Brown Trout Spawning Location and Relationship to Suitable Winter Habitat

Matthew L. Skoog
Department of Aquatic Biology
Bemidji State University

Brown trout are a popular game fish throughout much of the world. Understanding habitat requirements is necessary for the successful management of brown trout. This study looks at the spawning habitat preferences and relationship of redd location to wintering habitat of brown trout in the Straight River, Minnesota. Brown trout in the Straight River were found to spawn in similar habitat to brown trout looked at in previous literature. All redds were located on gravel substrate. Seventy eight percent of redds were associated with some sort of cover. Water velocities at the redd sites had a mean of 0.525 m/s (95% CI±.0.04). Mean redd depth was 49.2 cm (95% CI±3.496). Temperature (mean=3.35℃), conductivity (mean=0.456 ms/cm), dissolved oxygen (mean=9.78 mg/L), and pH (range 4.54-6.01) were also examined. Evidence of a relationship between wintering habitat and spawning location was found. When the relationship between wintering habitat and mean winter HSI values for 100 m sections was examined, the relationship is insignificant at each minimum HSI value that was examined. When the relationship of distance to site specific wintering habitat was examined, the relationship was found to be significant for every minimum wintering HSI value that was examined (HSI=0.65 p=0.003)(HSI=0.55 p=0.0355)(HSI=0.50 p=0.0001).

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Introduction

Brown trout, *Salmo trutta*, are a popular game fish throughout much of the world. Because of the popularity and socioeconomic benefits of brown trout, much time and many resources have been dedicated to the study of brown trout. Understanding habitat requirements of brown trout, especially the habitat needs for spawning, is important to the continued management success.

Previous literature has indicated that brown trout spawn in a wide range of habitats although the success of spawning depends on the selection of certain habitat characteristics. Reported optimum ranges for various microhabitat characteristics important for spawning include water depth (23-215 cm) by Wollebaek et al. (2008) while Raleigh et al. (1986) reported that the minimum depth brown trout will spawn in is 15 cm. Water velocity preferences for brown trout spawning were reported to be 2-124 cm/s by Wollebaek et al. (2008) while Raleigh et al. (1986) reported an optimum range spawning velocity range of 40-70 cm/s and a total spawning velocity range of 13.7-90 cm/s. Particle size at spawning locations ranged from 2-37 cm in one study (Wollebaek et al. 2008) while the range of spawning substrate size has been reported by Raleigh et al. (1986) to be 0.3-10 cm. Raleigh et al. (1986) also reported redd placement was often at the head of riffles.

Suitable wintering habitat is also an important factor for the survival of brown trout. During the winter, brown trout become cover oriented, and tend to move to deeper water with lower velocities to conserve energy and limit predation (Raleigh et al. 1986). Previous research has indicated that the optimal velocity range for wintering brown trout is 5.7-16 cm/s, optimal depth range of 50-75 cm, and optimal substrate type ranging from sand to boulders (Cunjak and Power 1986). Cunjack and Power (1986) also found that 89-100% of brown trout selected locations with some form of cover during winter. Palm et al. (2007) found that bank-side cover was also important for brown trout in the selection of wintering habitat.

There is some evidence of a relationship between the spawning habitat and critical wintering habitat of brown trout. Zimmer and Power (2006) suggested

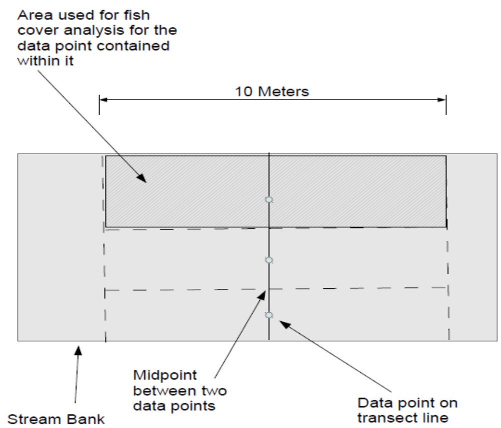

Figure 1. – How the stream was divided in order to conduct fish cover assessments for each data point. The area used for each data point is outlined by the dashed line.

