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Interactions between Rainbow Trout and Bridgelip Sucker Spawning in a Small Washington Stream

Abstract

We investigated the interactions between two sympatric native fishes (rainbow trout and bridgelip sucker) spawning in Umtanum Creek, a tributary of the Yakima River in central Washington. We used redd surveys to determine spawn location and timing of rainbow trout and bridgelip sucker. We determined microhabitat characteristics of rainbow trout and bridgelip sucker spawning areas and measured the degree of disturbance of rainbow trout redds by spawning bridgelip sucker as well other rainbow trout. Emergence traps were used to compare the mean survival to emergence (STE) rate of experimentally protected rainbow trout redds to those left unprotected. The first behavioral observations of bridgelip sucker spawning are also reported here. Both temporal and spatial overlap in spawning of rainbow trout and bridgelip sucker were observed. No differences were found in the water depth and water velocity used by rainbow trout and bridgelip sucker for spawning. Spawning behavior of bridgelip sucker entailed extensive substrate modification (i.e., digging) prior to the release of gametes. During spawning surveys, bridgelip sucker were observed spawning in 3 of 21 rainbow trout redds in 1994 and 5 of 15 rainbow trout redds in 1995. Estimated mean STE of protected rainbow trout redds (11.2%) was significantly greater ($P<0.02$) than rainbow trout redds that were unprotected (2.6%). Of those unprotected rainbow trout redds, the mean STE of rainbow trout redds disturbed by bridgelip sucker and other rainbow trout was 0.4% and 2.8%, respectively. When spawning habitat is severely limited, emergence rates of earlier spawning rainbow trout may be reduced due to redd superimposition by bridgelip sucker.

Introduction

Variation in the reproductive success of stream-dwelling salmonids has been correlated to water quality (Coble 1961), substrate quality (Witzel and MacCrimmon 1981), and spawner density (McNeil 1962). As spawner density increases the probability of redd superimposition also increases. Few studies have examined the role of intraspecific competition for spawning space (McNeil 1962, Beard and Carline 1991) and even fewer have examined interspecific competition (Hayes 1987).

Suckers (Catostomidae) are one of the most common fishes in middle to low elevation streams of the Pacific Northwest and commonly coexist with salmonids such as rainbow trout (*Oncorhynchus mykiss*). Studies examining dietary overlap (Trojnar and Behnke 1974, Tremblay and Magnan 1991) or relative abundance (Hubert and Guenther 1992) suggest that competition exists between catostomids and salmonids. Conversely, Li (1975) suggested that competition between salmonids and catostomids for food or space occurs less frequently than previously believed or perhaps is nonexistent. In a study examining competition for space between rainbow trout and Sacramento sucker (*Catostomus occidentalis*) in three California streams the two species were segregated vertically within the water column throughout most of their life history (Baltz and Moyle 1984). If two species coexist, mechanisms must have evolved or are currently evolving, that limit interspecific competition. Without these mechanisms, ecological theory would predict that one species would become extinct. Information concerning catostomid life history and in particular their relationship with other fish species is needed.

Bridgelip sucker (*C. columbianus*) are native to the Fraser and Columbia River basins (Wydoski and Whitney 1979) and have been reported to be the fourth most abundant resident species in the middle Columbia River (Gray and Dauble 1977). A study conducted between 1957 and 1958, on the relative abundance of fishes in the Yakima

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River, found that catostomids were the second most abundant species in the upper Yakima River (Patten et al. 1970). During that survey of the entire Yakima River, bridgelip sucker was ranked 8 in abundance compared to rainbow trout that ranked 18 in abundance. More recently, Pearsons et al. (1996) reported that suckers (*C. columbianus* and *C. macrocheilus*) comprised 16.5% (rank 2) and rainbow trout comprised 6.8% (rank 4) of all fish observed during electrofishing surveys of the upper Yakima River in 1994. Although the spawning ecology for many species of catostomids has been described in the scientific literature (McCart and Aspinwall 1970, McSwain and Gennings 1972, Moyle and Marciochi 1975), little is known about the bridgelip sucker. Dauble (1980) conducted a life history study of bridgelip suckers in the middle Columbia River and examined the age structure, growth, spawn timing, fecundity, and diet of the species. However, bridgelip sucker spawning behavior has not been reported.

During our fieldwork on rainbow trout spawning in the Yakima River basin, we observed spatial and temporal overlap between spawning bridgelip sucker and rainbow trout in several tributaries of the Yakima River. We examined spawning interactions between bridgelip sucker and rainbow trout in one of those tributaries, Umtanum Creek. The objectives of our study were: 1) measure the proportion of rainbow trout redds disturbed by bridgelip sucker spawning activity; 2) examine the spawning behavior of bridgelip sucker; and 3) determine the effect of bridgelip sucker spawning on the survival to emergence (STE) of rainbow trout eggs.

