ATTACHMENT 1

DESABLA-CENTERVILLE PROJECT

Additional Licensee Information in Response to 10(j) Agencies' Comments on FERC's Draft Environmental Assessment and Determination of Inconsistencies Regarding 10(j) Recommendations and Prescriptions for New License for the DeSabla-Centerville Hydroelectric Project, FERC No. 803

On January 14, 2009 FERC filed its Section 10(j) Preliminary Determination of Inconsistency with the three Section 10(j) agencies involved in this relicensing [U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), and California Department of Fish and Game (CDFG)]. In response, USFWS, NMFS and CDFG filed comments on FERC's Preliminary Determination of Inconsistency; USFWS letter dated February 26, 2009, and NMFS and CDFG letters dated February 27, 2009.

The following information is provided by Pacific Gas & Electric Company (PG&E or Licensee) in response to the California Department of Fish and Game (CDFG) letter to FERC dated February 27, 2009 re: Section 10(j) Preliminary Determination of Inconsistency and Comments on the Draft Environmental Assessment for the DeSabla-Centerville Hydroelectric Project. Licensee's comments provided below are referenced directly to the CDFG letter, however, the comments are also intended to indirectly address the USFWS and NMFS letters as well since the topics and data presented by the three 10(j) agencies were somewhat similar across all three letters. Comments that directly reference the USFWS letter are specifically noted.

1. Fish Screening of Lower Centerville diversion and Hendricks Head dam (Pages 2-19)

1. Age class structure

CDFG commented that: "there is simply too little data available for FERC staff to conclude that the data '*generally demonstrate that age class structure of the trout populations within project affected stream reaches is sufficient to demonstrate viable fish populations.'*"

CDFG omitted 2007 data presented in Licensee's Updated Fish Population Study Results (December 2007), which includes *Age Class Distribution*. The length frequency histograms for fishes observed in 2007 near Project diversions are shown below in Figures 1–6 (Figures E6.3.2.2-12 through 17 in PG&E's December 27, 2007 Updated Study Report). Contrary to CDFG's statements, the figures support findings that trout populations appear to be self-sustaining and viable.

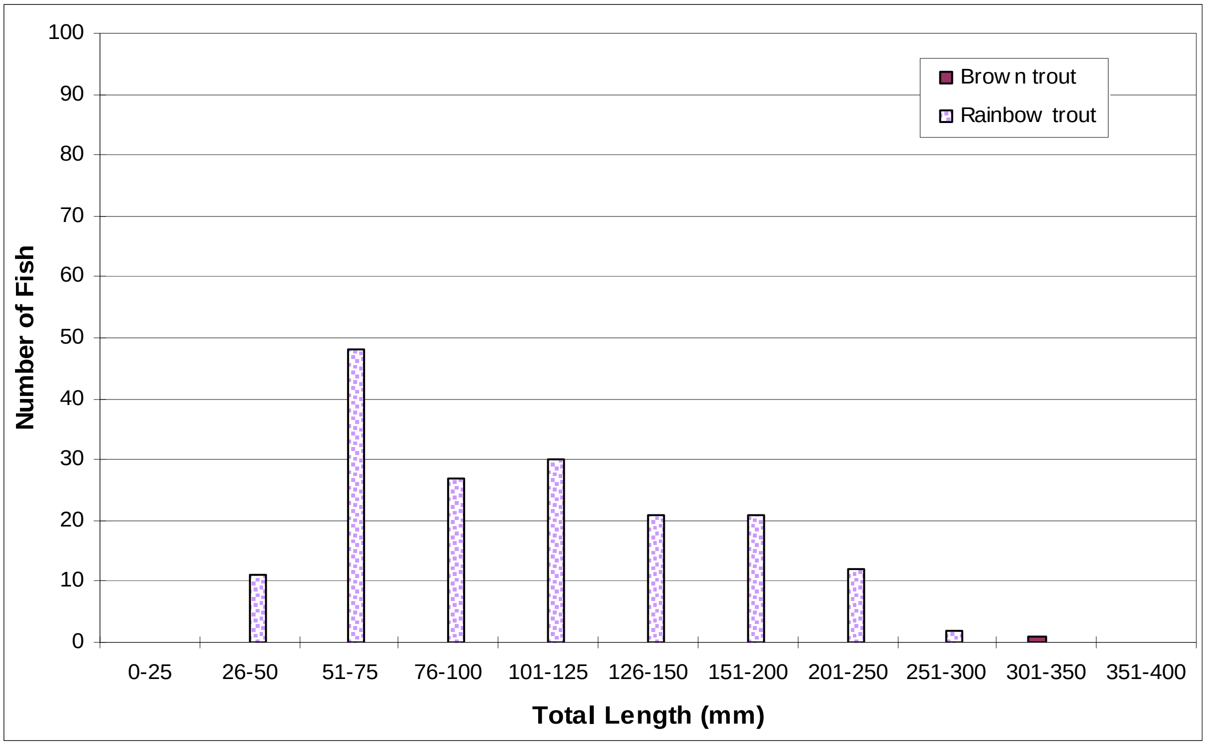


Figure 1. Length frequency distribution of fish observed during snorkel surveys in Butte Creek upstream of Butte Creek Diversion Dam (Butte 72.1), October 2007 (PG&E 2007).

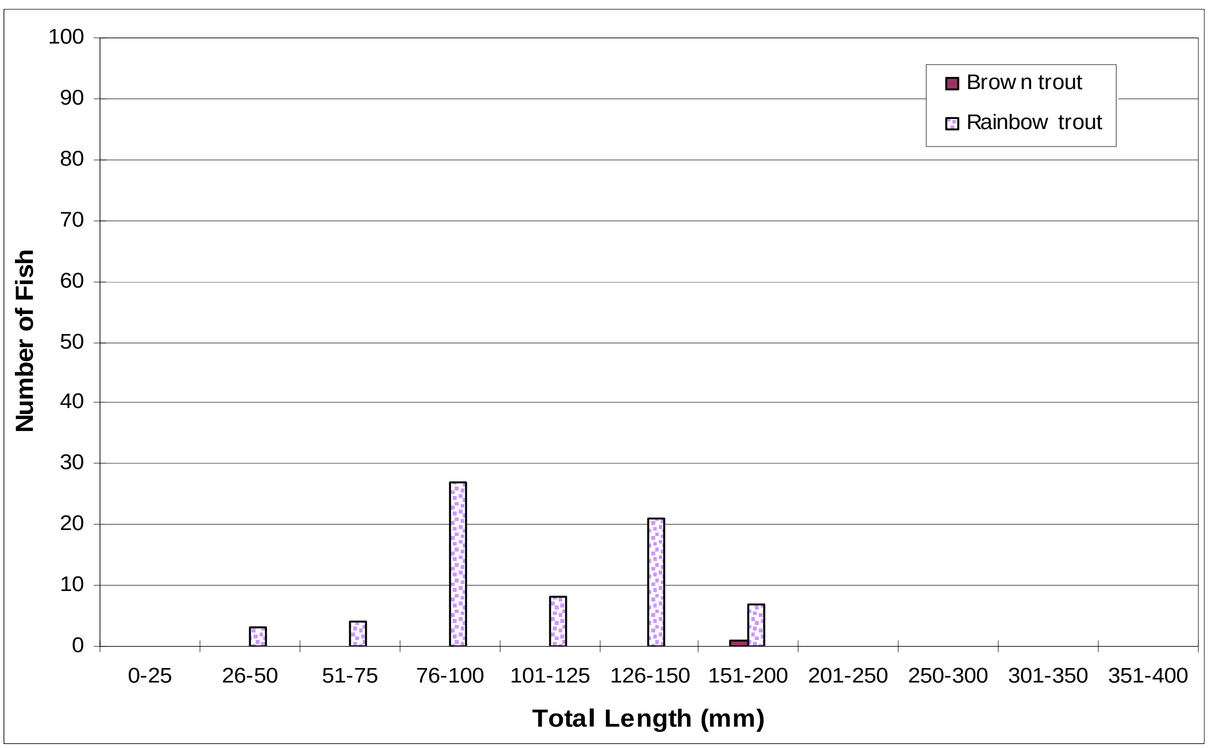


Figure 2. Length frequency distribution of fish observed during snorkel surveys in Butte Creek downstream of Butte Creek Diversion Dam (Butte 71.9), October 2007 (PG&E 2007).

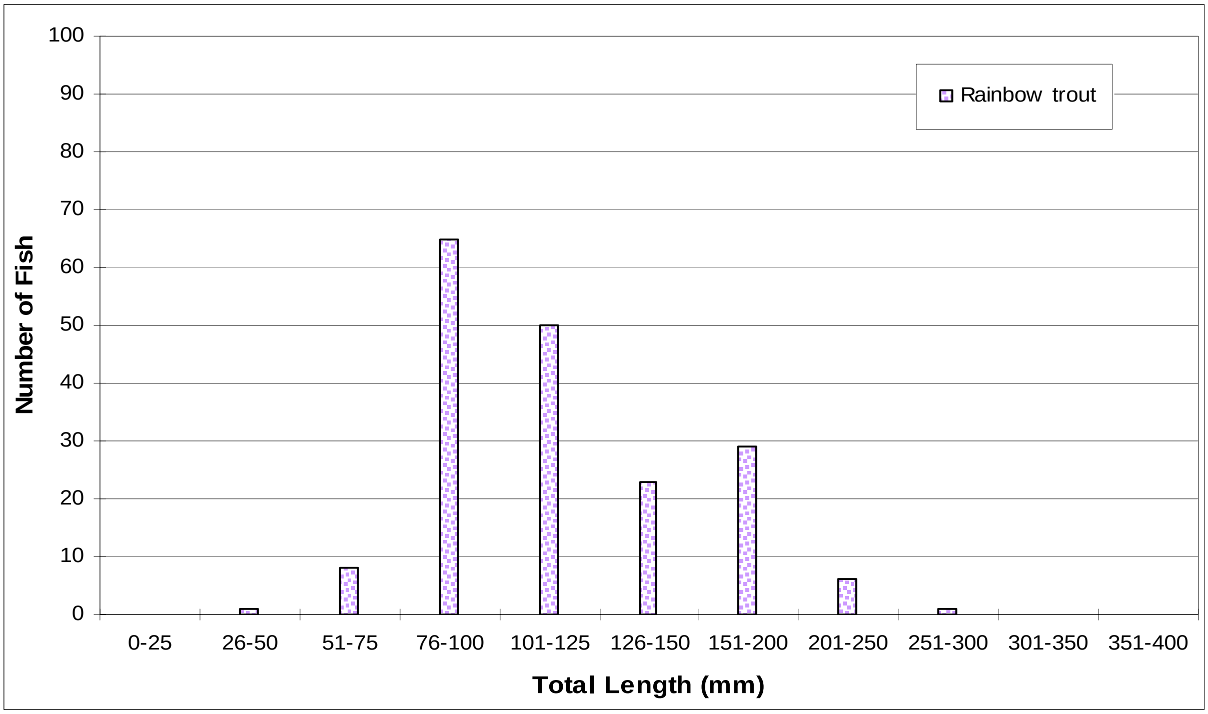


Figure 3. Length frequency distribution of fish observed during snorkel surveys in Butte Creek upstream of Lower Centerville Diversion (Butte 62.0), October 2007 (PG&E 2007).

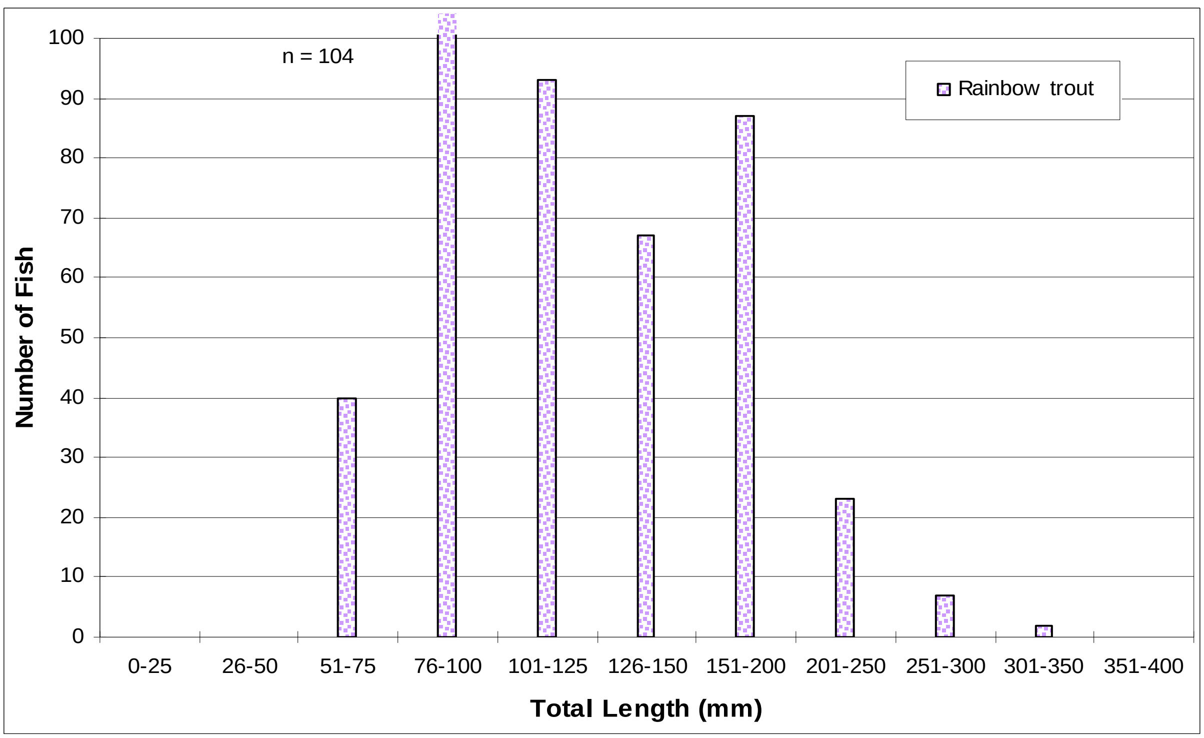


Figure 4. Length frequency distribution of fish observed during snorkel surveys in Butte Creek downstream of Lower Centerville Diversion (Butte 61.7), October 2007 (PG&E 2007).

