoring is therefore often conducted by local abundance estimation in selected areas (for discussions on different approaches, see Otis et al. 1978; Royle and Nichols 2003; Brashares and Sam

*Corresponding author: maka@norceresearch.no
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2005). However, the ability of such subsample surveys to detect temporal variability in abundance depends on the precision of estimation methods, which typically drops with decreasing density of the target organism (see, for example, Bohlin et al. 1989; Joseph et al. 2006). There might also be biases associated with abundance estimation methods, such as detection bias due to changes in animal activity rates or susceptibility to catch methods over time (Didham et al. 2020), size-dependent catchability (e.g., Borgstrøm and Skaala 1993), or detection probability varying among microhabitats (Boback et al. 2020). Improvement and validation of abundance estimation methods is therefore important to management and conservation efforts that depend on accurate data to guide decision making.

Estimation of local abundance of juveniles is key in salmonid research and population monitoring because it enables researchers to compare fish densities and recruitment in time and space. Electrofishing and direct underwater observations through drift diving are two commonly applied methods for counting salmonids, but the accuracy of both methods is subject to a range of both abiotic (Gardiner 1984; Jensen and Johnsen 1988; Hayes and Baird 1994; Peterson et al. 2004; Rosenberger and Dunham 2005; Meyer and High 2011) and biotic variables (Kennedy and Strange 1981; Pert et al. 1997; Habera et al. 2010; van Poorten et al. 2017). Observed fish density at a given site may vary seasonally (e.g., Tschaplinski and Hartman 1983; Cunjak and Power 1986; Riehle and Griffith 1993; Bonneau and Scarnecchia 1998; Niemelä et al. 2001) and between day and night (e.g., Riehle and Griffith 1993; Hubert et al. 1994; Bonneau and Scarnecchia 1998), and diel shifts in habitat use may also influence actual fish density at the microhabitat scale (e.g., Muhlfeld et al. 2003; Eikaas 2016). Such variability complicates comparisons across studies, especially in large rivers where only a fraction of the fish habitat may be monitored by standard methods.

Diel variation in abundance estimates has received little attention in salmonid research. Counting of fish by drift diving is mostly conducted in daylight, but some studies have suggested that detection rates for juvenile fish are higher at night (Gries et al. 1997; Grost and Prendergast 1999; Roni and Fayram 2000; Thurow et al. 2006). However, Thurow and Schill (1996) found no diel differences in estimated density of Bull Trout *Salvelinus confluentus* parr when comparing drift diving at day and night. Similarly, electrofishing of salmonids is regularly done in daylight, although studies of nonsalmonid fish species have found electrofishing at night to yield higher estimates of both species diversity and fish densities in lotic (Paragamian 1989; Sanders 1992; Copp 2010; Graynoth et al. 2012) and lentic habitats (Dumont and Dennis 1997; Pierce et al. 2001; Schoenebeck et al. 2005; Ross et al. 2016; Blackwell et al. 2017). Saunders et al. (2011) demonstrated that the density of three trout species could be accurately estimated by nighttime electrofishing, but studies comparing night and daytime sampling for salmonids are lacking.

In one of the first systematic comparisons of diurnal and nocturnal sampling of stream salmonids, we conducted drift diving and electrofishing during autumn in the River Namsen in Norway. Our aim was to test the following null hypotheses:

1. Drift dive counts of small salmonids do not differ between night and day sampling.
2. Catch per unit effort by backpack electrofishing of small salmonids does not differ between night and day sampling.

METHODS

Study area.— River Namsen is situated in central Norway (Figure 1). Field surveys were performed between Trongfossen and Løvmoen, above the part of River Namsen accessible to anadromous salmonids. Mean river width in the studied area is about 140 m, and upstream catchment area is 1,035 km^2. The studied river section is affected by reduced discharge due to transfer of water to a hydroelectric power station further downstream. A minimal flow of 12 m^3/s from May 1 to October 31, and 2 m^3/s during the rest of the year (measured at station 139.15.0 by the Norwegian Water Resources and Energy Directorate), is maintained by releasing water from the dam at an upstream lake.