Study Area

Umtanum Creek is a second-order tributary that enters the Yakima River at rkm 225 and has a watershed area of approximately 138 km^2. Umtanum Creek is 26 km long and flows through a basalt canyon. Much of the watershed is composed of shrub-steppe habitat, except in the higher elevations where some conifers are present. Riparian vegetation consists of willow (*Salix* spp.), black cottonwood (*Populus trichocarpa*), and quaking aspen (*P. tremuloides*).

Umtanum Creek is the only perennial spawning tributary for fishes within a 38 km reach of the Yakima River (Figure 1). Rainbow trout and bridgelip sucker migrate from the Yakima

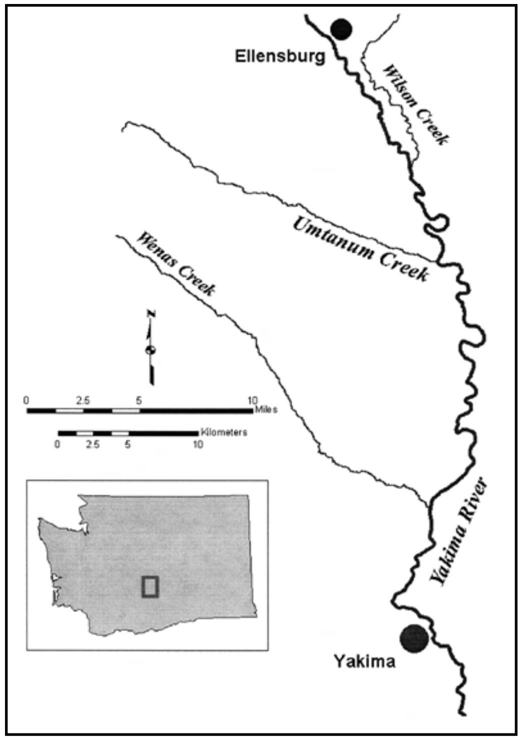

Figure 1. Map of the upper Yakima River and Umtanum Creek.

River into Umtanum Creek during the spring to spawn. Upstream beaver dams limit spawning in Umtanum Creek to the lower one kilometer of the creek. Although resident rainbow trout spawn in Umtanum Creek, they are much smaller than the migratory form and are found throughout the creek (Martin et al. 1994).

The study area consists mostly of riffle and run habitat with a few small pools. During the study period the average wetted width and depth of the stream was 2.4 m and 0.25 m, respectively. The substrate was primarily composed of cobble and large boulders interspersed with patches of gravel suitable for salmonid spawning (Thurow and King 1994).

Methods

Spawning

Spawning migrations of rainbow trout and bridgelip sucker were assessed using a weir and fish trap in 1994 (experimental year). A trap and two V-shaped weirs were installed approximately 100 m upstream from the confluence with the Yakima River. The trap and weir frames were constructed of wood and covered in a welded wire screen with 1 cm openings. The trap was designed to capture all adult rainbow trout and bridgelip sucker entering or leaving the creek. The fish trap was divided into two compartments to segregate those fish moving upstream from fish moving downstream. The trap was checked daily to determine the number of fish entering or leaving the study reach. All fish captured were anesthetized with a tricaine methanesulfonate (MS-222) solution, identified to species, measured (fork length) to the nearest millimeter, and weighed to the nearest gram. The direction of movement was also recorded. Two sample t-tests were used to examine differences in the length and weight of rainbow trout and bridgelip sucker. Fish captured moving into the study reach were released approximately 50 m upstream from the trap in a small pool to reduce the probability of fallback. Fish moving out of the study reach were released approximately 20 m downstream from the trap also in a small pool, which allowed for fish to fully recover before reentering the Yakima River. In 1995, the fish trap and weir were not installed in Umtanum Creek to determine what effects, if any, the fish trap and weir had on the relative abundance (i.e., trap avoidance) of both rainbow trout and bridgelip sucker (observational year).

The reproductive status and sex of each fish captured were recorded. The primary method of determining sex was whether or not fish exuded eggs or sperm. However, the presence of secondary sexual characteristics (e.g., tubercles) was used when gametes were not released (Wydoski and Whitney 1979). In 1994, female rainbow trout captured immigrating into the stream were tagged with a 5 cm t-bar anchor tag inserted at the base of the dorsal fin. Tags consisted of two different colored vinyl tubes. Each tag had a unique combination of color-coded tubes that allowed for the identification of an individual female rainbow trout. The unique color-coded tags in each female rainbow trout allowed us to determine the location and number of redds constructed by each female rainbow trout. Male rainbow trout were tagged with 2.5 cm orange anchor tags in cooperation with an ongoing study on rainbow trout movement within the Yakima River basin (Bartrand et al. 1994).