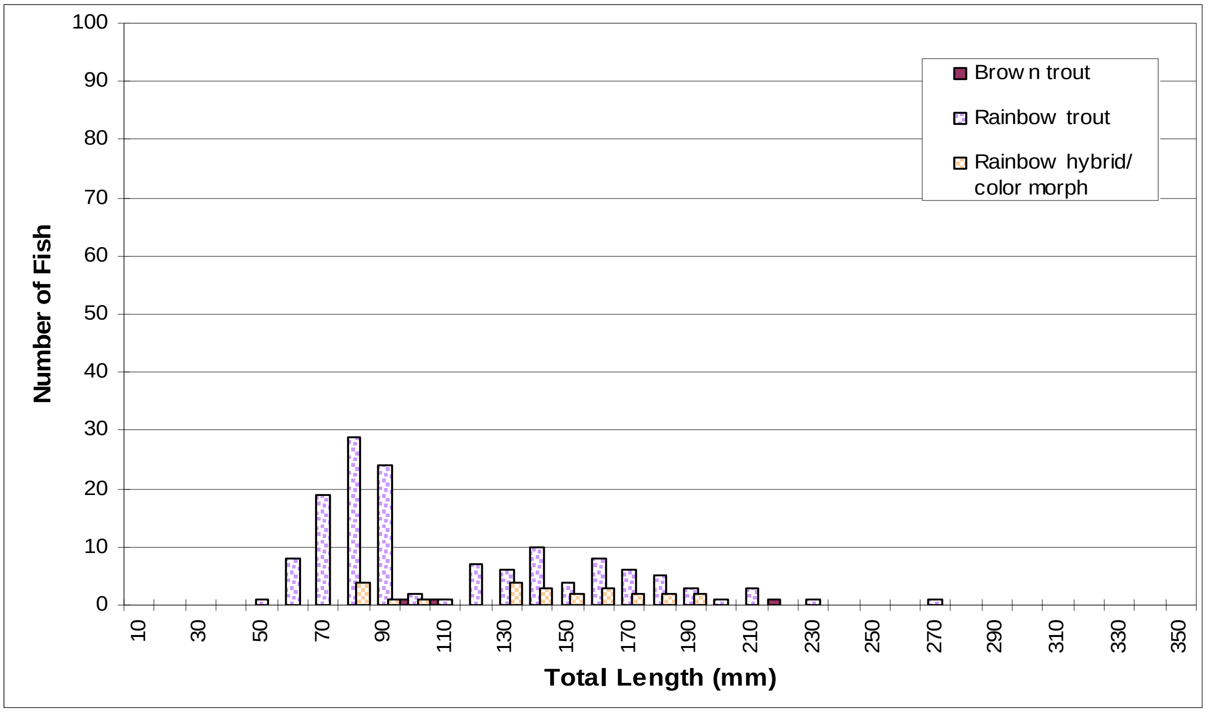


Figure 5. Length frequency distribution of fish captured during electrofishing in the West Branch Feather River upstream of Hendricks Diversion (WBFR 29.3), September 2007 (PG&E 2007).

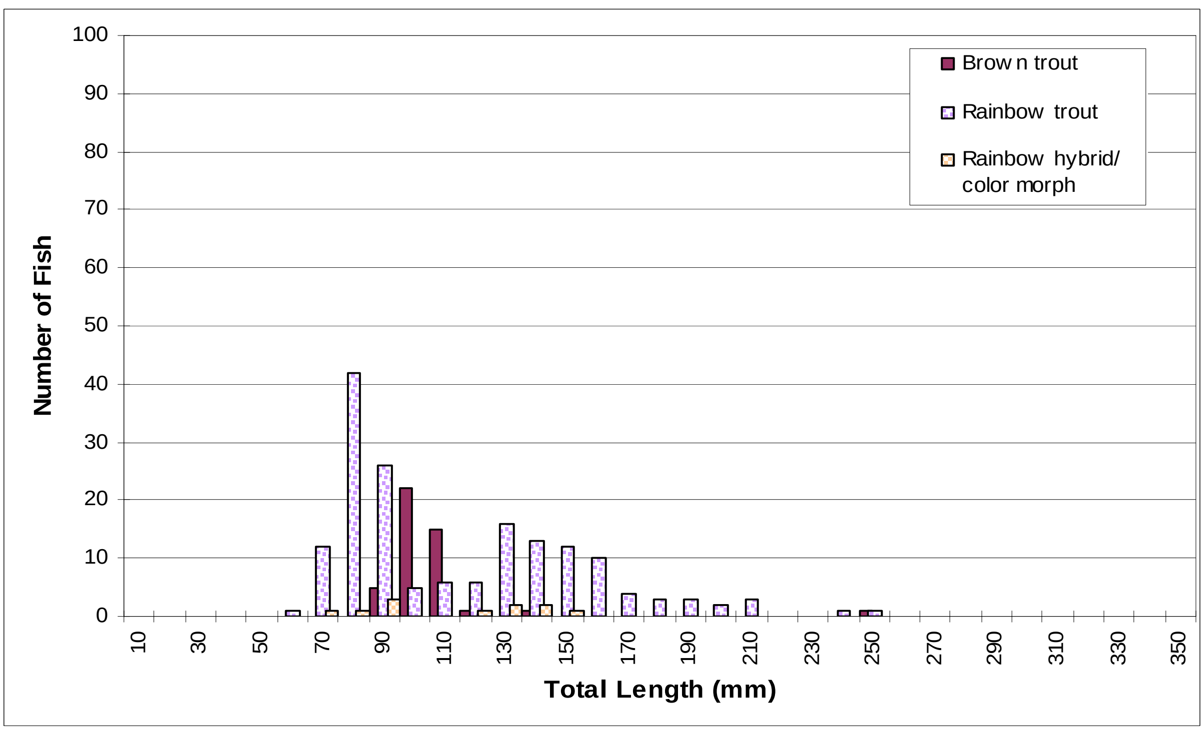


Figure 6. Length frequency distribution of fish captured during electrofishing in the West Branch Feather River downstream of Hendricks Diversion (WBFR 28.5), September 2007 (PG&E 2007).

2. Condition of trout

The results of Fulton's Condition Factor (k) at each of the four sites monitored by electrofishing in 2007 is presented in Table 1. Trout condition appears to be healthy within Butte Creek and the WBFR, which supports FERC's original decision.

Table 1. Trout abundance and growth condition factors (k-values) sampled by electrofishing in Butte Creek and the West Branch Feather River, 2007.

				Rainbow trout			Brown trout		
Stream	**Site Name**	**Site Label**	**Year**	**Sample size**	**% Total**	**Ave. K**	**Sample size**	**% Total**	**Ave. K**
Butte Creek	Downstream Butte Creek Diversion	Butte 71.9	2007	111	99.1%	1.00	1	0.9%	0.92
	Upstream Lower Centerville Diversion	Butte 62.0	2007	207	100.0%	1.08	0	0.0%	-
West Branch Feather River	Upstream of Hendricks Diversion	WBFR 29.3	2007	164	98.2%	1.04	3	1.8%	1.10
	Downstream of Hendricks Diversion	WBFR 28.5	2007	177	79.7%	1.03	45	20.3%	1.10
AVERAGE ALL BUTTE CREEK SITES IN 2007						**1.04**			**0.92**
AVERAGE ALL WEST BRANCH FEATHER RIVER SITES IN 2007						**1.04**			**1.10**
AVERAGE ALL SITES IN 2007						**1.04**			**1.04**

Licensee acknowledged that there are locations within the canal system that act as upstream migration passage barriers; these were discussed in the Fish Entrainment section of the License Application (PG&E 2007). Licensee considered water velocities within the canals and the absence of vertical drops at the canal entrances when evaluating the ability of fish to exit the canal entrances.

During spill conditions (when the photo presented by CDFG appears to have been taken, though not noted), the flow into the canal is typically higher (up to 110 cfs in Hendricks Canal and 170 cfs in Lower Centerville Canal) and would likely have water velocities at the gates that exceed trout burst swim speeds; however a proportion of this flow is typically returned to the stream channel at the canal regulating gates complicating entrainment risk analyses.

3. Comparison to historical observations

The historical data from 1977–2007 was included in PG&E's December 27, 2007 Updated Study Report (Table E6.3.2.2-11), which included 5 years of survey data. Licensee believes that CDFG calculations using two years of data (1977 and 2006) to describe populations within the Project affected reaches is inaccurate and misleading. In fact, the Updated Study Report included standard deviation of trout densities across years. The mean trout density observed from 1977–2007 was 320.6 trout/100 m with a standard deviation of 268.1. Therefore, CDFG's comparison of the highest value (1977) to the lowest (2006) identifies the range of variability in the stream rather than a decreasing population trend.

Several environmental factors affect trout population variability or the ability to sample them, including water year-type. Rainfall has varied greatly over time; 1976–1977 were the two driest years on record (1926–current), whereas 2006 was a wet year. Dry water conditions likely allowed for greater population estimate precision, as well as concentrated populations within the stream channel. For example, higher flows in 2006 prohibited the use of electrofishing in the upper WBFR, and the methods were therefore not comparable to 1977 (fish were surveyed using mark-recapture and electrofishing in 1997). Fish population monitoring on the WBFR has also shown population variability related to water-year type; surveys conducted during wet years appear to show lower population abundances compared to surveys conducted in dry years (Figures 7–8); however, it does appear that water-year type is not the only environmental factor that may influence fish populations or population surveys.

In addition to variations in populations as a result of overall stream conditions, trout populations respond negatively to peak flows, depending of the timing of the flow. For example, studies on the McCloud River using an individual based population model (IBM) for trout species identified that brown trout react negatively to peak flows in the fall–winter. Conversely, rainbow trout react positively to peak flows in the winter and negatively to peak summer–fall flows (PG&E 2009). In addition, annual peak flood flows have shown to be negatively correlated to overall population abundances in subsequent years in the South Feather River Basin (Stillwater 2006).

Data from WBFR and Butte Creek indicates large variability of trout populations between sites and years. Data did not indicate a clear trend over time. CDFG's discussion did not include the data from 2007, which when included, contradicts CDFG claims of a "92% reduction in 29 years" in the WBFR and a "55% reduction in abundance over 20 years" in Butte Creek. The WBFR 2007 data (which was gathered by electrofishing), indicates that the population was similar to that of 1987 and further shows the level of variation within a given stream reach (Figure 7). Butte Creek 2007 data identifies a several fold increase in trout abundance upstream of Butte Creek Diversion between 2006 and 2007 (both years were sampled via snorkel methods) (Figure 8).

