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Nocturnal emergence of juvenile rainbow trout from winter concealment relative to light intensity

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Abstract

This study examined the relationship between light intensity and the number of juvenile rainbow trout (*Oncorhynchus mykiss*) visible to a snorkeler during February in the Henrys Fork of the Snake River, Idaho, USA. Fish were concealed in the substratum during daylight. Emergence from concealment was observed from 30 to 80 min after real sunset time and began when stars were first visible (pyranometric irradiance, 4.5×10^{-3} W^{-2}). Densities of visible fish were negatively correlated with light intensity ($r^2 = 0.81$, $P < 0.001$). Later at night, densities decreased in the presence of moonlight and artificial light. Fish were observed to feed at night.

Introduction

Daytime hiding behaviour during the fall and winter has been well documented for stream-dwelling salmonid fishes. Increased use of cover by juvenile brown trout (*Salmo trutta* Linnaeus) as temperatures decreased during the fall and winter in stream aquaria was shown by Hartman (1963). More recently, numerous researchers have observed fish concealing themselves in cover in their stream environments as water temperature drops below a threshold temperature. The behaviour has been noted for members of the genera *Salmo* (*i.e.*, Rimmer *et al.*, 1983), *Oncorhynchus* (*i.e.*, Hillman *et al.*, 1987), and *Salvelinus* (R. A. Cunjak, Fisheries and Oceans, Moncton, Canada, unpubl.).

Nocturnal behaviour of juvenile trout in winter has been little studied. Campbell & Neuner (1985) were apparently first to report winter nighttime observations of wild fish. They described the emergence of juvenile rainbow trout (*Oncorhynchus mykiss* (Walbaum)) from concealment in the substratum about 1 h after sunset and their return to the substratum at dawn. Other generalized observations of winter nighttime activity have been reported by Swift (1964) for brown trout, and by Needham & Jones (1959) who counted three times more trout during a winter night than during the day in a pool in Sagehen Creek, California.

Our winter observations in the Henrys Fork of the Snake River (Contor, unpubl.) concurred with those of Campbell & Neuner (1985), indicating that night snorkeling would permit the observation of juvenile rainbow trout that were out of concealment. In this study, we sought to evaluate whether light intensity was a major stimulus for the movement of juvenile rainbow trout out of concealment in the Henrys Fork of the Snake River by assessing possible relationships between light intensity and the numbers of fish visible to a snorkeler.

Study area

Located in Fremont County in southeastern Idaho (44 °20′N; 111 °24′W), the Henrys Fork of the Snake River is a fourth order stream that flows into Island Park Reservoir at an elevation of about 1866 m. The study reach, adjacent to the community of Last Chance, was 2.2 km long and began 8 km below Island Park dam. It had a mean width of 100 m and a gradient of 0.3%. Flow (11 m^3 sec^{-1} during the study) drawn from the hypolimnion at 4 to 6 °C and about 6 m^3 sec^{-1}

from the Buffalo River kept the reach free of surface or anchor ice during the winter of 1986–87, despite air temperatures as low as −30 °C and a snow pack that ranged from 0.5 to 2.1 m. During the study period in February 1987, maximum daily water temperatures ranged from 3.0 to 6.6 °C.

Aquatic macrophyte beds, predominantly *Myriophyllum* sp., on gravel substratum were present across most of the channel at the onset of winter and thinned as winter progressed. Boulders, gravel, undercut banks, sagebrush (*Artemesia* sp.) and grasses dominated the bank areas.

Other fish species abundant in the study area were mountain whitefish (*Prosopium williamsoni* (Girard)) and mottled sculpin (*Cottus bairdi* Girard). Predators capable of taking juvenile trout that were present in the study area during the fall and winter were osprey (*Pandion haliaetus* (Linnaeus)), bald eagle (*Haliaetus leucocephalus* (Linnaeus)), great blue heron (*Ardea herodias* Linnaeus), belted kingfisher (*Ceryle alcyon* (Linnaeus)), common merganser (*Mergus merganser* Linnaeus), mink (*Mustela vison* (Bangs)), and river otter (*Lutra canadensis* Goldman).