In 1994 and 1995, spawning surveys were conducted in the lower 1-2 km of the creek. During 1994, spawning surveys were conducted a minimum of once daily throughout the rainbow trout and bridgelip sucker spawning season (14 March – 5 June) and twice daily during the peak of spawning (1 –30 April). Because fish were not individually tagged in 1995, spawning surveys were conducted every 2 - 5 days (15 March – 1 June). All spawning surveys including spawning behavior observations were conducted from the stream bank. The small size of the stream and incised stream channel, coupled with excellent water clarity provided the ideal situation for conducting observations from the stream bank in 1994 and 1995. Rainbow trout redds were identified by the presence of a distinct pot and tailspill (Orcutt et al 1968; Crisp and Carling 1989). Bridgelip sucker spawning behavior had not been previously described in the literature. Several investigators reported that both largescale sucker (*C. macrocheilus*) and white sucker (*C. commersoni*) prepare a spawning area or create depressions in the substrate by removing smaller substrate (Hayes 1956; McCart and Aspinwall 1970). Spawning areas of bridgelip sucker were easily discernible by the absence of periphyton and the lack of smaller substrate (e.g., gravel). Bridgelip sucker eggs adhere to the substrate decreasing the likelihood of being transported downstream. Removal of one or more large cobbles and visual inspection for eggs underneath confirmed that spawning had occurred.

Spawning Habitat

Stream discharge was monitored using a staff gauge located near the mouth of the stream. Discharge (m^3/s) was calculated at various gauge heights from velocity measurements taken along a fixed transect at 60% of the water depth, using a Marsh-McBirney Model 201D electronic flow meter. Temperature was recorded using a continuous recording Ryan thermograph.

In 1994 and 1995, microhabitat measurements were recorded for all rainbow trout redd or bridgelip sucker spawning sites using methods adapted from Orcutt et al. (1968) and Crisp and Carling (1989). The length and width of a spawning area were measured to the nearest centimeter using a tape measure. Water depths were measured to the nearest centimeter in the pot, tailspill, and adjacent to rainbow trout redds. Current velocities (m/s) in rainbow trout redds were measured at the most upstream point of the pot (60% of the total depth) and at the transition point between pot and tailspill (surface, 60% of the total depth, and bottom) using a Marsh-McBirney Model 201D electronic flow meter. Bridgelip sucker spawning habitat was delineated by the area of the substrate disturbed during spawning (i.e., lack of periphyton and gravel). Average water velocity (60% of total depth) and depth were calculated for bridgelip sucker spawning sites based upon three measurements taken at equidistant points across the maximum width of the spawning site. Mann-Whitney U-tests were used to determine if differences existed in the mean length, width, water depth, and velocity of rainbow trout and bridgelip sucker spawning habitat. The significance level for all statistical analyses was $P < 0.05$.

Redd Disturbance

We defined disturbance as the physical disruption of a redd. Disturbance of rainbow trout redds was detected by placing white rocks along the perimeter and across the center of the tailspill of all rainbow trout redds. The size of the rocks ranged between 2 and 4 cm in diameter, a size that would not be dislodged by the current. The extent of the redd disturbance was determined by estimating the proportion of the tailspill that remained intact.

In 1994, all redds ($N = 21$) were enclosed using 5 cm wire mesh to ensure that only one female rainbow trout had spawned in that area and to protect redds from disturbance by other fish (experimental year). On 19 April 1994, before bridgelip sucker began spawning, wire exclusions were removed from a random sample of 50% of the rainbow trout redds (treatment). The wire exclusions were not removed from the remaining redds to ensure that those redds would not be disturbed (control). Rainbow trout redds constructed after bridgelip sucker spawning had ended were also included in the control group.

In 1995, the wire exclusions around the rainbow trout redds were not installed to determine if the presence of wire exclusions in the study area affected the spawning site selection of either species and subsequently influenced the number of rainbow trout redds disturbed (observational year). However, redd disturbance was monitored in a similar manner as previously described in 1994. The number of rainbow trout redds constructed and disturbed, and the extent of disturbance by bridgelip sucker or rainbow trout was recorded.