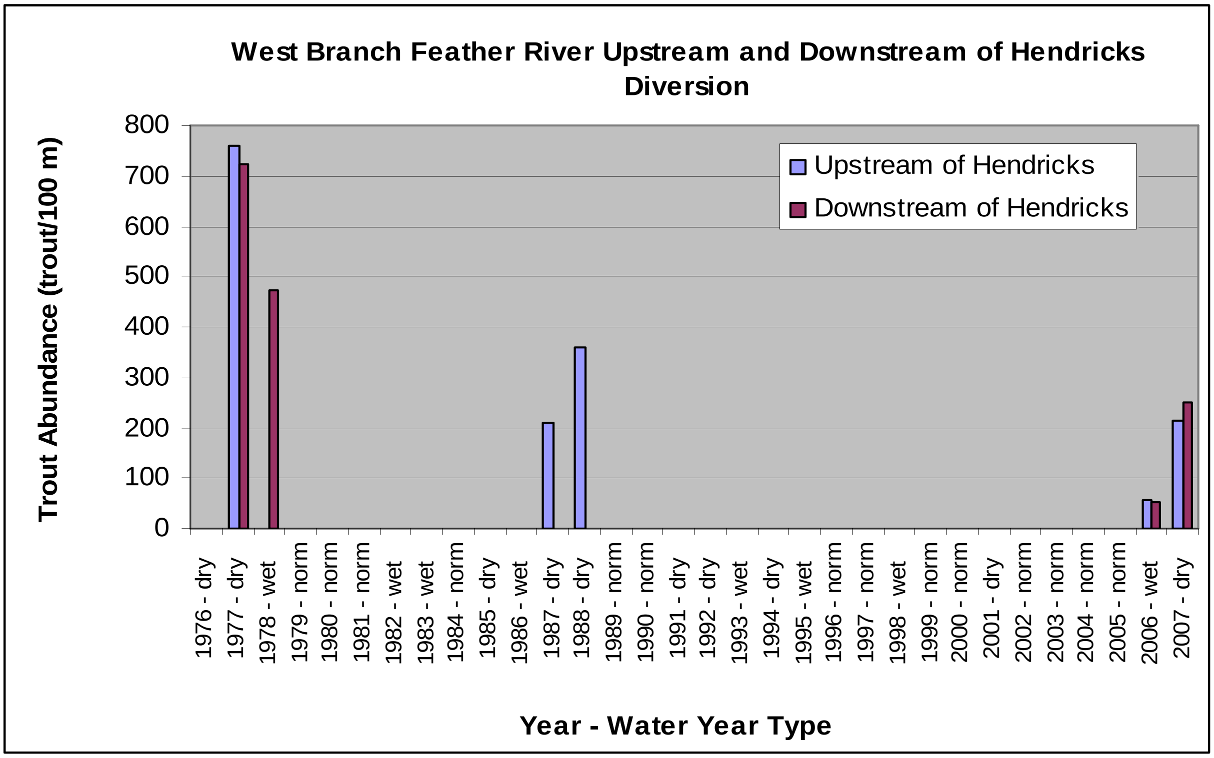


Figure 7. Trout abundance estimates upstream and downstream of Hendricks Diversion, West Branch Feather River, 1977–2007.

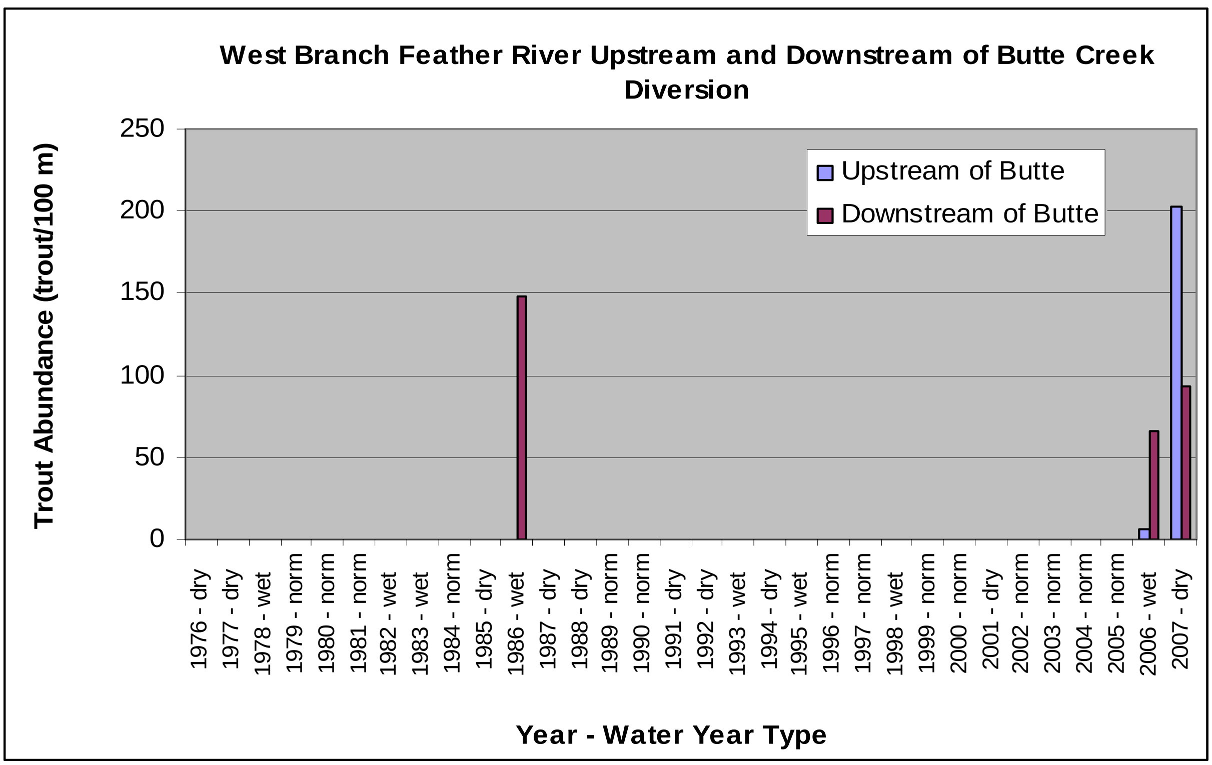


Figure 8. Trout abundance estimates upstream and downstream of Butte Creek Diversion, Butte Creek, 1977–2007.

Cumulative Impact Analysis of Ongoing Entrainment

CDFG referenced 2006 population abundance estimates at the project diversions related to entrainment and specifically pointed out the difference between populations upstream and downstream of the major diversions. Because of varying methods in 2006, Licensee re-surveyed fish sites upstream and downstream of each major diversion, per the agencies requests and FERC Order, using similar methods for each in 2007. Using similar methods between upstream and downstream surveys yielded similar population estimates (Figure 9 [included in PG&E's December 27, 2007 Updated Study Report, Figure E6.3.2.2-25]).

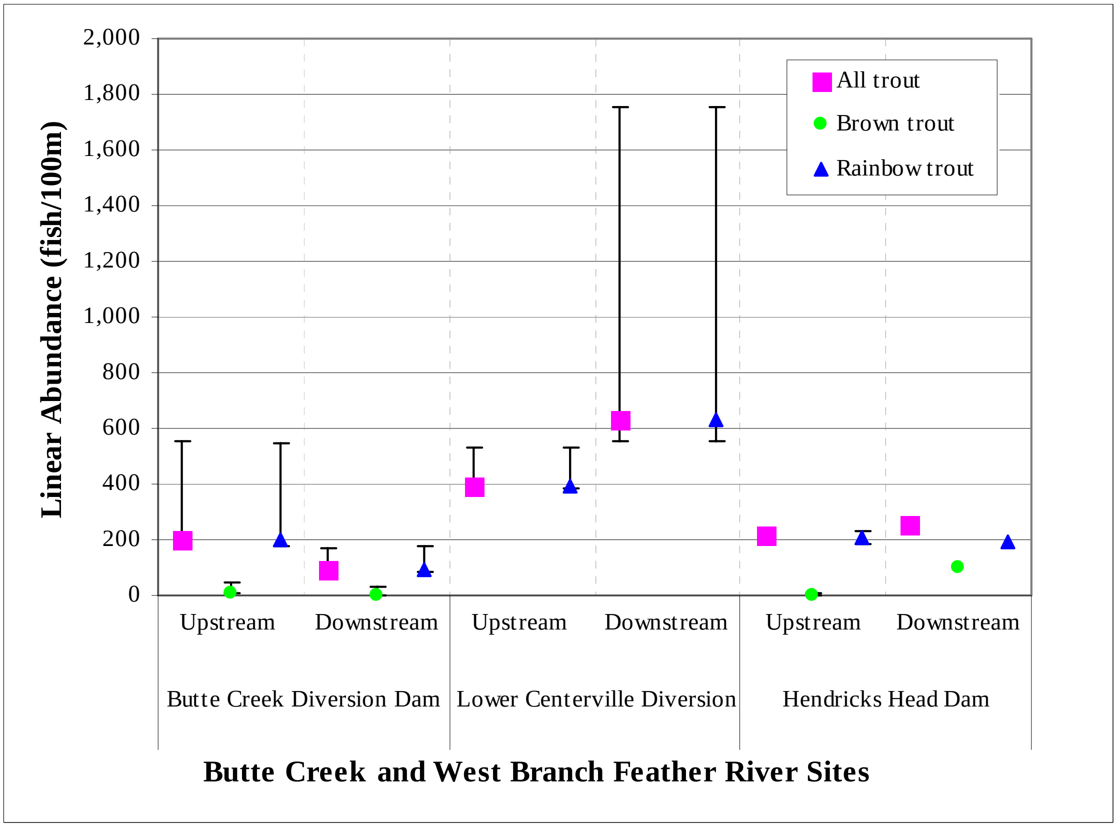


Figure 9. Linear abundance estimates, with 95 percent CI, from snorkel and electrofishing surveys at Project diversions in Butte Creek and the West Branch Feather River, 2007.

Cumulative Impact Analysis of Lack of Connectivity between Upstream and Downstream Habitat.

CDFG included a summary of a study conducted by Graf (Graf, 2007) regarding fish movement. Though components of CDFG's summary are accurate, other key components of the study were omitted. Graf measured movement in three ways:

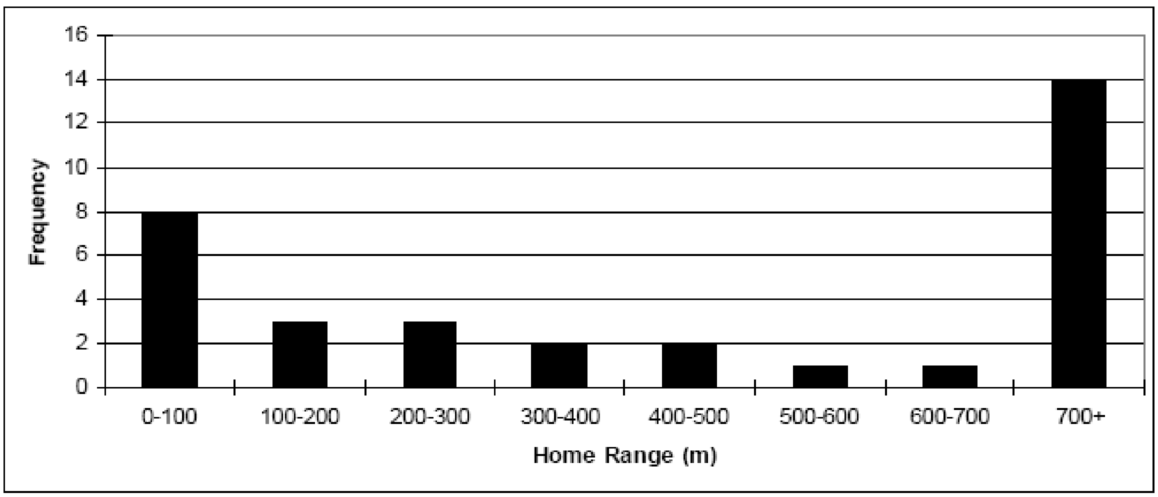
- home range, defined as the extent of a fish's movement (*i.e.*, the distance between the upstream- and downstream-most re-sight locations)

- <u>total movement</u>, measured as the sum of the absolute value of all measured movements, where upstream movement was recorded as positive and downstream movement was recorded as negative
- <u>displacement</u>, measured as the net distance a fish moved over the course of the study (*e.g.*, where upstream movement was positive, downstream movement was negative, equal movement upstream and downstream results in a net movement of zero)

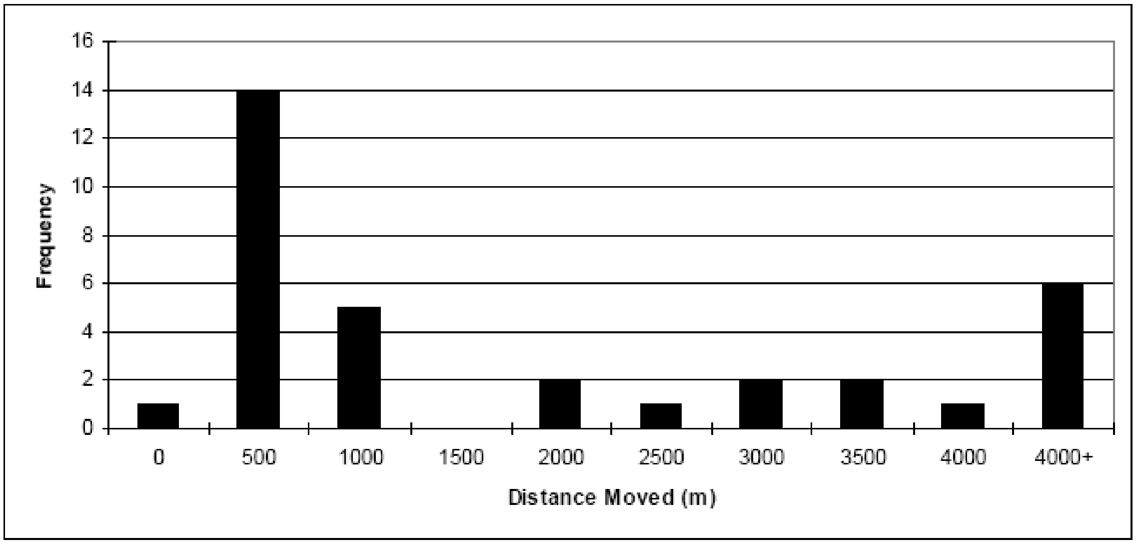
The following figures are inserted directly from the Graf report (Graf, 2007; Figure 2).