Fish species native to the study area are landlocked Atlantic Salmon *Salmo salar*, Brown Trout *Salmo trutta*, Threespine Stickleback *Gasterosteus aculeatus*, and European Eel *Anguilla anguilla*. The common name "småblank" refers to the Atlantic Salmon population restricted to the upper part of River Namsen, separated from the downstream anadromous Atlantic Salmon due to postglacial isostatic land uplift about 9,500 years ago (Berg 1984). Småblank are relatively small (<300 mm) and mature at a size of 120–150 mm (Thorstad et al. 2009). They are found in an 85-km-long stretch of River Namsen between waterfalls situated 51 and 300 m above sea level, as well as in several tributaries to this section of River Namsen.

Field surveys were performed in September 2015, September 2016, and September 2017 (Tables 1, 2). During the field surveys, water temperature varied from 10.3°C to 13.0°C and conductivity varied from 20 to 52 μS/cm. Discharge in the upper part of the surveyed area, measured at station 139.15.0, varied from 12.5 to 15.2 m^3/s, with no discernable differences in discharge between night and day sampling of the same drift dive

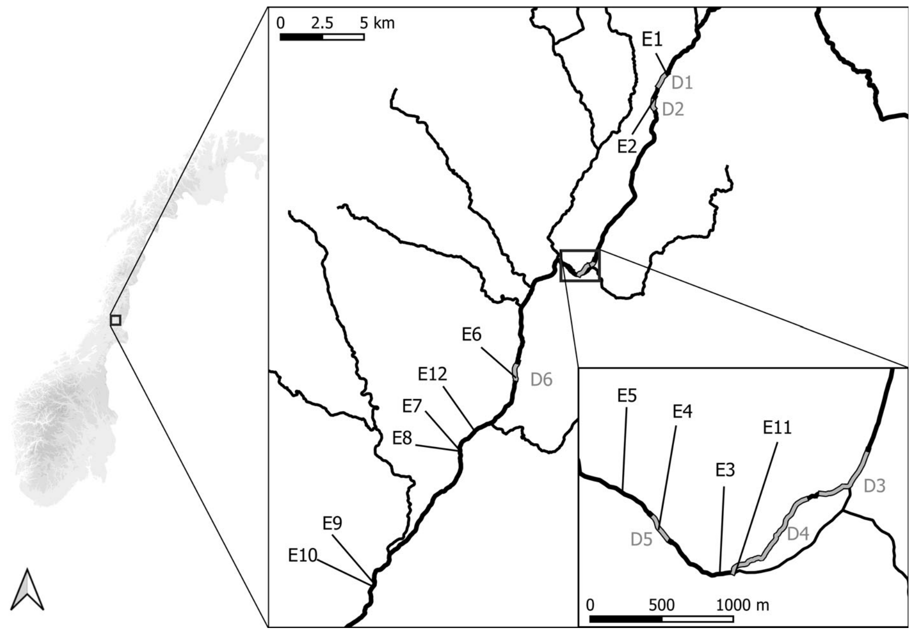

FIGURE 1. Study area in the main stem of the River Namsen, Norway. Sites for electrofishing are indicated with lines and denoted E1–E12. Drift dive transects are shown with gray color and denoted D1–D6.

transects or electrofishing sites. All data collection at night was performed between 90 min after sunset and 60 min before sunrise, and data collection at daytime was performed between 270 min after sunrise and 90 min before sunset.

Drift dive counts.— Drift dive counts were performed by snorkeling in dry suits as described by Skoglund et al. (2021). Two researchers drifted in parallel down five river transects, with the distance between divers large enough that double observations of fish were deemed unlikely. One researcher inspected the sixth and final transect. Transects were 235–1,000 m in length, measured by the tracking function on a handheld GPS (Table 1; Figure 1). Each transect was surveyed once at daytime and once at night, with 13 to 38 h between visits. Three transects were first surveyed at daytime and three first at night. Night dives were performed using 1,500-m handheld torches (TecLine 1500 II; Tecline, Mierzyn, Poland) that were swept from side to side. The divers' ability to detect fish appeared to be restricted by depth, water velocity, and substrate rather than visibility, which was generally good (>8 m). For each dive, the researchers reported an estimate of the width of the observation sector in which they could effectively detect fish while drifting with the current, and the width of this observation sector was multiplied with transect length to yield a coarse estimate of the surveyed area for each dive (Table 1). Estimated width of the observation sector varied from 3 to 6 m and was generally somewhat broader in daylight than at night. Mesohabitat and dominant substrate categories were noted by visual inspection (Table 1).