Survival to Emergence

Rainbow trout and bridgelip sucker that immigrate and spawn in Umtanum Creek reside in the Yakima River below the mouth of Umtanum Creek (Bartrand et al. 1994). The estimated fecundity of female rainbow trout that spawned in Umtanum Creek was based on the relationship between fork length and fecundity of rainbow trout (Koski 1966, Tagart 1976, Barlaup et al. 1994) collected from this section of river between 1992 and 1994 (Steve Martin, Washington Department of Fish and Wildlife, personal communication). The linear relationship between fecundity and fork length based upon data from 21 rainbow trout can be summarized by the following equation: Fecundity = -1350.7 + 7.0055 (fork length) where fork length is in millimeters ($P < 0.001$; df = 19; $r^2 = 0.69$). Using this regression model, we estimated the fecundity of each female rainbow trout that spawned in Umtanum Creek in 1994. All female rainbow trout captured moving downstream of the trap were squeezed to determine if any eggs were retained after spawning. The total number of eggs deposited in Umtanum Creek by each female was then estimated by subtracting any retained eggs from the fecundity estimate.

Emergence of rainbow trout fry was determined by installing emergence traps over rainbow trout redds after completion of the bridgelip sucker spawning season. The body of the emergence trap was similar to that described by Phillips and Koski (1969). Velcro tape was used to seal the openings into the trap. A collection bottle similar to that described by Fraley et al. (1986) was used. Emergence traps were cleaned and checked daily. Capture efficiency for rainbow trout fry was believed to be 100% due to their large size. If female rainbow trout constructed multiple redds, all redds were trapped and subsequent fry captured in traps were combined for data analysis. Survival to emergence rates (STE) were calculated by dividing the number of rainbow trout fry emerging from a redd by the numbers of eggs deposited in the redd(s) estimated from the fecundity equation. The effect of any disturbance during spawning (e.g., superimposition) was determined by comparing STE rates of control and treatment groups using a Mann-Whitney U-test. In 1995, because the fish trap was not installed and the length of each female rainbow trout was unknown, emergence traps were not installed either.

Results

1994 Spawning Surveys

In 1994, stream discharge varied slightly between March and May with a mean of 0.12 m^3/s. Rainbow trout generally moved upstream into the study site and spawned earlier than bridgelip sucker; however some temporal overlap did occur. In 1994, the median passage date of rainbow trout and bridgelip sucker was 31 March and 19 April, respectively. Rainbow trout moved upstream into Umtanum Creek from 13 March to 27 April. In 1994, bridgelip sucker spawning movements began on 1 April and ended on 7 May. However, the number of days for 98% upstream passage for rainbow trout and bridgelip sucker was 39 d and 7 d, respectively.

During 1994, 51 rainbow trout were captured moving into Umtanum Creek. Water clarity was excellent and trap efficiency was 100% (no untagged rainbow trout were observed upstream from the trap). Male rainbow trout ($N = 31$) outnumbered female rainbow trout ($N = 20$). Of these fish, six male and one female rainbow trout had been captured and tagged moving into Umtanum Creek in previous years (Gabriel Temple, Washington Department of Fish and Wildlife, personal communication). The mean fork length (SD) of female rainbow trout was 349 (24) mm compared to 334 (61) mm for male rainbow trout. Rainbow trout spawning began on 27 March and ended on 6 May. Two female rainbow trout were void of eggs upon entering the trap and were not observed constructing redds (Figure 2). In 1994, 21 redds were constructed by 18 female rainbow trout in Umtanum Creek. Two female trout constructed more than one redd (i.e., 2 – 3 redds). Multiple redds constructed by a single female trout were located close to one another (<1 m) and were treated as a single redd in the data analysis ($N = 18$). Nine test redds were also found during the surveys and defined as areas of digging that lacked typical redd morphology. Test redds were excavated and found not to contain any eggs.

During 1994, 129 bridgelip sucker immigrated to the Umtanum Creek study area. The mean fork length (SD) of female and male bridgelip sucker was 424 (21) mm and 378 (35) mm, respectively. Both male and female bridgelip sucker were significantly greater in fork length and weight than male ($P < 0.001$) and female ($P < 0.001$) rainbow trout (Table 1).

Bridgelip sucker began spawning on 20 April and completed spawning on 26 April (Figure 2). Bridgelip sucker were observed spawning in nine separate sites at water temperatures ranging between 8°C and 19°C. Prior to spawning, bridgelip sucker used relatively slow and deep water that provided some overhead cover. Spawning aggregations primarily consisted of a single female and a large single dominant male and between 2 and 10 smaller subdominant males. Sex determinations of bridgelip sucker during observations were made based on size (Hayes 1956, Dauble 1980). Female bridgelip sucker were significantly greater in fork length than males ($P < 0.001$). On a spawning site, the female bridgelip sucker assumed an upstream position from the males. Male bridgelip sucker maintained positions on either side of the female, with the dominant male closest to the female. Proximity of males to the females appeared to be size dependent, similar to that described for salmonids (Keenlyside and Dupius 1988). The largest male appeared to be dominant in most