Figure 2. The frequency of the (a) home range, (b) total movement, and (c) displacement distance of rainbow trout. Home range was measured as the distance between the upstream-most and downstream-most relocation. The total distance was the absolute value of all movements summed. Displacement was measured as the net movement of fish over the duration of the study, where downstream movements were recorded as negative values.

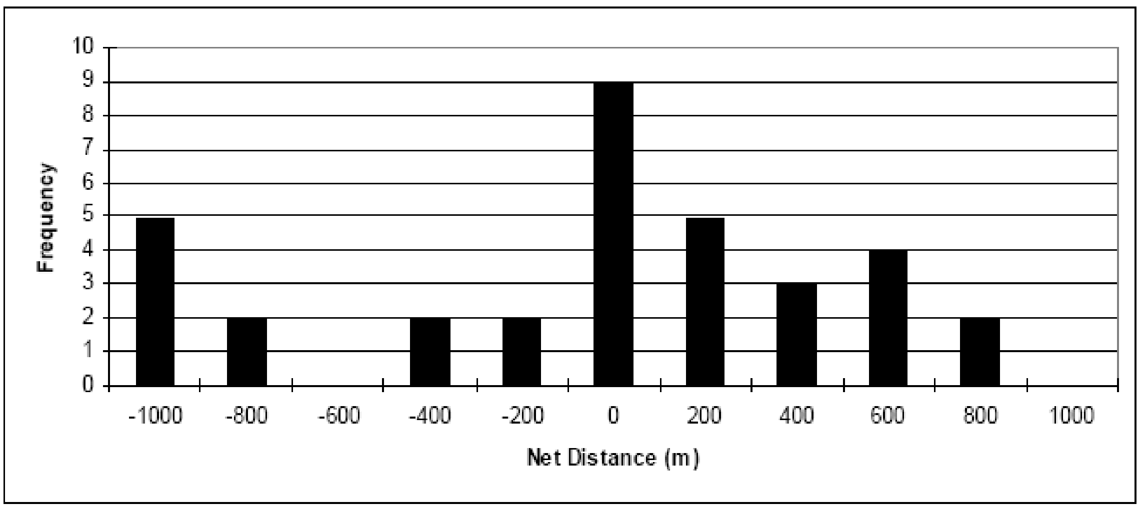
a)



b)



c)



The total movement of trout (summing all upstream and downstream movement) could indicate activity. The net distance of any one fish in any one direction appeared to be less than 1,000 m and the majority showed little net movement overall (Graf Figure 2c). This would indicate that the total movement was balanced between upstream and downstream movement for most fish.

Graf observed that rainbow trout moved in response to stochastic events. For example, rainbow trout moved into tributary streams during spring high flows. Trout moved downstream within the mainstem during a period when water levels on the Truckee River "dropped to uncharacteristically low levels" and one study reach was dewatered yielding high water temperatures that caused mortality of study fish. However, Graf noted that the median range of movement was only 440 meters (range 10–6,434 meters), whereas trout have the ability to move several miles within the mainstem WBFR as well as into tributary streams. Trout movement within Butte Creek is restricted by natural barriers within the mainstem as well as tributaries due to the steep canyon character of the stream channel in addition to any Project features.

CDFG points to the importance of genetic flow related to trout ability to move. However, Graf noted that *"[T]here were no obvious migrations during the spawning season. …It instead seems more likely that rainbow trout in the Truckee are opportunistic and spawn locally.*" CDFG notes that "it is true that resident trout populations do not rely on spawning migrations to fulfill their life histories", but cites a study from Graf (2008) indicating that rainbow trout may move up to 6500 meters in the Truckee River (a larger, much lower gradient river than the WBFR). However, only 1 fish in that study moved that far; in fact, 85% of the fish moved 1000 meters or less (according to CDFG's representation of Graf's [2007] data), and Graf's original paper (page 20, and page 24 Figure 2a of Graf [2007]) indicates that 59% of the population moved less than 700 meters. Contrary to the CDFG assertion that "genetic flow cannot happen because the project blocks movement" (CDFG page 16), the following biological facts support FERC's original determination:

- Resident trout populations do not rely on spawning migrations to fulfill their life histories.
- Genetic flow regularly occurs under current conditions, from the upper to the lower watershed by virtue of regular spill and bypass flows which allow downstream movement of trout.
- The size of both the upper watershed (over 12 miles of mainstem, plus tributaries) and lower watershed (over 14 miles down to Miocene, plus several major tributaries) provides extensive stream area for any trout that do migrate (presuming they can surmount natural barriers in the high gradient areas).
- Genetic flow for trout in the WBFR is irrelevant, given that CDFG continues to plant hatchery trout at the upper end of the watershed (in Philbrook Reservoir) on a regular basis, and these fish can move downstream throughout the entire watershed. Facilitating gene flow between naturalized trout populations (upstream and downstream of Hendricks Diversion Dam) of hatchery origin that continue to be genetically influenced by ongoing planting of CDFG hatchery trout does not warrant a fish ladder.

Licensee agrees that both brown trout and rainbow trout move within the stream. Licensee stated in the License Application (Entrainment) that, based on the composition of fish in the stream compared to within the canals, brown trout appear to migrate more than rainbow trout (*e.g.*, the number of brown trout in the canal was disproportionately large compared to rainbow trout). Licensee believes that rainbow trout have the ability to move to avoid stochastic events and Project diversions do not play a major role in hindering that movement based on Graf (2007).

CDFG provides a comparison of habitat (using percent of maximum WUA as a metric) upstream and downstream of Hendricks Diversion Dam to support its position for a fish ladder (page 17). This comparison neglects several key points that are germane to FERC's original determination:

- First, percent of maximum WUA is a theoretical and inappropriate metric for comparison in this situation. During the time period CDFG cites in Figure 11, "maximum WUA" does not even exist historically. Thus, CDFG is comparing current conditions to something that never occurred, and inferring that differences between upstream versus downstream percentages of that non-existent condition are meaningful. A more appropriate comparison is to use percent of unimpaired WUA, which can be calculated from the tables in Section 6.3.2.8 of the License Application by dividing the monthly proposed WUA values by the corresponding monthly unimpaired WUA values (these data also use a much longer period of record than CDFG's 4 years cited in their Figure 11). This calculation reveals that, although WUA downstream of Hendricks Diversion Dam is certainly lower that upstream of the dam during the summer months, the differences are not as great as suggested by CDFG's analysis.

- Second, nearly all the stakeholders in this license proceeding recognize that there is a trade-off between additional summer flow downstream of Hendricks Diversion Dam, and maintaining adequate habitat and water temperature for the listed spring-run Chinook salmon in Butte Creek. The current conditions in the Lower WBFR (*i.e.*, below Hendricks Diversion Dam) support a healthy trout population (including outmigrants from the upper watershed), provide many miles of diverse rearing and spawning habitat, and are enhanced by inflow from numerous tributaries and proposed higher minimum flows in normal water years. CDFG's position that a fish ladder will somehow "better protect" trout in already suitable downstream Lower WBFR habitat from 1) adverse habitat conditions, 2) adverse effects of restricted gene flow with the upstream hatchery-influenced trout population, or 3) lack of opportunity to migrate, is not supported by the data.
- Third, trout are density dependant species. The trout populations in the Lower and Upper WBFR are both viable and not isolated from critical habitat. Therefore population densities should adjust in both reaches regardless of a ladder at Hendricks Diversion Dam and providing access of trout from the lower WBFR to the upper WBFR would likely not result in a change in abundances in the Upper WBFR.

2. Resident Fish Monitoring

As discussed above, CDFG excluded 2007 data in all of their analyses. Discussions of declining population "trends" using (in some cases) two years of data is inappropriate. Rather, the data as reported in the Updated Fish Population Study Report (PG&E 2007) identifies sometimes large variances in trout populations between sample years and site locations within reaches. The data did not identify any trends, decreasing or increasing.

5. Annual Fish Stocking

Licensee understands that FERC staff believes some level of fish planting is appropriate for the Project. As discussed in the draft EA, a 1983 agreement between Licensee and CDFG requires funding for fish stocking. The CDFG is now seeking clarification about the quantity of any future fish stocking. Licensee would like to bring FERC's attention to the fact that since 1983 there has been a 40% reduction of resident fishing license sales in California. This fishing license sales reduction provides evidence that supports consideration of a reduction in the amount of fish stocking in the new license.

See http://www.dfg.ca.gov/licensing/statistics/statistics.html California sport fishing license sales.

The following information is provided by PG&E in response to the U.S. Fish and Wildlife (USFWS) letter to FERC dated February 26, 2009 re: Comments on the Draft Environmental Assessment and Section 10(j) Preliminary Determination of Inconsistency Letter for the DeSabla-Centerville Hydroelectric Project.

Section F2, page 11 of USFWS letter regarding MIF downstream of Lower Centerville Dam on Butte Creek

The USFWS has asserted that their recommended flows for this portion of Butte Creek (the middle sub-reach) should be adopted by FERC, since they provide greater spawning WUA than FERC's recommended flows. However, FERC's proposed MIF in the Environmental Assessment properly considers several important issues:

- The number of spawners in this sub-reach already exceeds the available spawning habitat under any flow (page 168 of the EA), resulting in unavoidable superimposition of redds. Under current conditions, there is redistribution of holding salmon back downstream to available spawning habitat below Centerville Powerhouse, lessening the overcrowding in the upstream area (page 167 of the EA). A flow regime that attracts even more salmon into the middle sub-reach diminishes use of the available spawning area downstream of Centerville Powerhouse, further aggravating over-utilization of the middle sub-reach area and the resulting redd superimposition. A balance must be struck between increasing spawning habitat area, and increased attraction of spawners into the middle sub-reach.
- The EA correctly notes that the USFWS proposed flow would result in only marginal increases in WUA in the middle sub-reach. Contrary to the "more WUA is better" approach that the USFWS is recommending, all of the historical data indicate that the middle sub-reach is already over-utilized (page 168 of the EA), and that greater salmon production is best achieved by encouraging greater spawner use of available spawning habitat below Centerville Powerhouse.

References

Graf, P. 2007. The movement behaviors of a non-native trout in the Truckee River, CA. An applied study for the re-introduction of Lahontan cutthroat trout. November.

PG&E (Pacific Gas and Electric Company). 2007. Exhibit E, Amended Section 6.3.2.2 - Characterization of Fish Populations in Project Reservoirs and Project-Affected Stream Reaches (Study 6.3.3-4): Updated Study Report incorporated fish sampling data collected by PG&E in late 2007; in compliance with FERC order, and filed December 27, 2007.

PG&E (Pacific Gas and Electric Company). 2009. Individual-Based Model Instream Flow Evaluation (Study FA-S8), Technical Memo 54. McCloud-Pit Project, FERC Project No. 2106. San Francisco, CA. January.

Stillwater (Stillwater Sciences). 2006. South Feather Water and Power Agency fish population monitoring 2005. Prepared by Stillwater Environmental Services for South Feather Water and Power Agency. Davis, California March.

ATTACHMENT 2

The Movement Behaviors of a Non-Native Trout in the Truckee River, CA

An Applied Study for the Re-Introduction of Lahontan Cutthroat Trout

Peter Graf, 2007

The Movement Behaviors of a Non-Native Trout in the Truckee River, CA

An Applied Study for the Re-Introduction of Lahontan Cutthroat Trout

By

Peter Graf

Advised by Mary Peacock, Ph.D.

11/16/2007

Abstract

Most research on fish movement has shown that adult salmonids are sedentary, often spending the majority of their lives in a single pool (Gerking 1959, Gowan et al. 1994). However, these results have come into question because of recent work with sampling techniques that were not previously available (Gowan et al. 1994). Recent evidence has shown that some salmonids may regularly travel long distances (Riley et al 1992; Riley and Fausch 1995; Gowan and Fausch 1996). Current thinking is that salmonid populations are strongly influenced by the geomorphology of the stream, and that population structure and movement will vary widely from basin to basin (Riley and Fausch 1995).