there may be some tradeoff between spawning and overwintering habitat requirements, especially in larger fish. The tradeoff between spawning and wintering habitat is the selection of a less than optimal spawning site to allow for improved access to optimal wintering habitat. The tradeoff between spawning and wintering habitat may be due to the need to take advantage of optimal winter habitat to decrease the risk of mortality and allow for a greater likelihood of survival into the next spawning season. Another possible reason for brown trout choosing spawning sites with easy access to wintering habitat is because of the energetic cost of migrating from spawning habitat to suitable wintering habitat. Bohlin et al. (2001) found that migration in salmonids reduces fitness. The relationship between spawning and wintering habitat has not been well examined in the literature and could be of importance in habitat restoration efforts. Habitat restoration has become increasingly important in the management of trout streams (Palm et al. 2007). Because brown trout may be selecting habitat for multiple life functions, it is important to consider the relationship between various critical habitats for the most effective stream restoration (Zimmer and Power 2006).

The objectives of this study are 1) examine the spatial relationship of spawning habitat to wintering habitat for brown trout 2) compare the preferred spawning habitat in the Straight River to previous literature 3) develop a timeline for the spawning season in the Straight River.

Study Area

Straight River near Park Rapids, Minnesota is a popular spring fed brown trout fishery that flows for

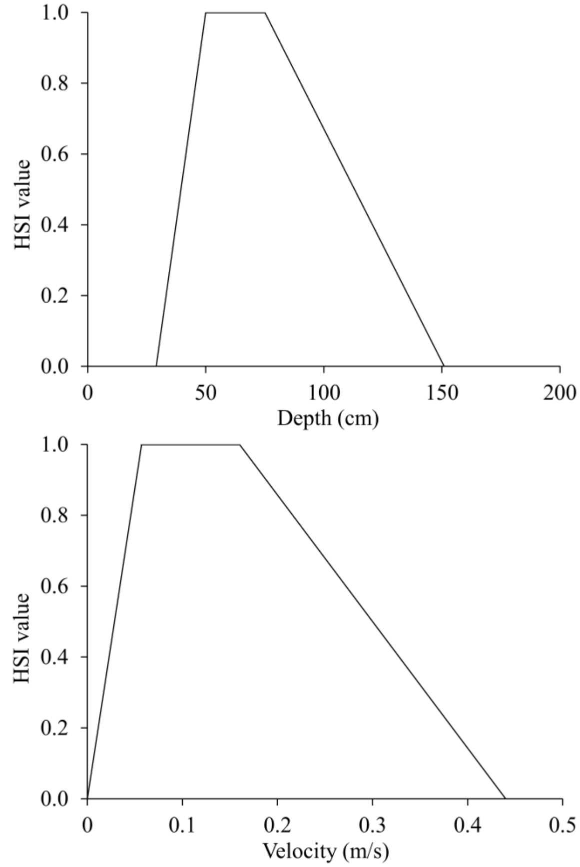

Figure 2. – Depth (A) and velocity (B) HSI curves for wintering brown trout.

37 km through wooded and marshy areas. This study was conducted on the upper 12.8 km of the river starting below the dam at the south end of Straight Lake.

Methods

Redd assessment- The study area was floated weekly in a canoe starting one week prior to spawning (10 October 2012) until one week after no new redds where found (23 November 2012). While floating, new redds where identified and coordinates where taken using a Garmin eTrex 20 handheld GPS (3m accuracy). At each new redd, various habitat characteristics where recorded. Water depth (cm) was measured from the surface to the bottom of the pit (defined by Zimmer and Power 2006). Water velocity (m/s) was measured with a flow meter (Global Water FP101) at 8 cm above bottom of the pit. Conductivity (ms/cm), dissolved oxygen (mg/L), water temperature (℃), and pH where recorded using a handheld multi-parameter instrument (YSI 556 MPS). Spawning substrate was classified using a

Wentworth scale (Wentworth 1922). Cover was considered present if the cover was directly

Table 1. The coordinates for creating HSI curves for depth (cm) and velocity (m/s). The X value corresponds to the measured values. The Y corresponds to the HSI value.