Methods

To evaluate the relationship between light intensity and the dusk emergence of juvenile rainbow trout, we made multiple snorkeling passes at 20–45 min intervals through a series of study sites from daylight to starlight. Snorkeling observations were made in conjunction with light intensity measurements on 6, 7, 14, 15, 20, and 21 February 1987 from about 1200 to 0100 h Mountain Standard Time. A different 150–250 m long snorkel lane was randomly selected and used repeatedly on each date. All lanes were 2 m wide and extended along the stream margin adjacent to the bank. Juvenile trout in the reach were concentrated in areas with water velocities less than 15 cm s^{-1} and at depths between 20 and 40 cm (Contor, unpubl.). To compare numbers of fish observed on successive counts on a sample date, we calculated relative observed numbers as a percentage of the maximum number of fish observed on that date.

One snorkeler (the same individual throughout) made all the counts, using a diving light and moving in an upstream direction through the lane. Displacement of juvenile rainbow trout was minimal when trout were approached carefully. Juvenile trout moved away from and around the snorkeler and returned to their approximate previous locations as the snorkeler moved on. Fish that appeared extremely similar were sometimes found in identical positions on subsequent passes. We minimized displacement by not shining the light directly on fish, but instead directing the light beam to the underside of the water surface. This procedure prevented the light beam from extending beyond the snorkeler's range of vision.

The trout we observed were approximately 85–165 mm in total length, based upon daytime electrofishing captures (Contor, unpubl.), and were known from scale analysis (Angradi & Contor, 1989) to be in their first winter of life. Adult trout were occasionally seen, but disregarded.

We estimated irradiance with a 'Li-Cor' data recorder using a radiometric sensor. The sensor was a 'Li-Cor' pyranometer (LI-200SA) reading in Watts m^{-2} of radian flux incident on a receiving surface from all directions. Data were recorded as averages over 20 s intervals to add consistency at lower light levels. The meter was placed 10 cm above the water on a stand about 1 m from the bank.

Illuminance (unit: lux) is the density of luminous flux incident on a receiving surface from all directions that is visible to the average human eye (400–700 nm). The equation Watts m^{-2} *times* 680 = lux (or lumen m^{-2}) can be used to estimate illuminance from irradiance at 555 nm (Weast, 1970: Table 1). However, the equation is variable throughout the spectrum so estimates of visual light on surfaces (illuminance) only correlate with the estimates of irradiance. Light intensity, time, and water temperature were recorded before and after each snorkel pass. To facilitate comparisons with other systems, we calculated true sunset time by adjusting for latitude and longitude at our specific location. Times of observations are reported in hours before and after site-specific sunset time.

As a manipulative experiment, artificial light was supplied by a large commercial billboard on the riverbank. We turned on this sign 3 h after sunset during a moonless night to observe the response of juvenile rainbow trout to increased light intensity independent of solar-lunar events. This procedure increased light intensity at that site to a level similar to a full moon.

Results

On all six sampling dates, no juvenile trout were seen during daytime snorkeling. Dusk emergence of age-0 rainbow trout began 25–35 min after sunset (Fig. 1).

Table 1. Correlative values of irradiance in Watts m^{-2} and the $\log_{10}$ of Watts m^{-2}, illuminance in lux, and associated general terms.