The proposed research will assist the Truckee River Recovery Plan, whose primary goal is to establish a self-sustaining population of the extirpated and federally listed Lahontan cutthroat trout (LCT) (*Oncorhynchus clarki henshawi*). Rainbow trout (*Oncorhynchus mykiss*) are a primary concern for the reintroduction of LCT due to competition and the threat of hybridization between the two species. Using radio-telemetry, this study will target specific locations along the Truckee River to determine how rainbow trout populations are structured and distributed in the Truckee River Basin and how these populations vary across the river. This information is critical for resource managers involved with the reintroduction of LCT.

Project Overview

Most research on fluvial salmonids has indicated that individuals tend to be sedentary (Gerking 1959, Gowan et al. 1994). Adults establish a home territory and remain there, rarely moving more than 20 m from the location at which they were originally located (Gerking 1959, Solomon and Templeton 1976). This body of literature on fish movement has tended to support Gerking's (1959) influential theory of restricted movement. While some studies have shown that fish may move periodically during their lives, such as passive fry dispersal (Crisp and Hurley 1991, Daufresne et al. 2005), diel movement between feeding and resting locations (Bunnell et al. 1988), and upstream and tributary movements for spawning (Brown and Mackey 2004), these movements have been seen as specific behaviors that interrupt normal sedentary tendencies (Gowan et al. 1994).

Until recently, studies of fish movement have generally employed the same basic study design. Typically, fish were collected within small study reaches and given a unique identifying marker. Over a given period of time (1-4 years) the study sections would be sampled again, and the location of the recaptured fish would be analyzed. Usually these studies focused on widely spaced reaches, 50-500m in length (Fausch et al. 2002). The results from these studies have often supported the theory of restricted movement. However, as Gowan et al. (1994) persuasively pointed out, these studies appear to be biased towards finding only sedentary fish. For example, in some studies 15 to 90% of marked fish were never recaptured; the loss usually attributed to mortality and the difficulty in capturing fish in a stream environment (Young 1995). While this assumption may be warranted in some circumstances, the unaccounted-for fish should not go ignored, particularly in studies where efforts to recapture marked fish were concentrated in the same location as the fish were originally located (Gowan et al. 1994). Additionally, these studies have too often focused on small of reaches of river, limiting the scale of the study to only capture sedentary fish.

Confounding these studies is what researchers believe is a leptokurtotic distribution (high peak with long tails) of fish movement (Fausch et al. 2002). In this model, a large proportion of fish move only short distances (the peak) while a minority disperse more extensively (the tails). Because of the sample designs mentioned above, the sedentary fish are disproportionately recaptured. Meanwhile, mobile fish may disperse one kilometer to hundreds, yet because of the difficulties in sampling an entire river, are rarely included in analyses. Empirical studies employing extensive mark-recapture techniques (Skalski and Gilliam 2000), two-way weirs (Gowan and Fausch 1996), and radio telemetry (Young 1995) have supported the leptokurtotic distribution model (Fausch et al. 2002). Additionally, studies on marked rainbow trout (*Oncorhynchus mykiss*) and Dolly Varden (*Salvelinus malma*) have found that fish do occasionally move long distances (> 40km), well beyond what researches assumed was a fish's home range, and that these movers are a small proportion of the population (Bjornn and Mallet 1964).

These more recent studies that have captured fish movement have led some to theorize that populations may have fish with mobile and sedentary life strategies (the "movers" and "stayers") (Grant and Noakes 1987, Hilderbrand and Kershner 2000, Huges 2000). Additionally, individuals may alternate between behaviors; remaining in a localized area for months to years and then moving long distances (Brown and Mackey

1994). Others have suggested that the observed variability in movement behavior may be a plastic response at the individual level to resource abundance and distribution and that these behaviors are highly variable temporally (Fausch et al. 2002). For example, Schlosser (1995a) found that a population's movement patterns were most related to the creation and destruction of beaver ponds, a scale that spans decades. Additionally, in a study that spanned 4 years, Schlosser (1995b) found that the majority of movement by most species occurred over the course of 4 days.

A re-examination of the restricted movement paradigm has taught us that fish movement is more variable and dynamic than previously thought. However, even in most studies where mobile fish were observed, sedentary behaviors predominate. Rodriguez (2000) has cautioned that studying fish movement with the a priori goal of categorizing a population as conforming or not conforming to the restricted movement paradigm may lead to an overemphasis in capturing movement. Often researches have found high turnover rates (1 – proportion of marked individuals that remain in the study section) and equate them with a highly mobile population. Rodriguez has argued that to accurately describe movement, turnover rates and displacement need to be disentangled. For example, in small study reaches, fish need only to move short distances (i.e. displacement) to leave the study section and in turn be counted as mobile individuals. This results in high turnover rates but with low displacement distances. Gowan and Fausch (1996) and others have found that short ranging behaviors are common for stream salmonids during the summer months, yet classifying these fish as mobile or sedentary is a reflection of the scale at which we design our studies (Hilderbrand and Kershner 2000).

Studying fish behavior is an inherently difficult task. Because of logistical constraints, ecologists are often forced to choose a scale at which to study rivers. However, to capture both small scale ranging behavior and long-distance dispersal, study designs must operate at multiple scales. Hierarchical models with nested sampling designs are one approach that may help overcome the shortcomings of single-scale studies (Fausch et al. 2002). Overcoming these difficulties in the field is necessary to better understand fish population dynamics, metapopulations, and species conservation (McMahon and Matter 2006).

The Riverscape Approach: Landscape ecology has taught us the importance of space, scale, and the connectivity of habitats in ecological processes. Recognizing the importance of spatial complexity and the geographic arrangement of habitats has provided ecologists with a new perspective on the mechanisms controlling population dynamics. Traditionally, ecologists have studied the distribution and organization of organisms in order to understand underlying mechanisms controlling population patterns. More recently, ecologists have begun to study the effects of spatial pattern on abundance and demography (Fausch et al. 2002). A recent series of papers have taken the principals of landscape ecology and applied them to riverine systems. These aquatic ecologists have recognized that spatial complexity is not limited to terrestrial systems, and that organisms within a river system must move through, and in some cases choose, patches with different qualities (Rincon et al. 2000). Using a landscape approach, researchers have effectively modeled fish habitat selection (Rincon et al. 2000), population dynamics (Grossman et al. 1995), and population genetic structuring (Neville et al. 2006). While some of the principles of landscape ecology (habitat heterogeneity and connectivity) have been implicit in freshwater ecology, they are often studied independently and without consideration of the mosaic as a whole.

Fausch et al. (2002) have argued that many of the holes in our understanding of riverine fish, including movement, can be filled by using a landscape approach. They argue that too often ecologists have limited their research to short fragments of the river, which has lead to an inadequate understand of the ecology of fish and poor management practices. For example, because it has been assumed that fish stay localized, and because of the difficulties in studying a stream environment, ecologists have often limited their observations and experiments to small study reaches over short time spans. These results are then used to scale-up to the entire river (Fausch et al. 2002). For fisheries managers, the results from these studies do not adequately address the larger scale issues that they most commonly face, such as flow manipulation and invasive species (Fausch et al. 2002). Additionally, human impacts on rivers often occur at multiple spatial scales such barriers splitting a river into isolated patches or homogenizing habitat by channelization. (LePichon et al. 2006). However, a landscape approach is more than increasing the spatial extent of a study (Fausch et al. 2002). Instead, researchers need to consider how individual behaviors at a micro-scale are linked to watershed-scale population dynamics. The study of movement behavior is one conduit to this link. For example, at a micro-scale, an individual's decision to stay or move can influence large-scale dynamics such as population persistence and connectivity (McMahon and Matter 2006). Additionally, because of the complex life stages of stream fishes and stage specific needs, spatial heterogeneity can affect population viability (LePichon et al. 2006).

There are inherent tradeoffs when choosing to incorporate scale into a study design, particularly when time is also a factor. In the case of studying fish movement, large scale studies often miss small ranging behavior movement while small scale studies focus is to narrow. One solution to this problem has been to incorporate multiple methods capable of capturing movement at different resolutions. Alternatively, studying movement behaviors at an intermediate scale may allow for insight into both small and large scale patterns. Intermediate-scale dynamics, such as sub-population behavior in patches of different qualities and in different locations, is a reflection of individual response to local conditions and, when pieced together, a large-scale representative of the populations as a whole. Fish populations and communities are most affected by processes that occur at intermediate scales both spatially and temporally (Fausch et al. 2002). Fausch et al. (2002) has argued that it is this intermediate scale understanding that is needed to bridge the gap between research and conservation.

Lahontan Cutthroat Trout (LCT) and the Truckee Basin: In 1970 the LCT was listed as an endangered species (Federal Register Vol. 35, p. 13520) Later, to facilitate management and recreational fishing, LCT were re-classified as a threatened species (Federal Register Vol. 40, p. 29864). The listing of the LCT led the US Fish and Wildlife Service (USFWS) to create a recovery plan (Short-term Action Plan for the Recovery of LCT in the Truckee River Basin 2003) that addressed the conditions that led to the extirpation of LCT and possible impediments to the establishment of a naturally reproducing population (USFWS 1995).

There are currently no naturalized reproducing LCT in the Truckee River and its immediate tributaries. One population of reproducing LCT in the Truckee Basin is separated from the Truckee River by two dams and two reservoirs. LCT historically occupied the entire Truckee River basin, persisting in over 2,000 square miles of interconnected streams and lakes (USFWS 1995). LCT evolved in both high elevation cold water habitats and warmer alkaline lakes, expressing both a migratory and resident life history (USFWS 1995). Resident individuals occupied both tributaries and the main stem Truckee River while migratory fish moved throughout the Truckee Watershed. For both populations, the Truckee River and its tributaries provided spawning and rearing habitat. Connectivity between tributaries, the main stem, and lake habitats is likely necessary for long term persistence of LCT populations (Dunham et al.1997; Neville et al. 2006). A networked system where individuals can move and populations can mix will promote the repopulation of locally extirpated LCT without having to stock every tributary in the basin.

Fluvial LCT, like all stream-dwelling cutthroat trout, are unable to persist with non-native salmonid competitors (Dunham et al. 1997). Rainbow and cutthroat trout are closely related species that will compete for the same resources. Additionally, trout are density-dependent species; often hatchery-reared fish have lower growth rates, fecundity, and survival when implanted in streams with wild competitors (Bohlin et al. 2002). By occupying the larger river system, rainbow trout eliminate the connectivity between cutthroat populations. Population viability studies have shown that many western U.S. inland trout species persisted historically in highly variable environments by living in large interconnected stream systems with a metapopulation dynamic (e.g., cutthroat trout

Oncorhynchus clarki, Ray et al. 2000; bull trout, *Salvelinus confluentus,* Dunham and Rieman 1999; Rieman and Dunham 2000). Isolated populations, therefore, do not represent a viable alternative to restoration of interconnected systems for many salmonids. During the recovery of greenback cutthroat trout, a threatened cutthroat species now approaching de-listing, the provision that no populations of greenbacks be sympatric with non-native salmonids was seen as essential to the recovery of the species (Young and Harig 2001).

Rainbow Trout Hybridization: The introduction of non-native salmonids has contributed to the decline of all cutthroat trout species including LCT, particularly in disturbed systems where non-natives are able to out-compete native cutthroat trout for resources (USFWS 1995). Of the 40 non-native fish species that currently inhabit historic range of LCT, brown and rainbow trout are the most prevalent. Until five years ago, rainbow trout had been stocked in the Truckee River for recreational fishing. The introduction began in the 1870's by both private and public entities (USFWS 1995). Rainbow and cutthroat trout are both spring spawners, and because they are closely related species they readily hybridize. Due to the abundance and of naturalized rainbow trout in the Truckee Basin, the threat of hybridization is a primary concern for managers.

The Current Project: An initial step in reintroducing LCT is identifying sections of the Truckee River system where the threat of hybridization and competition with rainbow trout is limited. Complete removal of non-native rainbow trout is both controversial and in most cases infeasible. Instead, managers must hope to understand interactions among salmonid species, and in turn realize opportunities for co-existence. The recent appreciation for fish mobility has lead to research on how movement differs among species, populations within a species, and size classes (Schrank and Rahel). One outcome of these studies has been the realization that populations, while occupying the same river basin, may be kept separate due to habitat preference or life history strategies. However, because the restricted movement paradigm has dominated fisheries management for the past 40 years, biologists often attempt to define populations geographically rather than biologically (Young 1995). For example, in attempts to re-populate LCT in the Truckee River managers have chosen to based focus on reaches because of their location rather than choosing reaches based upon ecological condition. Because non-native salmonids are seen as the primary impediment to reintroduction, an understanding of their distribution in the river system, habitat preferences, and movement dynamics will assist managers in the planning and execution of establishing a viable LCT population. In this study I will describe how rainbow trout are moving within the Truckee River system in order to assist managers attempting to reintroduce LCT. These data will provide a baseline for future studies on LCT movement in the Truckee Basin to be compared against. To answer all of the questions concerning rainbow trout movement multiple studies at a range of scales is needed. Here, I have focused on an intermediate scale to quantify: (1) if fish size is related to mobility, (2) if location in the watershed is related to mobility, and (3) and if flow can be used as a predictor of fish movement. The results from this study will provide insights into how non-native fish in the Truckee River respond to local conditions at an individual, patch, and population scale.