Depth X	Depth Y	Velocity X	Velocity Y
29	0	0.000	0
50	1	0.057	1
75	1	0.160	1
151	0	0.430	0

overhanging the redd, in direct contact with the redd, or deflecting current away from the redd.

Means and 95% confidence intervals were calculated for pH, dissolved oxygen, conductivity, and temperature at the redd sites. Histograms showing the range of pH, dissolved oxygen, conductivity, and temperature where also created along with a scatterplot showing the change in temperature over time. Substrate and cover types were sorted and counted using ArcGIS.

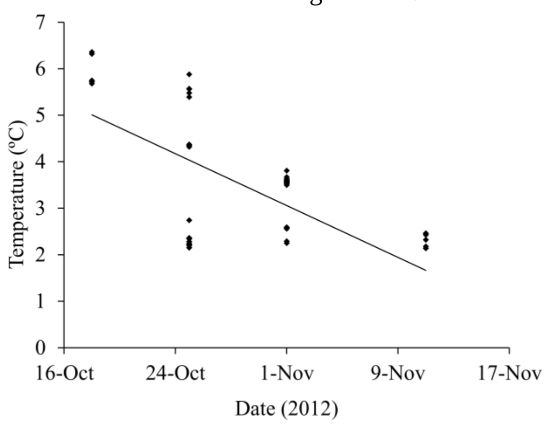

Figure 3. – Relationship between temperature (℃) at redd sites and week of the spawning season

Winter habitat classification- To classify wintering habitat, the study reach was divided into 50 m transects and measurements for each parameter included in the winter habitat suitability model (HSI) were taken over the course of five weeks (28 February 2013 - 4 April 2013).

Stage height was recorded in January to establish a winter base flow. Stage height was also recorded during each data collection period to ensure that winter base flow levels were maintained throughout the duration of data collection.

At each transect, habitat measurements were taken at three points in the river. The points where equally spaced starting at the south or east bank. Coordinates where taken at the midpoint of each transect with a handheld Garmin eTrex 20 GPS unit (3m accuracy). At each, point water depth was measured to the nearest cm using a meter stick. Velocity was measured (m/s) using a flow meter (Global Water FP101). Substrate was classified based on the Wentworth scale (Wentworth 1922). Instream fish cover was classified on a 1-4 scale using modified EMAP protocol (Kaufman et al. 1999). The protocol for scoring fish cover calls for the area 5 m upstream and downstream for the width of the river to be included in a single measurement.

In this study, the river was divided into three sections. Each section contained one point at which habitat measurements were taken. These points where fish cover scores were taken were located on each transect (defined earlier) at the midpoint of each fish cover scoring section. Each section extends 5 m upstream and downstream. The other edges of the section are defined by the bank and the midpoint between the data point in the section and the adjacent section. In the case of the middle data point, the center of the river and the outer data point was used to define the edge of the fish cover scoring section (Figure 1). Overhanging cover scores where determined using the same scoring system and areas surrounding the data points as was used in classifying instream fish cover. Overhanging fish cover was determined to be anything above the water within one meter of the surface of the water.

Data Analysis- Winter HSI scores were calculated individually for each parameter (depth, velocity, substrate, aerial fish cover, and instream fish cover). Winter HSI scores for substrate, aerial fish cover, and instream fish cover were based on the habitat suitability curves published by Raleigh et al. (1986). The winter HSI curves for depth and velocity where based on means and ranges of habitat from Cunjak and Power (1986) and Calkins (1989) and developed according to the methods from Raleigh et al (1986). A score of 1.0 was given to the range of optimum values given by Calkins (1989). The outer extent of the ranges of values from Cunjak and Power (1986) were assumed to be the outer values usable by brown trout during the winter season and were given scores of 0.01. Lines were then created between the points to develop the winter HSI curves for depth and velocity. Figure 2 shows the winter HSI curves for depth and velocity. The coordinates for the points used in the creation of the HSI curves are given in Table 1.