Electrofishing.— Electrofishing was performed with a model FA 4 backpack electrofisher (Terik Technology AS, Trondheim, Norway), which produces a pulsed direct current. The same electrofisher settings were used at all sites (voltage = 1,400 V). Fishing was performed by two researchers: one operating the apparatus and one carrying a bucket for keeping fish and both using a dip net to catch fish. See Bohlin et al. (1989) for a description of the method. Twelve sites with an area of between 75 and 266 m^2 were surveyed by one-pass electrofishing on two occasions (Table 2; Figure 1), one at daytime and one at night, using 1,500-m headlamps (Silva, Bromma, Sweden). The corners of each site were defined by easily recognizable rocks, and site areas were measured using a handheld laser distance meter. The same person operated the gear at the same sites both day and night. Seven sites were first fished at daytime and five first at night. Time between the start of daytime and nighttime fishing varied from 9 to 33 h (Table 2). Variation in water temperature and conductivity was assumed to be minimal between day and night fishing occasions at each site, as discharge variation was negligible.

All sites were conducive to backpack electrofishing with depths less than 0.8 m and water velocities below ~0.5 m/s. Sites were roughly rectangular in shape, with the riverbank as the boundary on one side and three open boundaries on the other sides. Site E8 was about 50 m from the

TABLE 1. Starting time, number of parallel divers, and physical characteristics for the six drift dive transects in River Namsen, Norway. For the Area column, area = length × perceived width of control sector × number of divers.

Transect	Date	Time (hours)	Length (m)	Divers	Area (m^2)	Mesohabitat	Dominant substrate
D1–day	Sep 16, 2016	1112	975	2	10,725	Glide and run	Gravel and cobble
D1–night	Sep 18, 2016	0125	975	2	6,825		
D2–day	Sep 16, 2016	1214	670	2	7,370	Glide and run	Cobble and boulders
D2–night	Sep 18, 2016	0230	670	2	5,360		
D3–day	Sep 17, 2016	1145	425	2	5,100	Pool upstream weir	Mud, sand
D3–night	Sep 16, 2016	2125	425	2	4,250		
D4–day	Sep 17, 2016	1209	830	2	7,470	Run, pools, and rapids	Gravel, cobble, boulders, and bedrock
D4–night	Sep 16, 2016	2148	920	2	6,440		
D5–day	Sep 17, 2016	1320	235	2	1,880	Glide, riffle, and run	Bedrock and boulders
D5–night	Sep 16, 2016	2358	235	2	1,410		
D6–day	Sep 16, 2016	1640	1,000	1	4,500	Glide, run, and pool	Sand, gravel, cobble, boulders, and bedrock
D6–night	Sep 17, 2016	2108	1,000	1	4,500		

nearest shore, making all four sides open. Dominant substrate categories were noted by visual inspection (Table 2).

All fish were measured (total length) to the nearest millimeter and thereafter released close to land at the same site after each fishing occasion. Individual småblank and Brown Trout were classified into age-0 (young of the year) and age-1+ (age 1 or older) age-classes according to length frequencies.

Statistical analyses and graphics.— Statistical analyses were performed in R (R Core Team 2019). Plots were made using the R package ggplot2 (Wickham 2016). The map (Figure 1) was drawn using QGIS version 3.6.2 (QGIS Development Team 2019).

For drift dive data, numbers of fish observed per 100 m were pairwise compared between night and day counts at each transect using a Wilcoxon's signed rank test. Individuals not determined to species were omitted from statistical tests.

For electrofishing data, statistical tests were performed separately for age-0 and age-1+ Brown Trout. Småblank were not split into age groups because of low catch of age-0 fish. The numbers of småblank, age-0 Brown Trout, and age-1+ Brown Trout caught per 100 m^2 (N) was used as a measure of catch per unit effort (CPUE). The N-values were pairwise compared between night and day sampling at each site (E1–E12) using a Wilcoxon's signed rank test. Tests were run both with and without zeroes (observations where N at a given site was equal day and night).