Study Introduction

Understanding the movement behavior of inland salmonids has important consequences for the conservation and management of populations. For freshwater trout, movement among habitats is now accepted as the norm rather than the exception (McMahon and Matter 2006). In an applied setting, fish movement behavior has been used as an indicator of river health (Belanger and Rodriguez 2002) and as a guide for sensitive species management (Peterson and Fausch 2003). In the western U.S., the study of fish movement has had particular importance due to the status of native cutthroat trout. Historically, 14 subspecies of cutthroat trout occupied 11 western states. However, due to habitat loss and fragmentation, non-native competition, and overharvest, two cutthroat species are extinct and many are threatened. Limiting further population loss and protecting the genetic integrity of cutthroat species has become a cornerstone of management plans aimed at maintaining and expanding cutthroat populations. Consequent cutthroat research has focused on limiting the interactions with non-native competitors (Harig and Fausch 2000), and identifying and maintaining key contiguous sections of river (Schrank and Rahel 2006, Schmetterling 2001). Isolation management has been employed as a means to protect the genetic integrity of native cutthroat strains, however, this technique has its drawbacks such as inbreeding, elevating the susceptibility to population catastrophes, and fragmenting habitat (Novinger and Rahel 2003). Alternatively, identifying how species use a river and its resources may reveal opportunities for in-stream segregation.

Identifying preferences for temperature, food resources, or spawning habitat may assist in creating sympatric populations of native and non-native fish. The study of movement behavior is one conduit to identifying opportunities for sympatry. On a large scale, seasonal migrations identify critical habitat such as spawning grounds, winter refugia, and summer feeding areas. At a finer scale, short-distance movements are suggestive of habitat preferences such as temperature or feeding location. However, our interpretation of movement behavior may be a reflection of the scale at which we conduct research. (Fausch et al. 2002, Rodriguez 2002). Fausch et al. (2002) have argued that many of the holes in our understanding of riverine fish, including movement, can be filled by applying a landscape approach to river systems. They argue that too often ecologists have limited their research to short fragments of the river, which has lead to an inadequate understand of the ecology of fish and poor management practices. Because it has been assumed that fish stay localized, and because of the difficulties in studying a stream environment, ecologists have often limited their observations and experiments to small study reaches over short time spans. These results are then used to scale-up to the entire river (Fausch et al. 2002). For fisheries managers, the results from these studies do not adequately address the larger scale issues that they most commonly face, such as flow manipulation and invasive species (Fausch et al. 2002). Research should consider how individual behaviors at a micro-scale are linked to watershed-scale population dynamics. The study of movement behavior is one conduit to this link. At a small scale, an individual's decision to stay or move can influence large-scale population dynamics, such as population persistence and connectivity (McMahon and Matter 2006). Additionally, because of the complex life stages of stream fishes and stage specific needs, habitat heterogeneity is necessary for population viability (LePichon et al. 2006).

In this study, I address some of the questions that remain about the movement behavior of stream dwelling trout and to help managers re-establish the extirpated Lahontan cutthroat trout (LCT). There are currently no naturalized reproducing LCT in the Truckee River and its immediate tributaries. LCT historically occupied the entire Truckee River basin, persisting in over 2,000 square miles of interconnected streams and lakes (USFWS 1995). LCT evolved in both high elevation cold water habitats and warmer alkaline lakes, expressing both a migratory and resident life history (USFWS 1995). Resident individuals occupied both tributaries and the main stem Truckee River while migratory fish moved throughout the Truckee Watershed. For both populations, the Truckee River and its tributaries provided spawning and rearing habitat. Connectivity between tributaries, the main stem, and lake habitats is seen as a necessity for the persistence of LCT (USFWS 1995). By examining the movement patterns of non-native trout at multiple scales, this study will provide a baseline comparative data set for future studies on the movement behaviors of LCT in the Truckee River. Here, I investigated the movement behaviors of rainbow trout in the Truckee River, California over a large spatial and temporal scale. Nested within the large scales, movement behaviors were further examined at an individual level and within seasons. These data on the movement behaviors of non-native rainbow trout will assist managers charged with the task of re-establishing a viable population of Lahontan cutthroat trout.

Materials and Methods

Study Area

Naturalized rainbow trout were captured and radiotagged in the upper reaches of Truckee River, California between Lake Tahoe, California and the California/Nevada state line. The Truckee River originates from the northwest shore of Lake Tahoe at an elevation of 6,223' and flows approximately 105 mi before terminating in the endorheic Pyramid Lake, NV (3,810'). River conditions are dominated by high snowmelt flows April through June and low water conditions from late summer to fall (USFWS 2003). Additionally, rain-on-snow events in early spring can cause sporadic high flows. Flows in the Truckee are highly managed; all major inputs to the system, including Lake Tahoe, are controlled by dams. Minimum flows are maintained for water rights in Nevada, however because of the network of reservoirs and dams water flows are managed in such a way that higher reaches of river are often well below minimum flows. Salmonid species in the river include rainbow trout, brown trout, and mountain whitefish (*Prosopium williamsoni*). A number of tributaries are accessible from the main stem Truckee River and may provide seasonal habitat. It is unknown if resident trout move between the main steam and its tributaries, however sampling has shown that multiple age classes of both brown and rainbow trout occupy Donner Creek, Prosser Creek, and Martis Creek.

The study section on the Truckee River was broken into four study reaches based on both access and general river morphology (Table 1). Reach 1, the uppermost reach, begins at Lake Tahoe and extends to the confluence with Donner Creek. Reach 2 encompasses the Truckee downstream of Donner Creek to confluence with the Little Truckee River, below Boca Reservoir. Reach 3 extends from the Little Truckee to the town of Floriston. Below Reach 3, Reach 4 extends to the California/Nevada state line where a series of dams are a barrier to fish movement.

Table 1. Location and river characteristics of the four study reaches.

Reach	Length of Segment (km)	Elevation Range (m)	Average Flow (cfs)[a]
1	22.7	1895-1786	125
2	15.8	1786-1672	196
3	12.5	1672-1616	429
4	10.2	1616-1524	458

[a]Average flow for 2004-2005 was calculated using USGS stream gauges that best represented flow conditions in each study reach. For Reach 2, average flows from major tributaries were added to Truckee River flow to better represent river conditions.

Tagging and Tracking

Between 22 June and 30 September 2004, 39 rainbow trout and 7 brown trout were captured by electrofishing in the main stem Truckee River. Electrofishing was conducted from a raft in deeper reaches and during higher flows, and by foot during low flows. When captured from the raft, fish were held in a live well until a safe take-out location where surgery could be performed was reached. When captured on foot, fish were immediately brought to shore for surgery. When on shore fish were anesthetized in a solution of clove oil and ethanol. Lotek Wireless (www.lotek.com) 6-2 Nanotags (4.5 grams) were surgically implanted intraperitoneally anterior of the pelvic girdle. Each tag emitted a unique signal allowing for individual identification and operated on a 12-hour on/off cycle providing a battery life of ~11 months. Fish were weighed to the nearest gram and measured to the nearest cm (fork length). Tags were limited to <= 4% of the fish’s weight. Brown et al. (1999) and others have shown that tags weighing up to 12% of a fish’s body weight does not negatively affect swimming performance (Adams et al. 1998). Post-surgery, fish were allowed to recover in cooler flushed with freshwater. After regaining equilibrium, fish were released into calm water and watched until they swam away on their own power. Relocations efforts began between approximately 1 week after release and continued every week during the summer months and every-2 weeks during the winter months for the duration of the tags life (n=50 weeks of relocation).

A Lotek SRX 400 receiver attached to a four element Yagi antenna was used to relocate fish. Fish locations were identified by reducing the gain on the receiver while triangulating the signal. Locations were then recorded using a Garmin handheld receiver (spatial accuracy < 40 ft). In order to detect life after periods of no movement, fish were disturbed either by wadding into the river or by throwing rocks. However, this technique did not always provide proof of life; often fish would relocate after not moving during the disturbing effort. If a fish did not move for 218 consecutive days it was presumed dead. This time-span was the longest period where a fish did not move followed by upstream movement.

Data Analysis

From radio telemetry recapture data, the following measures were used to describe the movement behavior of rainbow trout in the Truckee River: (1) turnover; (2) home range; (3) displacement; and (4) total movement. Using these measures, I analyzed the effect of size, location in the watershed, and season on movement behavior.

Turnover rates were used as a basic measure of a fish’s mobility. Turnover rates were calculated as the proportion of new relocation sites relative to the total number of relocations, or the percentage of time a fish was relocated in a new location (Schrank and Rahel 2006). Using turnover rates I analyzed the relationship between mobility and fish size, initial release location, and season. Each fish with at least 3 relocations not including their initial release site was assigned a turnover rate (n=35).

Home range was defined as the extent of a fish's movement for the duration of the study. The distance between the upstream and downstream most re-sight locations were measured using a GIS (ArcView 3.3). When available, distances were measured on a GPS track file from a handheld Gamin receiver obtained while floating the river. In one section of the river a track file was not available; here I used a shape file digitized from a 1:100,000 hydrologic digital line graph (DLG). Again, the effect of fish size on home range was analyzed using regression and differences based on location in the watershed were tested with the non-parametric ANOVA (Kruskal-Wallis). A relationship between home range and turnover was tested using liner regression.

Displacement was measured as the net distance a fish moved over the course of the study. The distances between all of the resight locations for each individual fish were measured to the nearest 10 meters using the same methods followed in the measurement of home range. Upstream movement was recorded as a positive value while downstream movement was recorded as a negative value. Total movement was measured as the sum of the absolute value of all measured movements. Comparisons of total movement and displacement between seasons and location in the watershed were conducted using the Kruskal-Wallis test. Because of the spatial and temporal variability of flows in the Truckee River, seasons were determined using the Truckee hydrograph for the period of the study. For all reaches, spring began at the start of the high flows. Summer began when the spring flows became less variable and experienced a steady decline. Fall and winter were lumped and characterized by stable low flows.

Results

The following results are intended as preliminary findings of trout movement in the Truckee River and to assess the utility of radio telemetry in studying movement behaviors. These results will be used to guide future studies and analyses.

General capture results

A total of 39 rainbow trout and 7 brown trout were implanted with radio tags. One rainbow trout died immediately following surgery. The mortality was attributed to improper anesthesia concentrations. Over the course of the study, there were six confirmed mortalities. Two of the mortalities (1 brown trout and 1 rainbow trout) were caught and kept by anglers. The remaining four were tags recovered from the river the bottom. Nine fish were assumed to have died over the course of the study due to a no detectible movement for 218 days. This time span was chosen as the cutoff for mortality because it was the longest time span a fish did not move followed by upstream movement. The results following only apply to the tagged rainbow trout.

The average turnover rate for fish with at least 3 relocations (n=35) was 0.36 (range, 0.07-0.86) (Figure 1). This indicates that 64% of the time fish were relocated in the same position as previously located. Home range, displacement, and total distance moved were not correlated with the number of resight locations or the total number of days tracked. However, turnover rate was negatively correlated with the number of day tracked ($p < 0.05$, r squared = 0.44) and the number of relocation ($p < 0.05$, r squared = 0.45). The home range of tagged fish, measured as the distance between the upstream and downstream most location, varied greatly between individuals (Figure 2a). The median home range for rainbow trout was 440 m (std. dev. = 1483, range, 10-6434 m). The total distance fish moved during tracking ranged from 50 meters to 9260 meters (Figure 2b). The average was 1934 meters, the median was 610 meters (n=33, SD = 2386). The distance displaced over the course of the study ranged from 0 meters to 6080 meters (Figure 2c). The mean displacement distance was 730 meters, the median 300. (n = 33, SD = 1224). Of the fish with measured displacement distances, 52% had net downstream movement over the course of the study and 42% had a net upstream movement. Despite having moved up to 100 meters, two fish had no net displacement. During spring high flows, a rainbow trout briefly occupied habitat in Martis Creek immediately upstream of the confluence with the main stem. After two weeks, the fish moved back into the Truckee.

Table 2. Median distance moved and displacement of rainbow trout by river reaches.

Reach	Distance (SD)	Displacement (SD)	n
1	310 (3396)	-190 (2245)	9
2	220 (870)	10 (1910)	10
3	1620 (1875)	115 (1041)	15
4	2650 (2295)	-230 (1287)	6

*The distance moved is the sum of the absolute value of all measured movements. Displacement is the sum of all movements where downstream movements were recorded as a negative value.