The Y values in the habitat suitability curves are the HSI values while the X value corresponds to the measured value of the given parameter. The scores for the data collected were calculated using the measured parameter value as an X value in the linear equations of the HSI curves to calculate the Y or HSI

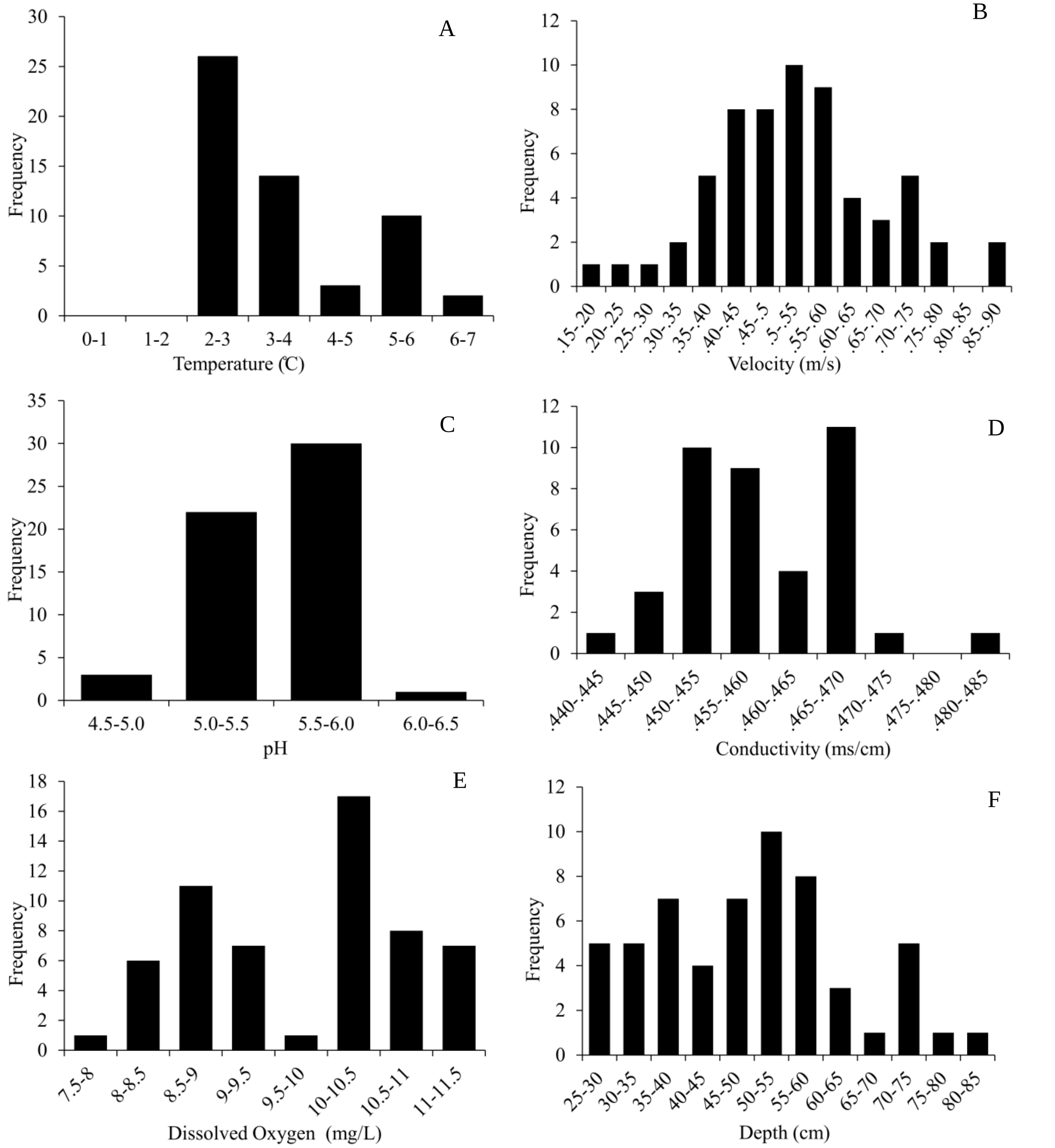

Figure 4. – Frequency of redd occurrence in relation to (A) temperature, (B) velocity, (C) pH, (D) conductivity, (E), dissolved oxygen, and depth within the Straight River, MN.

value. The equation used for determining the HSI for any given data point was (depth HSI + velocity HSI + substrate HSI + ((areal fish cover HSI + instream fish cover HSI)/2))/4. The fish cover scores were averaged so that cover would not be over represented in the calculation.