Watts m^{-2}	Log Watts m^{-2}	Lux	General term
0.000001	−6	0.0005–0.001	starlight
0.00001	−5	0.005–0.01	
0.0001	−4	0.05–0.1	moonlight
0.001	−3	0.5–1.0	
0.01	−2	5–10	dusk
0.1	−1	50–100	
1.0	0	500–1000	cloudy day
10.0	1	5000–10 000	
100.0	2	50 000–100 000	bright sunlight

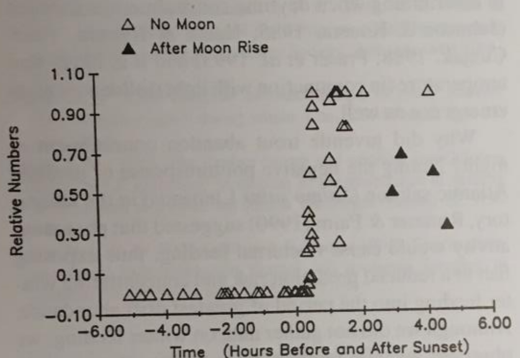

Fig. 1. Relative number (as a percentage of the maximum number of fish observed for a given site and date) of juvenile rainbow trout counted during winter snorkeling in relation to real sunset time with no moon (open symbols, N = 54) and after moon rise (solid symbols, N = 4) in the Last Chance reach of the Henrys Fork of the Snake River, February 1987.

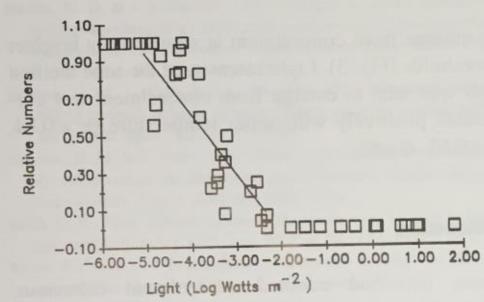

Fig. 2. Relative number (as a percentage of the maximum number of fish observed for a given site and date) of juvenile rainbow trout counted during winter snorkeling in relation to light intensity (N = 54) in the Last Chance reach of the Henrys Fork of the Snake River, February 1987. The solid line represents a regression for the 27 transitional observations ($r^2 = 0.81$, $P < 0.001$).

The numbers of fish observed in the water column increased until about 60–80 min after sunset, before moonrise. Fish often were observed feeding behind the dive lights during night snorkeling.

Dusk emergence began when stars were first visible, at light intensities near 4.5×10^{-3} W m^{-2}, and appeared to be completed when light intensities were about 1.0×10^{-5} W m^{-2}, before moonrise (Fig. 2). Relative fish abundance during the period of emergence, based on 27 observations, was negatively correlated with light intensity ($r^2 = 0.81$; $P < 0.001$) (Fig. 2).

The number of juvenile rainbow trout observed during nighttime snorkeling decreased in the presence of moonlight. On four nights, densities dropped from a mean of 11 fish 100 m^{-2} at a light intensity of 3.6×10^{-6} W m^{-2} before the moon rose, to a mean of 3 fish 100 m^{-2} at a light intensity of 5.1×10^{-4} W m^{-2} after the moon rose (Fig. 1).

The number of fish observed also decreased after the addition of artificial light. Before the addition of artificial light, we observed a density of 18 fish 100 m^{-2} at a light intensity of 1.3×10^{-6} W m^{-2}. Twenty minutes after the addition of artificial light, we observed a density of 13 fish 100 m^{-2} at a light intensity of 1.2×10^{-5} W m^{-2}. During the artificial light episode, we observed juvenile rainbow trout entering interstitial spaces between and under boulders. As night progressed, we saw no reduction in fish densities unless light intensity increased.

As water temperature at dusk gradually increased from 3.0 to 6.6 °C during the study period, trout began

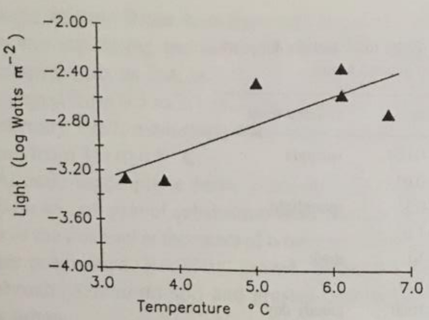

Fig. 3. Light intensity at the first observed emergence of juvenile rainbow trout from winter concealment after dusk in relation to water temperature ($r^2 = 0.64$, $P<0.05$) in the Last Chance reach of the Henrys Fork of the Snake River, February 1987.

to emerge from concealment at significantly brighter thresholds (Fig. 3). Light intensity at the time the first fish was seen to emerge from concealment was correlated positively with water temperature ($r^2 = 0.64$, $P<0.05$, $N = 6$).