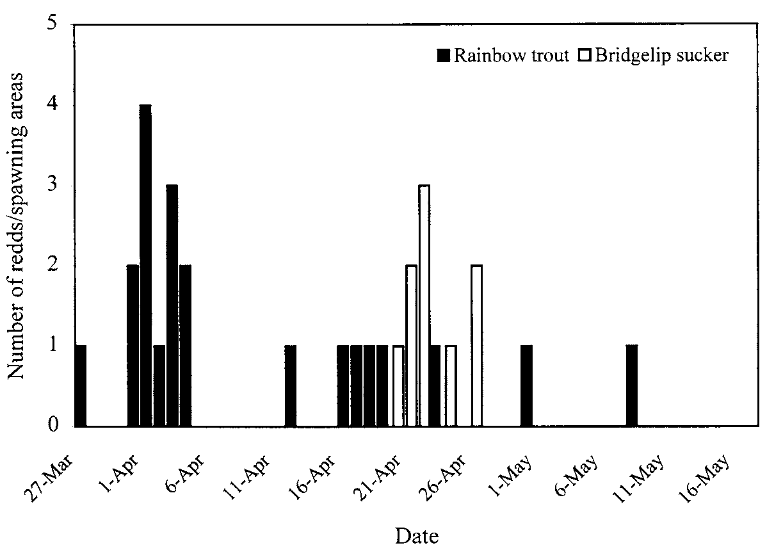

Figure 2. Abundance and spawn timing of rainbow trout redds and bridgelip sucker spawning areas found in Umtanum Creek, Washington, 1994.

TABLE 1. Summary statistics of rainbow trout and bridgelip sucker fork length (mm) and weight (g) captured moving into Umtanum Creek, WA in 1994. Asterisk denotes significant difference between fish species based on a two sample t-test (P<0.001).

	Rainbow trout			Bridgelip sucker		
Gender	*N*	Mean	SD	*N*	Mean	SD
Female						
Fork length*	20	349	24	53	424	21
Weight*	20	475	132	53	925	133
Male						
Fork length*	31	334	61	41	378	35
Weight*	31	434	156	41	677	173

instances. Aggressive interactions between the dominant male and other males, in the form of chases, were common.

Female bridgelip sucker exhibited spawning behaviors similar to that described for salmonids (Tautz and Groot 1975). A digging behavior was observed that consisted of high-frequency, high-amplitude modulations of the caudal fin for 3-5 seconds. Only female bridgelip sucker were observed exhibiting this behavior. The female bridgelip sucker would remain upright and stationary, presumably anchored to the substrate using her large anal or pectoral fins. This behavior was believed to be involved in removing smaller-sized substrate from the spawning site versus actually excavating the substrate for the purpose of burying eggs (e.g., salmonids). Algae, silt, and gravel were removed from the spawning substrate as a result of this behavior and depressions were created in the substrate several centimeters in depth. Modification of the spawning site continued until substrate of sufficient size (cobble) was encountered. Hence, depressions created by bridgelip sucker were not uniform and were influenced by substrate composition. The release of eggs by female bridgelip sucker was believed to occur during a behavior that consisted of high-frequency, low-amplitude modulations or quivering (Tautz and Groot 1975). The release of gametes was not observed because of the small size of the eggs and the turbulence that was produced during spawning. Eggs were predominately found under the large cobble within the spawning site. Egg clusters settled in the crevices between the larger rocks and adhered to the underside of rocks.

1995 Spawning Surveys

In 1995, the mean discharge during the study period was higher (0.32 m^3/s) and more variable than in 1994, decreasing throughout the spawning period. Fifteen rainbow trout redds were constructed in Umtanum Creek in 1995 (Figure 3). Spawning began on 27 March and ended 3 May. Some adult rainbow trout that immigrated from the Yakima River were observed above a logjam that created a 1.5 m waterfall. Umtanum Creek does have a resident rainbow trout population; however, these fish have been reported to be considerably smaller in size than the migratory population (McMichael et al. 1992). Of the 15 rainbow trout redds found in Umtanum Creek, 5 rainbow trout redds were found above the logjam and the remaining 10 redds were found below the logjam.

Approximately 400 bridgelip sucker immigrated into Umtanum Creek and spawned in 19 separate areas in 1995 (Figure 3). Spawning behavior was similar to that observed in 1994. No bridgelip suckers were observed spawning upstream of the logjam (724 m from mouth).