To investigate whether differences in night versus day CPUE varied with fish size, all småblank and Brown Trout were ordered according to length and split into three size groups: "small" ≤ first quartile < "medium" ≤ third quartile < "large." The numbers of småblank and Brown Trout in each group were pairwise compared between night and day sampling at each site using a Wilcoxon's signed rank test.

RESULTS

Drift Dive Counts

Both småblank and Brown Trout were observed at various depths (~0.1–3.0 m), from midriver to the riverbanks. Of the 226 salmonids observed, 12 individuals were not determined to species: 11 at night and 1 at daytime.

Småblank were observed at all transects at night, and no småblank were observed during daytime dives (Figure 2; Table 3). The mean number of småblank observed at night was 14 per transect (range = 2–37), or 2.29 småblank/100 m (range = 0.21–5.11; SD = 1.91). The number of småblank per 100 m was significantly higher at night than at daytime (Wilcoxon's signed rank test: $P = 0.031$, no zeroes or ties). The length of observed småblank was visually estimated to be in the range of 80–250 mm, and thus all were probably age 1+.

Brown Trout were observed during all but one dive, with a mean of 18 per transect at night and 4 at daytime (range = 0–40; Figure 2; Table 3). The number of Brown Trout observed was higher at night than at daytime for all six transects. The mean number of Brown Trout observed per 100 m was 3.62 at night (range = 0.30–9.79; SD = 3.47) and 0.64 at daytime (range = 0.00–1.70; SD = 0.71), and the difference was significant (Wilcoxon's signed rank test: $P = 0.031$, no zeroes or ties). The coefficient of variation

TABLE 2. Starting time of fishing and physical characteristics for the 12 electrofishing sites in River Namsen.

Site	Date	Time (hours)	Area (m^2)	Dominant substrate
E1–day	Sep 16, 2016	1440	146	Cobble and gravel
E1–night	Sep 17, 2016	2400	146	
E2–day	Sep 16, 2016	1330	122	Cobble and gravel
E2–night	Sep 17, 2016	2300	122	
E3–day	Sep 17, 2016	1430	130	Sand, gravel, cobble, boulders, and bedrock
E3–night	Sep 17, 2016	0200	130	
E4–day	Sep 17, 2016	1540	112	Bedrock
E4–night	Sep 17, 2016	0100	112	
E5–day	Sep 17, 2016	1645	170	Bedrock and cobble
E5–night	Sep 18, 2016	0100	170	
E6–day	Sep 19, 2016	1600	138	Cobble
E6–night	Sep 18, 2016	2300	138	
E7–day	Sep 9, 2017	1445	100	Gravel, cobble, and boulders
E7–night	Sep 10, 2017	0140	100	
E8–day	Sep 9, 2017	1345	130	Gravel, cobble, and boulders
E8–night	Sep 10, 2017	0050	130	
E9–day	Sep 9, 2017	1635	110	Gravel and cobble
E9–night	Sep 9, 2017	0315	110	
E10–day	Sep 9, 2017	1725	120	Cobble and boulders
E10–night	Sep 9, 2017	0415	120	
E11–day	Sep 17, 2015	1250	75	Sand and gravel
E11–night	Sep 17, 2015	2140	75	
E12–day	Sep 16, 2015	1600	266	Cobble
E12–night	Sep 17, 2015	0250	266	

(100 × SD/mean) was slightly lower for nighttime counts than for daytime counts (Table 3). The length of observed Brown Trout was visually estimated to be in the range of 80–700 mm (all probably age 1+), with the majority estimated to be 100–250 mm.

Electrofishing

Total catch was 61 småblank, with a mean length of 132 mm (range = 47–247 mm), and 166 Brown Trout, with a mean length of 99 mm (range = 45–222 mm; Figure 3). Mean length of småblank was 136 mm at night and 122 mm at daytime, and mean length of Brown Trout was 107 mm at night and 88 mm at daytime. The two smallest småblank (47 and 50 mm) were classified as possible age-0 fish, but all småblank were treated as one group in statistical analyses. Of the Brown Trout, 40 were classified as age 0 (45–64 mm) and 126 as age 1+ (69–222 mm). No other fish species were caught during electrofishing.