The total wintering HSI scores were then entered into ARCMap and converted to a raster graphic. The scores where then interpolated using IDW interpolation to create a model of HSI scores for every 1x1m cell within the river channel. Redd points where then overlaid onto the raster for analysis of the relationship between redds and wintering habitat. A distance from every redd to a minimum HSI level of 0.55, 0.65, and 0.75 was measured using the measure tool in ARCMap. These measurements where then included in histograms. Redd densities (#/100 m) were calculated at each redd point by measuring 50 m

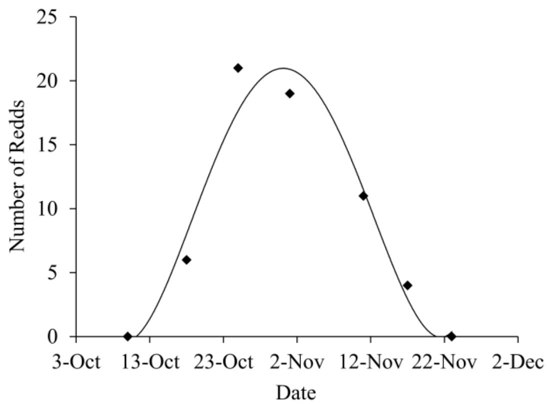

Figure 5. – Number of new redds each week during the spawning season in the Straight River, MN (2012).

upstream and downstream from the redd points and counting the
number of redds in the 100 m section using the measure tool in ARCMap. Mean winter HSI values were calculated for each raster cell using circular focal statistics (radius of 50 m). Distance from redd site to a mean winter HSI and site winter HSI values of 0.65, 0.55, and 0.50 were measured using the measure tool in ArcMap. These values were chosen because an increase in minimum HSI to 0.70 results in a very wide range of distance values and any minimum HSI of less than 0.50 results in all redds being located within suitable wintering habitat.

The distance from redd site to minimum mean winter HSI and distance to minimum winter HSI were then used to create scatterplots of redd density at redd point and distance to a minimum mean winter HSI value and minimum winter HSI value. This relationship between redd density and minimum mean winter HSI value and minimum winter HSI was analyzed using linear regression. Analysis of redd density to distance to a minimum mean 100 m HSI is considered the macrohabitat or reach scale in this study. The analysis of redd density to distance to a minimum site wintering HSI is considered microhabitat scale.

Results

Spawning- Water temperatures at the start of spawning season ranged from 5.68 - 6.36℃. There was a decline in water temperature as the spawning season progressed (Figure 3). Brown trout were found to spawn in the Straight River in water temperatures with a mean temperature of 3.35˚C (CI±0.40) (Figure 4A). The only substrate that redds were found on was gravel. Most redds were associated with some sort of cover (78%). Velocities at redd sites had a mean of 0.525 m/s (95% CI ±0.04) (Figure 4B). The pH levels at redd sites ranged from 4.54 to 6.01 (Figure 4C). Conductivity had a mean of 0.456 (95% CI±0.0001) (Figure 4D). Dissolved oxygen had a mean of 9.78 mg/L (95% CI±0.27) (Figure 4E). The mean depth at redd site was 49.2 cm (95% CI±3.496) (Figure 4F).

The occurrence of redds throughout the spawning season has a normal distribution pattern with the highest number of redds occurring in the middle of the spawning season. The beginning and end of the spawning season had much lower numbers of new redds. The first week (10 October 2012) of the study had zero new redds. The second week (18 October 2012) had 6 new redds. The third week (25 October 2012) had 21 new redds. The fourth week (1 November 2012) had 19 new redds. Week five (11 November 2012) had eleven new redds. Week six (17 November 2012) had four new redds and week seven (23 November 2012) had no new redds. The number of new redds peaked during third and fourth weeks of the spawning season (Figure 5). Redds were located in concentrated areas of the study reach. Some areas had a high density of redds while other areas had a low density or no redds at all (Figure 6).