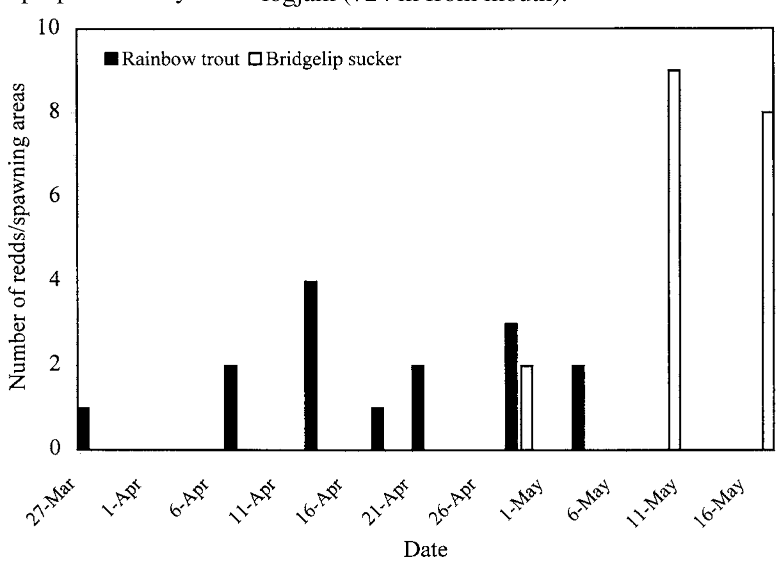

Figure 3. Abundance and spawn timing of rainbow trout redds and bridgelip sucker spawning areas found in Umtanum Creek, Washington, 1995.

Spawning Habitat

The size of a salmonid redd has been correlated with the size of the spawner (Pearsons et al. 1996). Bridgelip sucker spawning areas were significantly greater in length ($P < 0.001$) and width ($P < 0.001$) than rainbow trout redds (Table 2). Bridgelip suckers used a mean area of 6.59 m^2 compared to 0.49 m^2 for rainbow trout. Bridgelip sucker spawning areas were larger than rainbow trout redds due to the greater size and spawner density of bridgelip suckers (14 suckers/spawning area) compared to rainbow trout (2.4 rainbow trout/redd). No difference was detected in the water depth or water velocity of rainbow trout redds and bridgelip sucker spawning areas.

TABLE 2. Summary statistics of rainbow trout redds and bridgelip sucker spawning areas in Umtanum Creek, Washington, in 1994 and 1995. Asterisk denotes significant difference between fish species based on a Mann-Whitney U-test ($P < 0.001$).

	Rainbow trout			Bridgelip sucker		
Parameter	*N*	Mean	SD	*N*	Mean	SD
Length (m)*	38	1.03	0.37	25	4.58	3.42
Width (m)*	38	0.45	0.14	25	1.30	0.75
Water velocity (m/s)	36	0.17	0.05	25	0.15	0.04
Water depth (m)	38	0.38	0.18	25	0.38	0.13

Redd Disturbance

Bridgelip sucker were observed disturbing 3 of 21 rainbow trout redds (14%) in 1994 and 5 of 15 rainbow trout redds (33%) in 1995. Disturbance of the rainbow trout redds by bridgelip sucker was severe, and in all eight cases the tailspill of the rainbow trout redd was completely excavated. Bridgelip sucker eggs were found in all superimposed rainbow trout redds. The white rocks marking the rainbow trout redds were dislodged by spawning bridgelip sucker and found downstream (>1 m) from the original redd location and often buried under gravel presumably excavated from the rainbow trout redd. Based on the absence of the white rocks placed on the perimeter and center of the tailspill, we concluded that the extent of disturbance of the rainbow trout redds was 100%.

In 1994, 2 of 21 rainbow trout redds (11%) were also disturbed by other rainbow trout. Disturbance by rainbow trout was generally less severe than by bridgelip sucker as indicated by the amount of gravel that was removed from the tailspill (< 40%). Because disturbance by rainbow trout occurred during the peak of rainbow trout spawning, no white rocks had been placed on these redds. Disturbance by rainbow trout was in the form of digging by female rainbow trout in the tailspill of an existing redd. Spawning was not observed (i.e., test redds) and both female trout constructed redds at a later date. A third rainbow trout redd was constructed in the pit and immediately upstream of an existing redd. Physical disturbance of the original redd appeared minimal (< 10%). In 1995, disturbance of rainbow trout redds by other rainbow trout was not observed. However, because female rainbow trout were not individually tagged, disturbance of rainbow trout redds by other rainbow trout could only be verified after white rocks were placed on the redd.

Survival to Emergence

STE rates of rainbow trout redds ranged from 0.0 – 17.8% (mean = 7.15%; SD = 6.5; $N = 17$; Table 3). The mean STE rate of the experimentally protected redds (11.2%; $N = 9$) was significantly greater ($P < 0.02$) than that of the unprotected redds (2.6%; $N = 8$; Table 4). Because redds in the unprotected group were disturbed by multiple sources, mean STE was also calculated based on the source of the disturbance. The STE rates of rainbow trout redds not disturbed ranged from 0.2 - 17.8% (mean = 11.5%; SD = 4.8; $N = 10$). Rainbow trout redds superimposed by bridgelip sucker had a mean STE rate of 0.4% (SD = 0.2; $N = 3$), while rainbow trout redds superimposed by other rainbow trout had a mean STE rate of 2.8% (SD = 0.8; $N = 2$).