For småblank, CPUE (individuals caught per 100 m^2 in the first pass; *N*) was significantly higher at night than at daytime (Wilcoxon's signed rank test: mean = 2.87 versus 0.95, $P = 0.009$; $P = 0.004$ when three zeroes were removed). For age-0 Brown Trout, *N* at night was almost identical to *N* at day time (Table 4; Figure 4). For age-1+ Brown Trout, *N* was significantly higher at night than at daytime (Wilcoxon's signed rank test: mean = 5.50 versus 2.65, $P = 0.045$; $P = 0.042$ when one zero was removed). There was considerable variation in *N* among sites, and the coefficient of variation across sites was somewhat higher for day estimates than for nighttime estimates (Table 4). When the catch was split into size groups, only large småblank and large Brown Trout were caught in significantly higher numbers at night than at daytime (Wilcoxon's signed rank test: $P = 0.168$ for small småblank, $P = 0.250$ for medium småblank, $P = 0.035$ for large småblank, $P = 0.595$ for small Brown Trout, $P = 0.137$ for medium Brown Trout, and $P = 0.044$ for large Brown Trout), but exact *P*-values could not be calculated due to tied values in all six groups.

Electrofishing yielded higher fish counts per area than drift dive counts (see Tables 3, 4). For the five electrofishing sites geographically overlapping with drift dive transects (sites E1, E2, E4, E6, and E11; see Figure 1), mean electrofishing catch per 100 m^2 (*N*) at night was 3.10 for småblank and 6.07 for age-1+ Brown Trout compared with a mean density of 0.40 småblank and 0.54 age-1+ Brown Trout per 100 m^2 observed by nighttime drift dive counts in the corresponding transects (D1, D2, D4, D5, and D6).

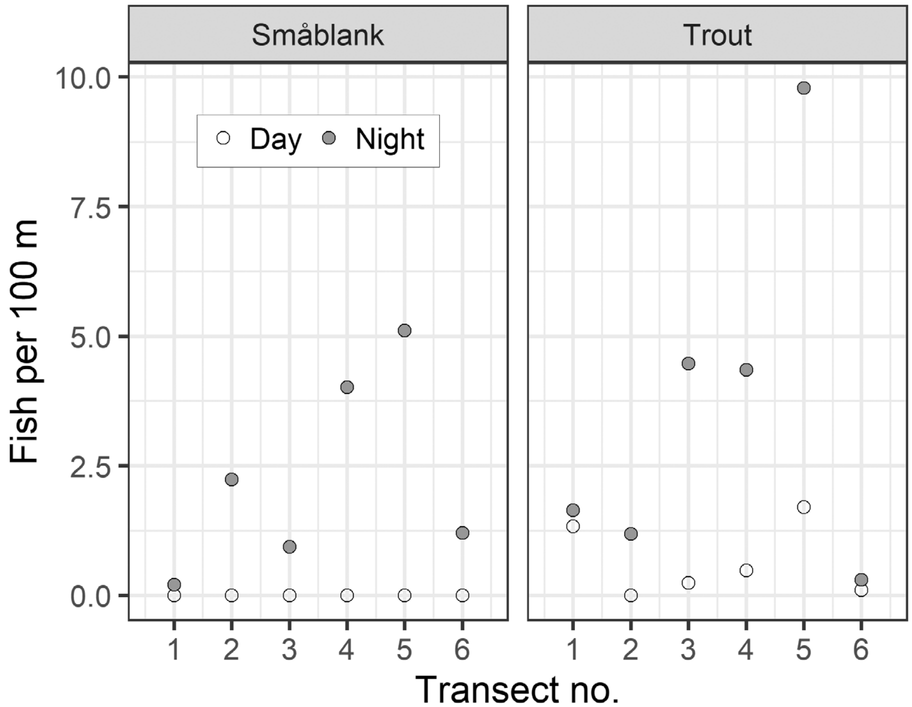

FIGURE 2. Numbers of småblank and Brown Trout observed per 100 m of inspected river length for the six drift dive transects. Individuals not determined to species are omitted.