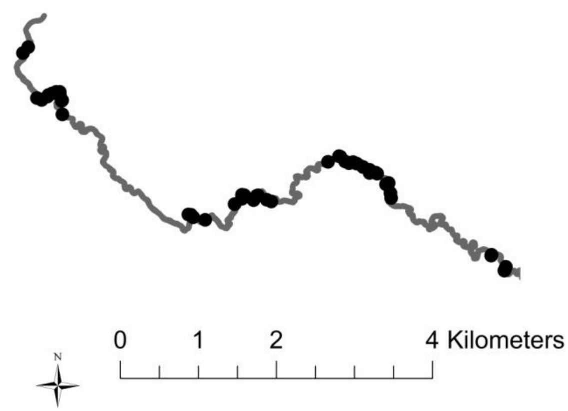

Figure 6. – Density of redds throughout the study reach. Each redd location is represented by a black circle.

Wintering analysis- Distance to suitable spawning habitat from redd site at various HSI values is shown in Figure 7. In Figure 7A, the minimum wintering HSI value is set at 0.75. The distance from redd site to wintering habitat with a score of greater than 0.75 has a wide range of values (0-692m). The mode range of values examined at 50 m intervals was 0-50 m. At a minimum wintering

HSI value of 0.65, distances ranged from 0-247 m with a mode range of 0-50 when examined at 50 m intervals. When distances from redd sites to HSI

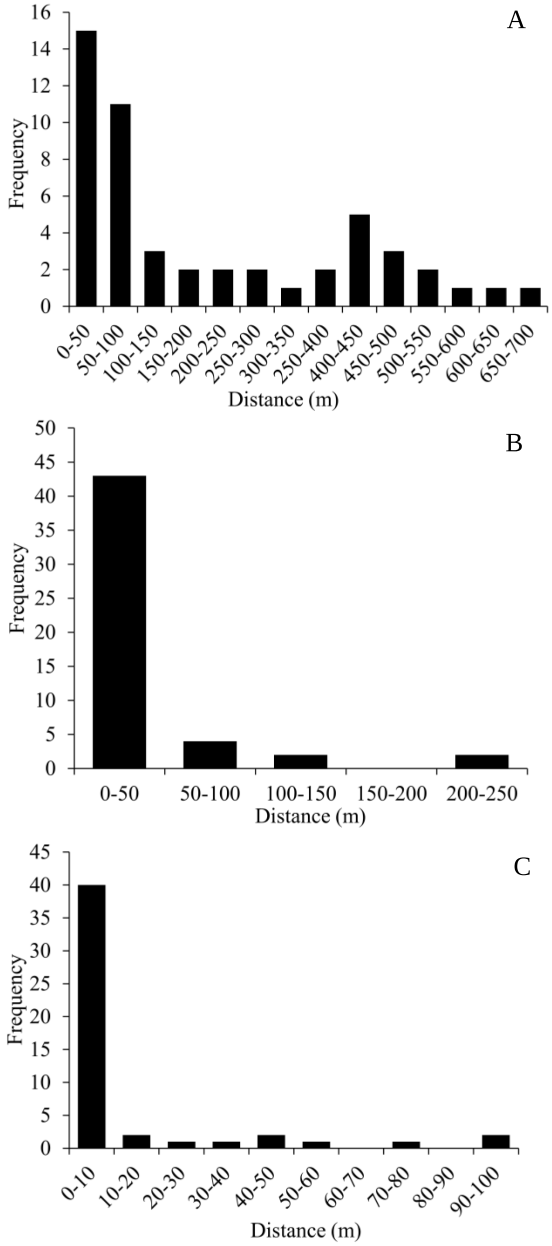

Figure 7. – Frquency of distances (m) from individual redds to minimum wintering HSI value of (A) ≥ 0.75, (B) ≥ 0.65, and (C) ≥ 0.55.

value is examined at a minimum wintering HSI value of 0.55, distances ranged from 0-96 meters with a mode range of 0-10 m when examined at 10 m intervals.

At the macro scale (mean HSI values for 100 m sections), analysis shows there is no significant relationship between redd density and distance to a minimum mean wintering HSI of 0.65 (p=0.80) (Figure 8A). When the same relationship is analyzed at a minimum mean wintering HSI of 0.55, the relationship is also insignificant (p=0.21) (Figure 8B). Also, when this same relationship is analyzed at a minimum mean HSI of 0.50 the relationship is insignificant (p=0.47) (Figure 8C).