Two rainbow trout redds suffered complete mortality due to abiotic factors (i.e., siltation and desiccation). Siltation was attributed to the proximity of the rainbow trout redd to a sand bar. Sand encroached the redd as discharge decreased. Installation of the emergence trap occurred after sand was deposited in the redd. Another redd constructed on the stream margin was desiccated due to a decrease in discharge after an emergence trap was installed. Excluding redds disturbed by abiotic factors, the mean STE rate of redds disturbed by rainbow trout and bridgelip sucker (mean = 1.4%; SD = 1.4; $N = 5$) was significantly lower ($P < 0.02$) than that of the undisturbed redds (mean = 11.5%; SD = 4.8; $N = 10$).

TABLE 3. Estimated number of eggs deposited and emergence of rainbow trout redds in Umtanum Creek, Washington, 1994 (RBT = rainbow trout; BLS = bridgelip sucker; SILT = siltation; DESI = desiccation).

Group	Fork length (mm)	Estimated number of eggs deposited	Source disturbance	Number of fry captured	Survival to emergence (%)
Control	364	1,159	-	141	12.2
Control	363	1,176	-	175	14.9
Control	361	1,178	-	210	17.8
Control	359	1,163	-	86	7.4
Control	336	1,003	-	112	11.2
Control	395	1,164	-	121	10.4
Control	363	1,192	-	164	13.8
Control	303	772	-	98	12.7
Control	329	954	-	2	0.20
Treatment	401/342	2,490[1]	-	349	14.0
Treatment	347	1,060	RBT	36	3.40
Treatment	361	1,178	RBT	26	2.20
Treatment	398	1,433	BLS	7	0.50
Treatment	309	814	BLS	4	0.50
Treatment	351	1,104	BLS	2	0.20
Treatment	344	1,059	SILT	0	0.00
Treatment	330	961	DESI	0	0.00

[1] Fry traps were not installed on individual redds due to proximity to each other.

TABLE 4. Summary of mean STE rates of rainbow trout redds by experimental group and source of disturbance in Umtanum Creek, Washington, in 1994.

Group	Number of redds	Mean egg to emergence (%)	95% confidence interval	
			Lower	Upper
		Experimental group		
Control	9	11.2	7.3	15.0
Treatment	8	2.6	0.0	6.6
		Source of disturbance		
Abiotic	2	0.0		
Bridgelip sucker	3	0.4	0.0	0.8
Rainbow trout	2	2.8	0.0	10.4
None	10	11.5	8.0	14.9

Discussion

Rainbow trout in Umtanum Creek exhibited spawning behavior similar to that previously described for salmonids (Hartman 1970, Tautz and Groot 1975, Keenleyside and Dupuis 1988). The observation concerning the spawning behavior (i.e., substrate modifications via digging) of bridgelip sucker suggests a further investigation of this abundant species is warranted. Dauble (1980) conducted the most comprehensive published study on the life history of bridgelip sucker in the central Columbia River. Although spawning behavior was not observed in that study, postspawning females were observed with severely eroded anal and lower caudal fins, a condition consistent with the spawning behavior observed in Umtanum Creek. Balon (1975) classified fishes in reproductive guilds based upon reproductive behavior and preferred spawning substrate. Bridgelip sucker was classified by Balon (1975) as an open substratum lithophil spawner. Our observations indicate this species is not simply a broadcast spawner and invests considerable energy in modifying the substrate composition before depositing eggs. Largescale sucker and white sucker have also been reported to create depressions during spawning (Hayes 1956, McCart and Aspinwall 1970), but detailed observations on the spawning grounds were not conducted.

Bridgelip sucker and rainbow trout exhibited temporal overlap during spawning in Umtanum Creek. No difference was found in the water depth or water velocity used by rainbow trout or bridgelip sucker suggesting physical overlap in preferred spawning habitat as well. Temporal overlap in spawning rainbow trout and bridgelip sucker has been observed in two other larger tributaries of the Yakima River (Pearsons and Martin 1994) and probably occurs in streams throughout the Columbia and Fraser River basins, but the amount of superimposition has not been quantified. We recommend that further work be conducted in streams larger than Umtanum Creek to determine superimposition frequencies across a range of stream sizes and spawner densities.