TABLE 3. Numbers of småblank and Brown Trout observed, numbers observed per 100 m of transect length, and numbers observed per 100 m^2 for the six drift dive transects, including mean, standard deviation (SD), and coefficient of variation (100 × SD/mean; CV). Individuals not determined to species are omitted.

Transect and statistics	Småblank	Småblank/100 m	Småblank/100 m^2	Brown Trout	Brown Trout/100 m	Brown Trout/100 m^2
D1–day	0	0.00	0.00	13	1.33	0.12
D1–night	2	0.21	0.03	16	1.64	0.23
D2–day	0	0.00	0.00	0	0.00	0.00
D2–night	15	2.24	0.28	8	1.19	0.15
D3–day	0	0.00	0.00	1	0.24	0.02
D3–night	4	0.94	0.09	19	4.47	0.45
D4–day	0	0.00	0.00	4	0.48	0.05
D4–night	37	4.02	0.57	40	4.35	0.62
D5–day	0	0.00	0.00	4	1.70	0.21
D5–night	12	5.11	0.85	23	9.79	1.63
D6–day	0	0.00	0.00	1	0.10	0.02
D6–night	12	1.20	0.27	3	0.30	0.07
Mean day	0.00	0.00	0.00	3.83	0.64	0.07
Mean night	13.67	2.29	0.35	18.17	3.62	0.52
SD day	0.00	0.00	0.00	4.79	0.71	0.08
SD night	12.50	1.91	0.31	12.95	3.47	0.58
CV day				125	110	113
CV night	91	84	89	71	96	110

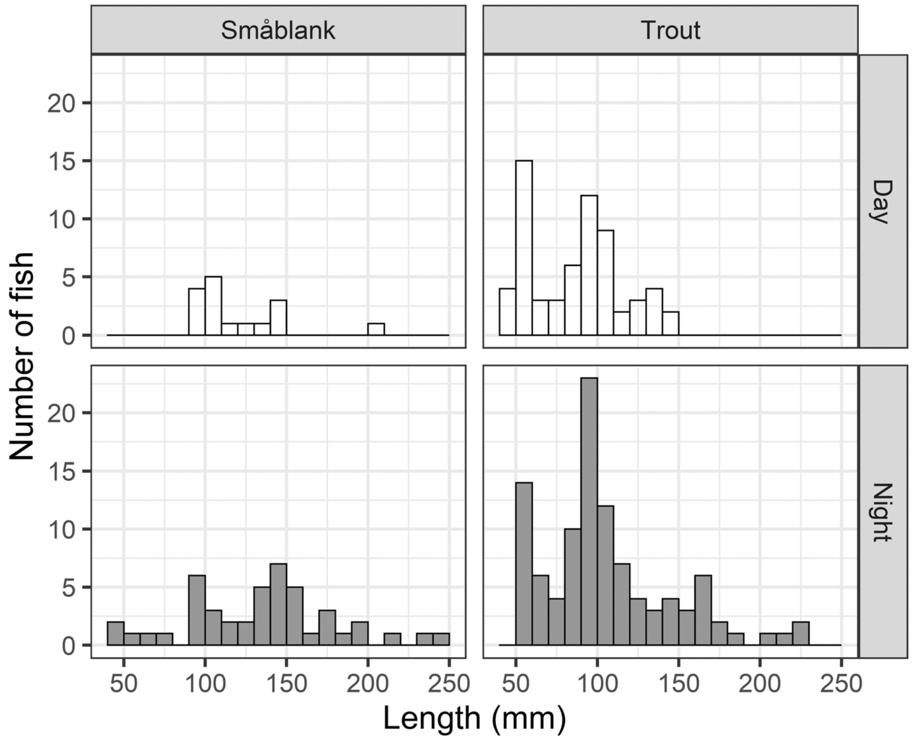

FIGURE 3. Length frequency distribution for småblank (left panels) and Brown Trout (right panels) caught by electrofishing at daytime (upper panels) and at night (lower panels).