__Movement and Fish Size__

In three instances the scale that was used to measure fish weight failed, therefore, length was the only parameter used in analyses related to fish size. Due to the weight of the radiotag, only fish over 212 grams were used in the study. The mean length of all tagged fish was 280 cm (SD 62, range 215-460). Reach 1 had the smallest mean length (237 cm, SD 26) while Reach 2 had the largest (307 cm, SD 58). Fish lengths were normalized using a square-root function. Tests for differences among reaches showed that there was a significant difference in fish length between Reach 1 and Reach 2 (ANOVA, d.f.= 38, $p < 0.05$, Bonferroni pairwise comparison).

There was no significant relationship between fish length and turnover rate (n = 32, r-squared = 0.07, $p > 0.05$), home range (ln transformed, n = 33, r-squared = 0.07, $p > 0.05$), or total movement (ln transformed, n = 33, r-squared = 0.11, $p > 0.05$). However, there was significant negative relationship between fish size and displacement (ln transformed, n = 33, r-squared = 0.15, $p < 0.05$).

Movement and Location in the Watershed

An initial test for differences in flow (ln transformed) between the four study reaches showed a significant difference between all reaches except for reach 3 and 4 (ANOVA, Bonferroni comparison, d.f. = 3, $p < 0.05$). Therefore, fish in reaches 3 and 4 were grouped together. When grouped by the three river reaches, there was no significant difference in turnover rate (n = 32, d.f. = 2, $p > 0.05$). However, there was a significant difference in total movement between the three reaches (Kruskal-Wallis test, H = 7.10, d.f. = 2, $p < 0.05$), home range (Kruskal-Wallis test, H = 6.74, d.f. = 2, $p < 0.05$) and displacement (Kruskal-Wallis test, H = 6.56, d.f. = 2, $p < 0.05$). In all cases, no pair-wise contrasts proved to be significant ($p > 0.05$). During the late summer and early fall of 2004 water levels dropped to uncharacteristically low levels. In particular, Reach 1 suffered from dewatering and high water temperatures. Of the ten fish tagged in Reach 1, six were either confirmed or assumed dead by the end of the dewatering period. Two of the remaining four moved downstream to reaches with a more steady input from tributaries during the low water period.

Movement and Season

Seasons were dictated by the hydrography of the Truckee River. The summer months spanned July through September. The winter months included October through March and the spring season was April through June. Total movement, displacement, and turnover rate was grouped according to the season the movement occurred in. There was no significant difference in the displacement of fish between the three season (Kruskal-Wallis test, $H = 3.58$, d.f. = 2, $p > 0.05$). There was, however, a significant difference in the total movement between the three seasons (Kruskal-Wallis test, $H = 9.65$, d.f. = 2, $p < 0.05$), where summer and winter movements were greater than during the spring (Bonferroni comparison, $p < 0.05$). Also, turnover varied significantly between the three seasons (ANOVA, d.f. = 2, $p < 0.05$) where summer rates were significantly larger than springs rates (Bonferroni comparison, 95% CI).

Figure 1. The frequency of turnover rates measured for rainbow trout over the duration of the study.

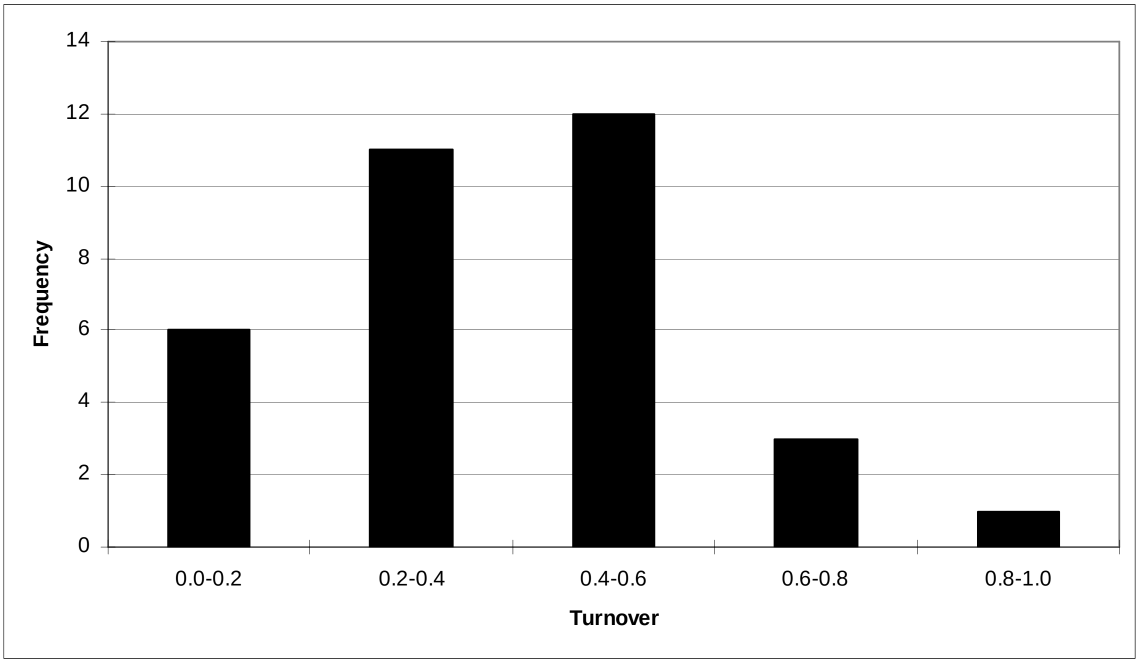
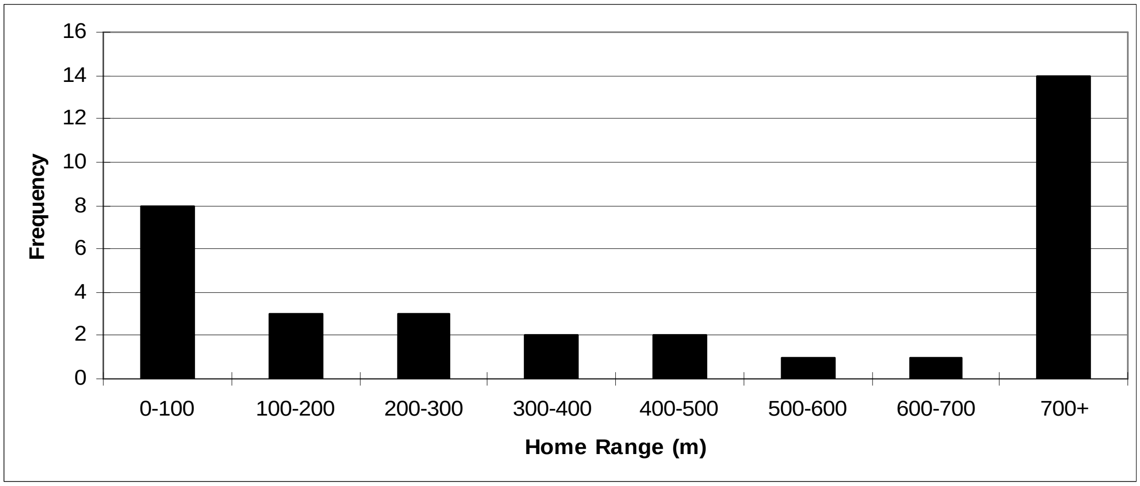
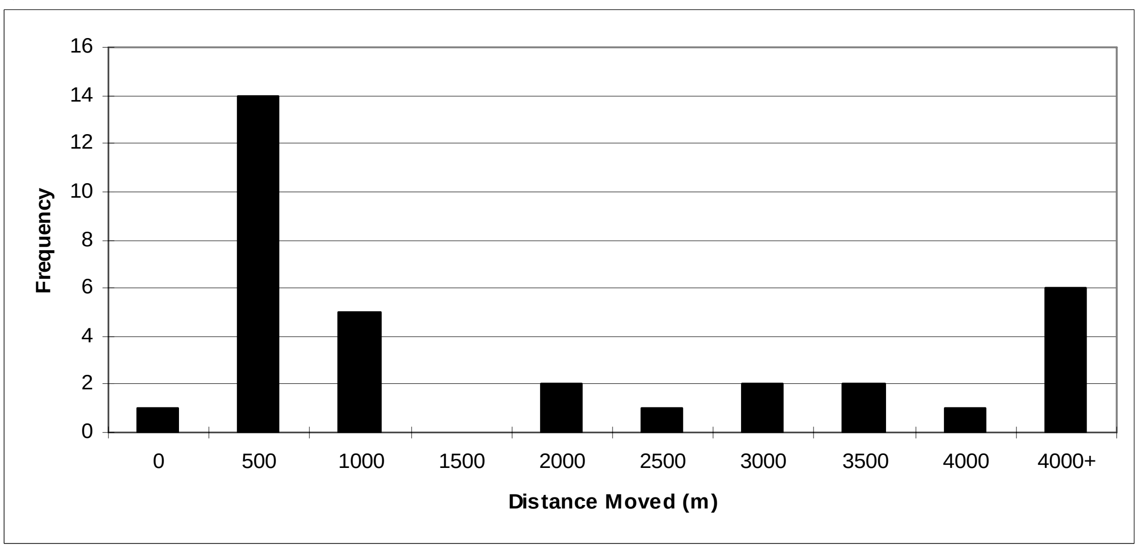


Figure 2. The frequency of the (a) home range, (b) total movement, and (c) displacement distance of rainbow trout. Home range was measured as the distance between the upstream-most and downstream-most relocation. The total distance was the absolute value of all movements summed. Displacement was measured as the net movement of fish over the duration of the study, where downstream movements were recorded as negative values.

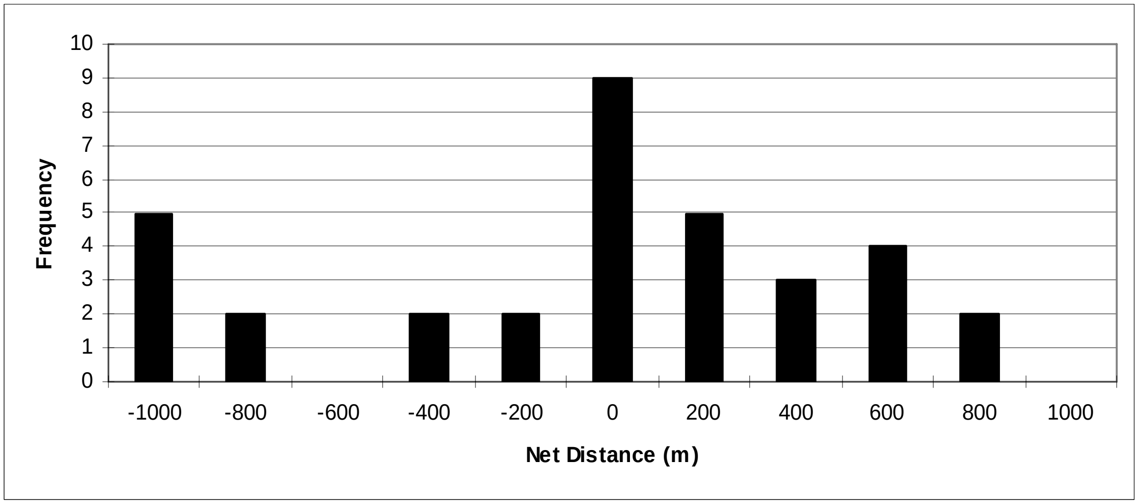
a)



b)



c)



Discussion

Collectively, tagged rainbow trout exhibited a wide range of movement behaviors. Fish size, location in the watershed, and season were all significant factors in influencing movement. Turnover rates were comparable with other studies on inland salmonids including cutthroat trout (Shrank and Rahel 2006, Hilderbrand and Kershner 2000) brook trout (Gowan and Fausch 1996), and brown trout (Heggenes 1988).

Turnover rates, or side fidelity, have often been used as a measure of fish mobility, however, used alone they can be a misleading measure of movement behavior. In this study, when fish did move, they occasionally moved long distances. These long-distance movements, while not as common, may be an important adaptive behavior. The ability to move in response to stochastic events is crucial to population persistence. There are two competing views on the relative fitness advantages of site fidelity versus mobility. In one view, mobile fish are seen as inferior and unable to hold advantageous positions in the river (Nakamura et al. 2002). These fish are often assumed to be smaller or of a less aggressive species. At a regional scale, sedentary behaviors would be advantageous in system where environmental fluctuations are synchronized, such as in rivers (Vannote et al. 1980). In this study, larger fish did have lower turnover rates, supporting the view that sedentary fish are the superior individuals in a population. However, a study on Bonneville cutthroat trout found similar results (larger fish moved less) but drew very different conclusions (Shrank and Rahel 2006). Here, the researchers were able to recapture tagged fish and found that the larger, more stationary fish were in poorer condition than smaller mobile fish. They proposed that during low flow conditions larger fish had fewer habitat options and were forced to remain in the deepest pools even if food levels declined. In this case, mobility may not necessarily be a disadvantage. If a watershed has connected reaches with different qualities, mobile fish may be better suited to take advantage of unequally distributed resources.