When the relationship of redd density to distance to minimum wintering HSI was analyzed at a micro scale (site HSI values), all three minimum HSI values had a significant negative relationship (p=0.0355, 0.0001, and 0.003 for minimum HSI values of 0.50, 0.55, and 0.65, respectively) with redd density
(Figures 8D, E, and F).

Disscussion

Spawning Habitat- The brown trout in the Straight River started spawning at a temperature range of 5.68-6.36°C. This range of temperatures is similar to the range of temperatures (6-12.8°C) that trigger spawning in brown trout (Raliegh et al. 1986) with a reproductive success peaking at 3-4°C (Vladic and Jatrvi 1997). This peak of reproductive success is very silmilar to water temperatures at the peak of spawning season in this study.

All redds in this study were found on gravel substrate. This use of only gravel substrate is well defined in the literature. Shirvell in Dungey (1983) fond a mean prefered substrate size of 7 mm. This preference for gravel is critical for the survival of brown trout eggs (Palm 2007) and fry (Heggenes 1988)

The range of water velocities at redd sites (0.86-0.18 m/s) are also similar although slightly higher than those those found in the literature. Raliegh et al. (1986) reports an optimal spawning velocity of 0.21 m/s to 0.52 m/s. In this study, many of the redds were found in this optimal range. There were also many redds found in ranges higher than the optmal range, but all of the redds were within in the range (0.09-1.18 m/s) reported as suitable by Raliegh et al. (1986). The mean velocity at redd sites in this study (0.525 m/s) is considerably higher than the mean velocity of 0.26 m/s reported by Shirvell and Dungey (1983). This pattern of higher velocitys in the Straight River could be caused by a limited amount of suitable substrate at lower velocities deemed optimal by previous literature.

All of the redds found in this study where found at optimal depth on the spawning depth HSI curve (depth greater than 24 cm) (Raliegh et al. 1986). The mean depth (49.2 cm) in this study was slightly deeper than that of the Shivell and Dungey (1983) study (39.4 cm). Dissolved oxygen levels at redd site are not well documented in the literature and are probably based on a minimum threshold for the survival of the eggs and fry. The minimum