DISCUSSION

Drift Dive Counts

This study demonstrates that drift dive counts of småblank and nonanadromous Brown Trout differ between night and day sampling. The most likely explanation for the diel variation in number of fish observed is that fish were hiding in coarse substrate like cobble and boulders during the day and were more active at night. Småblank have rather small home ranges (Davidsen et al. 2020), and as the drift dive transects were relatively long and covered various habitat types both close to the banks and midriver, it seems unplausible that the differences in fish observations were caused by diel migrations in and out of the surveyed areas. Brown Trout have been shown to stay deeper in lotic water columns at daytime than at night (Lennox et al. 2021), but the surveyed parts of River Namsen had no pools too deep for spotting fish holding positions on the bottom. It is also possible that fish were shier in daylight, escaping before divers spotted them, or that fish were more easily observed at night because they were momentarily stunned by the torches. However, juvenile Atlantic Salmon are readily observed up close by snorkelers at daytime during summer and early autumn in many other rivers (e.g., Morantz et al. 1987; Stradmeyer and Thorpe 1987; Heggenes et al. 1990), suggesting that the landlocked småblank population is more inclined to hiding at daytime than juveniles of anadromous Atlantic Salmon populations.

Drift dive counting is a standard method for stream salmonid population monitoring, both in Norway and internationally (e.g., Thurow et al. 2012; Vollset et al. 2014; Skoglund et al. 2021), making it crucial to understand which factors affect its precision and accuracy. This study suggests that detection rates (proportion of present fish observed) are higher at night than in daylight, but studies of closed populations with known abundance are necessary to quantify detection rates. Our data underline that monitoring data from nighttime drift dive counts cannot be compared with daytime counts without knowledge on diel differences in detection rates, which likely vary between species, fish size-groups, habitats, rivers, and seasons. For example, the proposed autumnal shift to a nocturnal activity pattern in small salmonids (Gibson 1978; Rimmer et al. 1983; Fraser et al. 1993, 1995; Heggenes et al. 1993) could mean that seasonal patterns in detection rates are opposite for daytime and nighttime drift diving (but see Gries et al. 1997; Imre and Boisclair 2004). Interspecific interactions may also affect detection rates or capture probabilities (Yackulic et al. 2018; Healy et al. 2022)—for example, a nocturnal activity pattern is hypothesized to be an adaptation to reduce predation risk in several temperate fish species (Emery 1973; Hanych et al. 1983; Culp 1989).

TABLE 4. Number of individuals caught (Catch) and number of individuals caught per 100 m^2 (N) for different fish groups, including mean, SD, and CV (100 × SD/mean), for the 12 electrofishing sites in River Namsen.

Site and statistics	Småblank		Age-0 Brown Trout		Age-1+ Brown Trout	
	Catch	*N*	Catch	*N*	Catch	*N*
E1–day	1	0.69	4	2.74	4	2.74
E1–night	1	0.69	5	3.43	10	6.86
E2–day	3	2.46	3	2.46	6	4.92
E2–night	3	2.46	2	1.64	5	4.10
E3–day	0	0.00	0	0.00	2	1.54
E3–night	6	4.62	0	0.00	19	14.62
E4–day	1	0.89	0	0.00	4	3.57
E4–night	3	2.68	2	1.79	11	9.82
E5–day	2	1.18	14	8.24	6	3.53
E5–night	2	1.18	6	3.53	16	9.41
E6–day	1	0.72	1	0.72	5	3.62
E6–night	6	4.35	2	1.45	4	2.90
E7–day	1	1.00	0	0.00	7	7.00
E7–night	3	3.00	1	1.00	3	3.00
E8–day	1	0.77	0	0.00	2	1.54
E8–night	2	1.54	0	0.00	3	2.31
E9–day	1	0.91	0	0.00	0	0.00
E9–night	2	1.82	0	0.00	2	1.82
E10–day	2	1.67	0	0.00	1	0.83
E10–night	4	3.33	0	0.00	4	3.33
E11–day	0	0.00	0	0.00	1	1.33
E11–night	4	5.33	0	0.00	5	6.67
E12–day	3	1.13	0	0.00	3	1.13
E12–night	9	3.38	0	0.00	3	1.13
Mean day	1.33	0.95	1.83	1.18	3.42	2.65
Mean night	3.75	2.87	1.50	1.07	7.08	5.50
SD day	0.98	0.66	4.06	2.44	2.27	1.99
SD night	2.26	1.43	2.07	1.33	5.63	4.08
CV day	74	70	222	206	67	75
CV night	60	50	138	124	80	74