Discussion

Once fish had adopted concealment behaviour, decreasing light intensity appeared to be a major stimulus for the emergence of juvenile rainbow trout from concealment cover during winter evenings. When light intensity fell below 4.5×10^{-3} W m^{-2}, juvenile rainbow trout began emerging. This occurred about 30 min after real sunset time, and supports Campbell and Neuner's (1985) generalized observation of juvenile rainbow trout emerging about 1 h after sunset. While our light intensity measurements were only made in February 1987, we observed similar daytime concealment and nocturnal emergence behaviour during 53 day and 165 night snorkeling surveys made from December 1986 to early April 1987. Riehle & Griffith (1993) observed the emergence of age-0 rainbow trout in early winter (November) at 6 °C in Silver Creek, Idaho, using procedures similar to ours. Numbers of visible trout in Silver Creek increased from none at sunset to a peak at about 1 h after sunset.

In the Henrys Fork, the number of unconcealed trout appeared to stabilize several hours after real sunset time in the absence of moonlight. However, increased light from a rising moon or the addition of artificial light after fish had emerged from the substratum caused a substantial reduction in observable trout, although water temperature did not change. This evidence supports our hypothesis that the decline in light intensity at sunset is a major stimulus for dusk emergence from daytime concealment by juvenile rainbow trout in the Henrys Fork. In a single set of observations at dawn in November, Riehle & Griffith (1993) found that the density of trout visible in Silver Creek was greatest 30 min before sunrise, but all trout were concealed 10 min prior to sunrise.

At lower temperatures, juvenile rainbow trout in the Henrys Fork emerged at lower light intensities, though the sample size was small and it was difficult to observe the exact instant of first emergence while trying to minimize the number of snorkel passes through a site to about one every 20–40 min. However, previous research indicates that temperature is a key factor in determining when daytime concealment is initiated (Johnson & Kucera, 1985; Hearn & Kynard, 1986; Cunjak, 1988; Fraser *et al.* 1993) and it is likely that temperature (in conjunction with light) influences night emergence as well.

Why did juvenile trout abandon concealment at night? Noting the negative photoresponse of juvenile Atlantic salmon (*Salmo salar* Linnaeus) in the laboratory, Rimmer & Paim (1990) suggested that photonegativity would cause nocturnal feeding, thus exposing fish to a reduced predation risk and concentrating winter feeding into the period of greatest drift abundance. Although we did not gather data on winter feeding, we observed juvenile rainbow trout feeding during night snorkeling. Although these observations were under artificial light, there are several examples from the literature (*i.e.*, Elliott, 1973; Riehle & Griffith, 1993) of fish feeding naturally at low light intensity during the winter. Jenkins *et al.* (1970) reported that trout fed at all hours of the day and night, at light intensities as low as 0.001 l× (star light), when they could not feed to satiation at 3.0–6.5 °C in an oligotrophic stream.

Food availability 2 h after sunset on the Henry's Fork was high during the February study. Although drift samples were not taken, clusters of hundreds of adult and emerging midges (Chironomidae) were present along the stream margins where juvenile rainbow trout were observed. Anderson (1966) reported that peak invertebrate drift occurred just after dark on moonless winter nights, and that moonlight greatly reduced winter invertebrate drift. During periods of moonlight, juvenile rainbow trout in the Henrys Fork may return to concealment cover in response to reduced food availability as well as to an increased perception of risk.

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