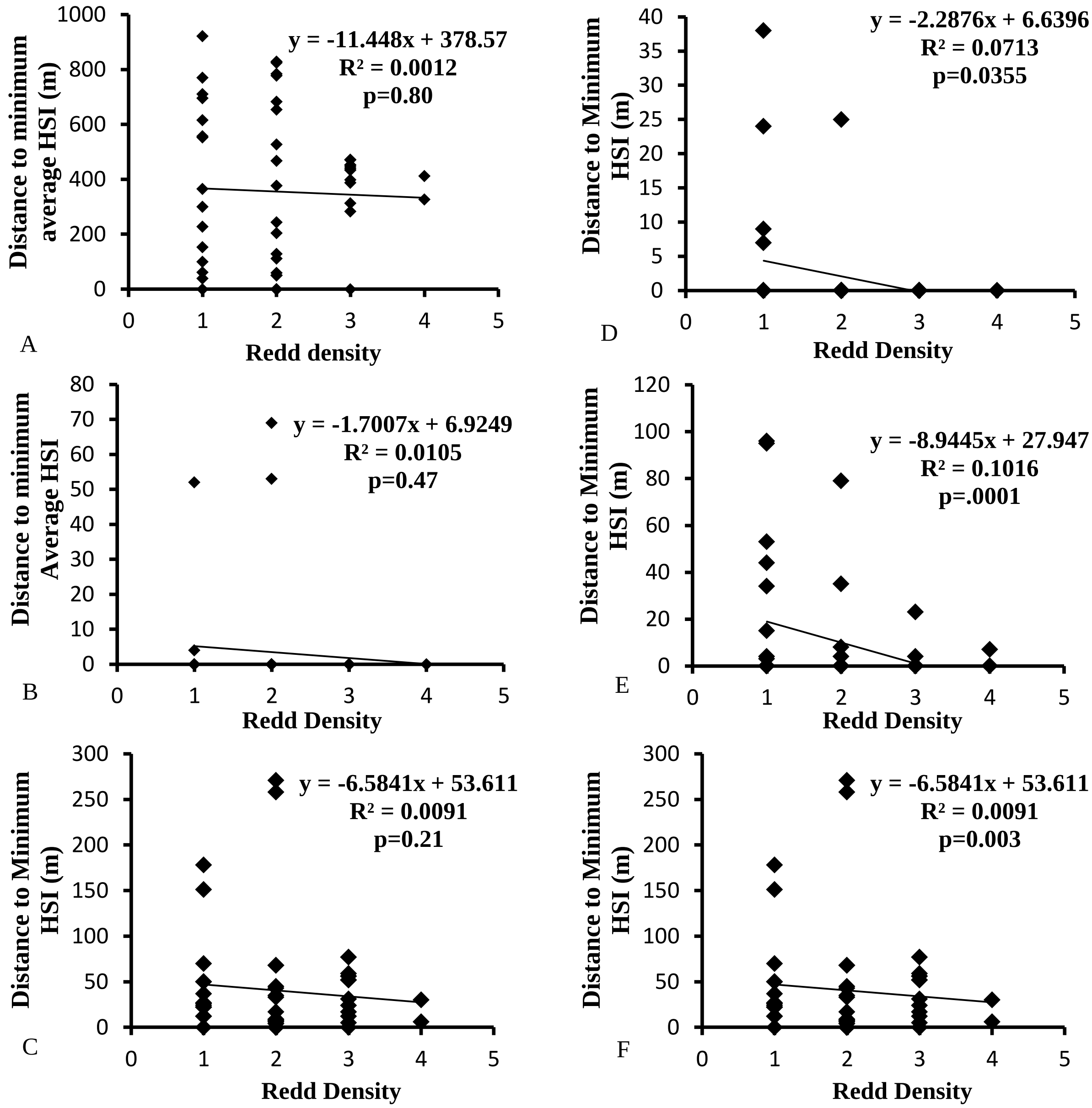

Figure 8- Shows the relationship of redd density to a minimum average wintering HSI of A. 0.65 B. 0.55 C. 0.50. and the relationship of redd density to minimum wintering HSI of D. 0.65 E.0.55 and E. 0.50.

level found in this study was 7.95 mg/L. Conductivity and pH at redd sites are also not well documented. These parameters may be more of a function of the water chemistry of the river as a whole and not site specific microhabitat parameters that brown trout are able to select.

Wintering analysis- In this study we were able to provide evidence to suggest that there is a relationship between spawing site selection and distance to site specific wintering habitat. The negative relationship between distance to a minimum HSI value and redd density shows that as you increase redd density, distance to suitable wintering habitat decreases. This relationship has not been well examined in the literature, but Zimmer and Power (2006) found some evidence of a tradeoff between spawning habitat requirments to allow for easier access to suitable wintering habitat. The fact that redds are found most frequently within 50 m of a suitable wintering site of 0.75 or less is further evidence of the influence of wintering habitat on spawning site selection. The strongest correlation between distance to site specific winter habitat and redd density is at an HSI level of 0.55.

This correlation is important in the consideration of stream rehabilitation and trout stream management. Roni et al. (2008) found that rehabilitation of stream habitats most often fails due to lack of undestanding of historic consitions and factors limiting biotic production. The results of this study should be taken into consideration when using habitat improvement as a tool for the management of brown trout populations, especially when using spawning habitat rehabilition as a means to promote natural brown trout production.

There was no relationship found between distance to minimum mean HSI values and redd density. This is probably because brown trout exhibit little movement in the winter months (Meyers et al. 1992). This evidence of lack of movement shows that brown trout must be selecting for specific habitat for the winter season. This explains our conclusion that there is a correlation between site specific wintering habitat and redd site selection and not larger scale overall wintering habitat suitability.

Future work is needed to corroborate the findings in this study. Future studies examining the relationship of spawning habitat to wintering habitat in brown trout should include a telemetry aspect to examine the actual migration of brown trout after spawning to examine how far they are migrating to wintering habitat. There is also considerable work needed in the area of brown trout wintering habitat preferences.

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