In contrast to surveys of adult anadromous salmonids in relatively small rivers (e.g., Skoglund et al. 2021), drift dive counts of small salmonids in wide rivers with complex habitat may not be expected to produce accurate estimates of population size. This is emphasized by the discrepancy between fish counts produced by drift diving and electrofishing from the same areas of River Namsen in this study. However, as no available method can be expected to reliably estimate true population size of small salmonids in large rivers, standardized drift dive counts could still be useful as a cost-effective method for comparing *observed* fish densities in time and space. Given consistent detection rates, this provides an index

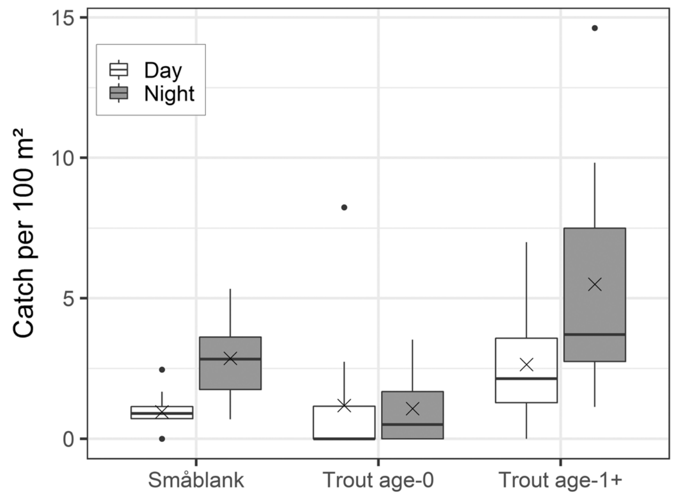

FIGURE 4. Catch (individuals/100 m^2) of småblank, age-0 Brown Trout, and age-1+ Brown Trout in single-pass electrofishing at 12 sites in River Namsen. The boxes show the medians (line inside box) and quartiles (box dimensions), while the whiskers show the extremes within 1.5 times the interquartile range. Crosses represent the mean value, and dots are outliers.

of fish density of great value in guiding management decisions.

Electrofishing

Catch per unit effort by backpack electrofishing of both småblank and age-1+ Brown Trout were higher at night than at daytime. The differences in CPUE may have been caused by higher catchability at night than at daytime or by diel fish migrations in and out of the electrofishing sites (i.e., differences in actual density). For example, a higher rate of emigration (fish escaping) from the sites in daylight, or fish being stunned by headlamps during nocturnal electrofishing, could lead to diel differences in catchability. However, experiments using closed populations with known abundance (e.g., electrofishing sites surrounded by block nets) are necessary to quantify diel differences in catchability without the influence of fish migrations.

Diel shifts in habitat use and position relative to the banks are known to occur in several fish species in both rivers and lakes (Copp and Jurajda 1993 and references therein). For example, anadromous Atlantic Salmon parr perform migrations between daytime refuges and nighttime feeding stations (e.g., Fraser et al. 1993). Higher catch of large småblank and Brown Trout during electrofishing at night suggests that larger individuals in particular display diel differences in habitat use. An alternative explanation could be that large fish were more prone to escape the electric field or react to visual cues in daylight than at night and more so than small fish. However, a radio-tagging study found that småblank >150 mm more often hold positions on sand and gravel substrate at night than in daylight (Eikaas 2016), supporting the idea that the microhabitat use of småblank is influenced by light intensity. The catch at our site E11, with a substrate of sand and fine gravel offering no fish shelter, indicates the same pattern; it was first surveyed at daytime with a catch of zero småblank and one Brown Trout and subsequently at night with a catch of four large (158–247 mm) småblank and five large (127–215 mm) Brown Trout.

CONCLUSIONS

Both hypotheses tested in this study were rejected; drift dive counts were higher at night than at daytime, and the same was true for CPUE by electrofishing. The findings are of obvious importance to future småblank monitoring programs and suggest that nocturnal fieldwork may improve monitoring of small riverine salmonids in general. Future research should focus on closed-population experiments to estimate diel differences in detection rates and catchability for these commonly applied abundance estimation methods.

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ORCID

Marius Kambestad https://orcid.org/0000-0002-9625-2733

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