Habitat availability influenced the proportion of rainbow trout redds that were disturbed by bridgelip sucker. In 1994, low water levels during the spawning season and an impassable beaver dam limited available spawning habitat to the lower 529 m of the creek. In 1995, water levels at the beginning of the spawning season were higher and some rainbow trout were able to ascend a logjam 724 m from the mouth of Umtanum Creek during periods of higher discharge. These rainbow trout redds were protected from redd superimposition by bridgelip sucker that were not able to ascend the logjam at a period of lesser discharge.

Other studies suggest that some fish may select existing redds sites for spawning. Essington et al. (1998) reported brown trout (*Salmo trutta*) and brook trout (*Salvelinus fontinalis*) preferred to spawn on existing redd sites. Hayes (1987) also suggested behavioral preferences for existing brown trout redd sites as spawning locations for later spawning rainbow trout. Both of these studies involved introduced species which are not sympatric in their native habitat. If bridgelip sucker prefer rainbow trout redds as spawning locations, we would expect some redd superimposition by bridgelip sucker even in streams without habitat limitations.

In 1994, when the fish trap, weir, and wire exclusions were installed in Umtanum Creek, 24% of the 21 rainbow trout redds were disturbed (3 by bridgelip sucker and 2 by rainbow trout). In 1995, when the fish trap, weir, and wire exclusions were not present in Umtanum Creek, 33% of the 15 rainbow trout redds were disturbed. Of those, only 10 rainbow trout redds were in habitat occupied by bridgelip sucker, which increases the superimposition rate to 50%. Based upon the proportion of redds that were disturbed in 1995, we feel that the fish trap, weir, and wire exclusions did not influence the number of rainbow trout redds disturbed by bridgelip sucker or other rainbow trout in 1994. The proportion of disturbed redds that we observed in our study during 1994 and 1995 might be high compared to other streams where rainbow trout and bridgelip sucker coexist. Umtanum Creek is small and has a high spawner density (rainbow trout and bridgelip sucker) because of passage barriers. Superimposition may also be more likely in small creeks, such as Umtanum Creek, where redds and spawning areas span the full width of the creek.

An accurate estimate of STE of naturally produced salmonid redds requires knowledge of the fecundity of each female and the use of emergence traps. The most comprehensive study done in this manner was conducted by Koski (1966) and involved installing emergence traps (similar design as used in this study) over 21 coho salmon (*O. kisutch*) redds. Koski (1966) reported that STE ranged from 0% to 78% with a mean STE of 27.1%. Using identical emergence traps in the Yakima River and an estimate of fecundity based on the size of the redd (Pearsons et al. 1996), the mean STE rate of rainbow trout redds sampled was 8% (Todd Pearsons, Washington Department of Fish and Wildlife, personal communication). Our estimated STE rates for undisturbed rainbow trout redds in Umtanum Creek (mean = 11.5%; range 0.2 - 17.8%) are within the range of these other two studies.

Stream-specific habitat conditions (e.g., proportion of fine sediments, gravel permeability, dissolved oxygen) could also directly influence STE rates. The proportion of fine sediments has been reported to be responsible for greater than 90% of the variability in salmonids embryo survival (Tappel and Bjornn 1983). Fry emergence traps have been found to increase sedimentation within the redd and negatively impact STE rates (Reiser et al. 1998). Phillips and Koski (1969) reported their fry traps (similar design as used in this study) had no significant effect on gravel permeability and intragravel dissolved oxygen concentrations. Reiser et al. (1998) reported significantly higher concentrations of fine sediments in substrate samples collected inside emergence traps than collected outside. In that study, fry traps were installed over 30 days prior to emergence and checked every 3 days. Although these factors do affect survival and were not specifically analyzed in our study, their importance in interpreting our results cannot be overlooked. In our study, temperature units were monitored to estimate time of hatching and emergence in order to minimize the duration emergence traps were installed on a redd. The mean (SD) number of days rainbow trout fry were captured following the installation of the emergence trap was 13 (6). Emergence traps were cleaned daily and discharge generally decreased rather than increased during the study period. Although a substrate analysis was not conducted, visual inspection during and after emergence did not indicate that fine sediment had accumulated within the emergence trap. Thus, we do not believe the influence of emergence traps in Umtanum Creek appreciably negatively biased the STE rates.

Our analysis of STE rates for redds disturbed by bridgelip sucker and rainbow trout concluded that redd superimposition by other fishes reduced survival. The small sample size of redds in this study limits a broader application of the results, but the magnitude of the difference in the STE rates suggests more research on the spawning ecology and habitat requirements of bridgelip sucker is warranted. Spawning habitat availability is routinely assessed for salmonids; knowledge of the habitat requirements of other and often more abundant species that coexist and interact with salmonids should assist biologists in better understanding how interspecific interactions may influence reproductive success.

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