Some researchers have suggested that a population may consist of both mobile and sedentary individuals. For example, two life histories are evident in anadromous rainbow trout, where some individuals migrate to the sea while others remain as residents. If, in inland streams, a percentage of individuals were predisposed to movement the population would fair better in the face of environmental fluctuation, while during stable periods those individuals predisposed to not moving would fair better and in turn help maintain a healthy population. In this study, histograms of total movement, displacement, and home range do suggest a bimodal distribution of movement lending support to the idea that two types of fish, 'movers' and 'stayers', exist within a population (Figure 2). Yet, a continuum of intermediate movement is also evident, and no significant relationship exists between turnover rate and distances moved as might be expected if two types of movement behaviors existed. At the individual level it remains unclear whether the behaviors are a true dichotomy, or more flexible depending on conditions at the reach scale.

The differences in movement behavior observed between reaches may indicate that resources are not uniformly distributed in the Truckee River. Models of fish movement have been shown to be an accurate predictor of habitat and water quality (Belanger and Rodriguez 2004). In this study, the downstream-most reaches had more consistent and the high average flow. In Reach 3/4 (the downstream most reach), fish were the most mobile; they had the largest displacement distance, total movement, and home range. Conversely, in Reach 1 (the upstream most reach), fish had the highest turnover rate and the shortest distances moved. These results could be interpreted in a number of ways. For instance, a highly mobile population could be an indicator of poor habitat conditions. In this case, fish are forced to move in order to find food sources or avoid poor habitat conditions, such as high temperatures or turbidity. Alternatively, a mobile population could also be an indicator of a healthy watershed with interconnected reaches allowing fish to select the most beneficial habitat. In the Truckee River, both cases seemed to exist over the duration of the study. A dry summer resulted in low water conditions throughout the river, particularly in Reach 1, where Lake Tahoe levels dropped below the lip of the dam. Riffles between pools became barriers to movement and water temperatures rose above 25 degrees Celsius in pools. These poor habitat conditions could explain the high turnover rates (actively seeking better habitat) with low total distances moved (both chemical and physical barriers to movement). In Reach 3/4, the high movement distances with lower turnover rates could be indicative of fish freely moving or staying depending on current conditions. However, these large movement figures could also be a reflection of simple geomorphic differences between the upper and lower watershed, i.e. habitat units are larger downstream compared with upstream. For example, downstream fish need to travel longer distances when moving from one pool to another. From a landscape perspective, the restricted movement of fish in Reach 1 was undoubtedly a reflection of poor habitat conditions. Of the 10 tagged fish in the Reach, 3 moved downstream below Donner Creek, the remaining 6 were confirmed mortalities.

There were no obvious migrations during the spawning season. In fact, fish were more active during the summer months than in spring, and fish moved greater distances in both the summer and winter compared with spring. The spring season was the shortest season, however turnover rate was negatively correlated with time and relocation. Similar patterns were observed in studies on cutthroat trout, where the frequency of movement was highest in July, after the spring runoff (Hilderbrand and Kershner 2000, Young 1995, Young et al. 1997). The flow in the Truckee is highly managed, however it does retain a natural pattern. For the Truckee, a true spring (or fall) spawning migration that is typically associated with trout may not be applicable. A spawning migration implies a directional, long distance movement to a separate habitat for the purpose of reproducing. In the Truckee, rainbow trout are well populated throughout the system; there are no locations not occupied during the year. Also, trout often use tributary streams for spawning (Schmetterling 2001), however nearly all of the tributaries to the Truckee have dams short distances upstream from the main stem. Furthermore, water releases from the reservoirs are highly variable depending on storage and demands downstream. It instead seems more likely that rainbow trout in the Truckee are opportunistic and spawn locally. As non-natives, some of whom are the progeny of hatchery reared fish, they may not have, or yet developed, natal spawning locations. Future studies specifically aimed at capturing spawning activity are needed to better describe the breeding behavior of trout in the Truckee River.

A parallel goal to describing the movement behaviors of rainbow trout was to assess radio telemetry as method for studying fish behavior and to evaluate its utility as a tool in the management of non-native trout in the Truckee River. As a tool, telemetry has greatly expanded our understanding of fish movement behavior. Previous studies using mark-recapture provided only a snapshot of an individual's life history. Now, we are able to directly monitor an individual's interactions with its environment. However, radio telemetry is not without its limitations, many of which were evident in this study. First, tag size limits our studies to only a segment of the population. In this study, we chose larger tags for their long battery lives over short lived tags that would have allowed us to include smaller fish. Yet, it is this segment of the population that might have the most interesting movement behaviors. How far age 0+ trout disperse from their emergence location has important implications for population expansion and invasion; both critical in the management of a non-native species. A second tradeoff made in this study was the scale at which we monitored fish. By tagging fish over a nearly 50 kilometer section of river, we were able to assess differences in movement behavior throughout the watershed. While this provided valuable insight into how the managed flows in the Truckee River affect movement, we were less able to accurately measure fine scale movement and habitat selection. For example, some researchers have used smaller scale, controlled studies to look at the interaction between cutthroat and non-native trout (Shemai et al. 2007). I believe this is a gap that if filled would greatly assist managers tasked with managing the re-introduction of Lahontan cutthroat trout. Lastly, while the results of this study are suggestive of patterns, further analyses are needed to untangle the effect of interacting factors. For example, Reach 2 had the lowest average movement number as well as the largest fish. An analysis that includes multiple factors will help determine if size is more important than location in the watershed, or if seasons effect locations differently.

Literature Cited

Adams, N. S., D. W. Rondorf, S. D. Evans, and J. E. Kelly. 1998. Effects of surgically and gastrically implanted radio transmitters on growth and feeding behaviour of juvenile chinnook salmon. Transactions of the American Fisheries Society 127:128-136.

Bélanger, G., and M.A. Rodríguez. 2002. Local movement as a measure of habitat quality in stream salmonids. Environmental Biology of Fishes 64:155-164.

Bernard, D.R. and E.K. Israelsen.. 1982. Inter- and intrastream migration of cutthroat trout (*Salmo clarki*) in Spawn Creek, a tributary of the Logan River, Utah. Northwest Science 56:148-157.

Bjornn, T.C., and J. Mallet. 1964. Movement of planted and wild trout in an Idaho river system. Transaction of the American Fisheries Society 93:70-76.

Bohlin, T., Sundstrom, L.F., Johnson, J.I., Hojesjo, J., and J. Pettersson. 2002. Density -dependent growth in brown trout: effects of introducing wild and hatchery fish. Journal of Animal Ecology 71(4):683-695.

Brown, R.S. 1999. Fall and early winter movements of cutthroat trout, Oncorhynchus clarki, in relation to water temperature and ice conditions in Dutch Creek, Alberta. Environmental Biology of Fishes 55:359-368.

Brown, R.S., Cooke S.J., Anderson, W.G., and R.S. McKinley. 1999. Evidence to challenge the "2% Rule" for biotelemetry. North American Journal of Fisheries Management 19:867-871.

Brown, R.S. and W.C. Mackey. 1994. Spawning ecology of cutthroat trout (*Oncorhynchus clarki*) in the Ram River, Alberta. Canadian Journal of Fisheries and Aquatic Science 52:983-992.

Bunnell, D.B., Isely, J.J, Burrell, K.H., and D.H. Van Lear. 1988. Diel movement of brown trout in a southern Appalachian river. Transactions of the American Fisheries Society 127:630-636.

Crisp, D.T. and M.A. Hurley. 1991. Stream channel experiments on downstream movement of recently emerged trout, *Salmo trutta* L. and salmon, *S. salar* L.—I. Effect of four different water velocity treatments upon dispersal rate. Journal of Fish Biology 39:347–361.

Daufresne, M., Capra, H., and P. Gaudin. 2005. Downstream displacement of post-emergent brown trout: effects of development stage and water velocity. Journal of Fish Biology 67:599-614.

Dunham, J.B., Vinyard, G.L., and B.E. Rieman. 1997. Habitat fragmentation and extinction risk of Lahontan cutthroat trout. North American Journal of Fisheries Management 17:1126-1133.

Dunham, J.B. and B.E. Rieman. 1999. Metapopulation structure of bull trout: influences of physical, biotic, and geometrical landscape characteristics. Ecological Society of America 9:642-655.

Fausch, K.D., Torgersen, C.E., Baxter, C.V., and H.W. Li. 2002. Landscapes to riverscapes: bridging the gap between research and conservation of stream fishes. Bioscience 52:483-495.

Garshelis, D. 2000. “Delusions in Habitat Evaluation.” In Boitani and Fuller (Eds.) *Research Techniques in Animal Ecology pp. 111-164.*

Grant, J.W.A. and D.L.G. Nokes. 1987. Mover and stayers: Foraging tactics of young-of-the-year brook charr, *Salvelinus fontinalis*. Journal of Animal Ecology 56:1001-1013.

Grossman, G.D., Hill, J., and J.T. Petty. 1995. Observations on habitat structure, population regulation, and habitat use with respect to evolutionarily significant units: a landscape perspective for lotic systems. American Fisheries Society Symposium 17:381-391.

Gerking, S.D. 1959. The restricted movement of fish populations. Biological Review 34:221-242.

Gowan, C. and K.D. Fausch. 1996. Mobile brook trout in two high-elevation Colorado streams: re-evaluating the concept of restricted movement. Canadian Journal of Fisheries and Aquatic Science 53:1370-1381.

Gowan, C., Young, M.K., Fausch, K.D., and S.C. Riley. 1994. Restricted movement in resident stream salmonids: a paradigm lost? Canadian Journal of Fisheries and Aquatic Science 51:2626-2637.

Hanski, J. and M. Gilpin. 1991. Metapopulation dynamics: brief history and conceptual domain. Biological Journal of the Linnean Society 42:3-16.

Harig, A.L. and K.D. Fausch. 2000. Factors influencing success of greenback cutthroat trout translocations. North American Journal of Fisheries Management 20:994-1004.

Heggenes, J. 1988. Physical habitat selection by brown trout (Salmo trutta) in riverine systems. Nordic Journal of Freshwater Research 64:74-90.

Hilderbrand, R.H. and J.L. Kershner. 2000. Movement patterns of stream-resident cutthroat trout in Beaver Creek, Idaho-Utah. Transactions of the American Fisheries Society 129:1160-1170.

Hughes, N.F. 2000. Testing the ability of habitat selection theory to predict interannual movement patterns of a drift-feeding salmonid. Ecology of Freshwater Fish 9:4-8.

Le Pichon, C., Gorges, G., Boet, P., Baudry, J., Goreaud, F., and T. Faure. 2006. A spatially explicit resource-based approach for managing stream fishes in riverscapes. Environmental Management 37:322-335.

Lonrarich, D.G., Lonrarich, M.R. and M.L. Warren. 2000. Effects of riffle length on the short-term movement of fishers among stream pools. Canadian Journal of Fisheries and Aquatic Science 57:1508-1514.

McMahon, T.E. and W.J. Matter. 2006. Linking habitat selection, emigration and population dynamics of freshwater fishes: a synthesis of ideas and approaches Ecology of Freshwater Fish 15:200–210.

Morita, K. and S. Yamamoto. 2002. Effects of habitat fragmentation by damming on the persistence of stream-dwelling charr populations. Conservation Biology 16:1318-1323

Nakamura, T. Maruyana, T., and S. Watanabe. 2002. Residency and movement of stream-dwelling Japanese charr, *Salvelinus leucomaenis,* in a central Japanese mountain stream. Ecology of Freshwater Fish 11:150-157.

Neville, H.M., Dunham, J.B. and M.M. Peacock. 2006. Landscape attributes and life history variability shape genetic structure of trout populaitons in a stream network. Landscape Ecology 21:901-916.

Novinger, C.D. and J.F. Rahel. 2003. Isolation management with artificial barriers as a conservation strategy for cutthroat trout in headwater streams. Conservation Biology 17:772–781.

Peterson, D.P. and K.D. Fausch. 2003. Upstream movement by nonnative brook trout (Salvelinus fontinalis) promotes invasion of native cutthroat trout (Oncorhynchus clarki) habitat. Canadian Journal of Fisheries and Aquatic Sciences 60:1502-1516.

Ray, C., Peacock, M., and J.B. Duhnam. 2000. Population structure and persistence of Lahontan cutthroat trout: results from a comparative study of isolated and networked streams. Report to U.S. Fish and Wildlife Service, Reno, NV.

Rieman, B.E. and J.B. Dunham. 2000. Metapopulations and salmonids: a synthesis of life history patterns and empirical observations. Ecology of Freshwater Fish 9:51–64.

Rincon, P.A., Hughes, N.F., and G.D. Grossman. 2000. Landscape approaches to stream fish ecology, mechanistic aspects of habitat selection and behavioral ecology. Introduction and commentary. Ecology of Freshwater Fish 9:1-3.

Rodriguez, M. A. 2002. Restricted movement in stream fish: the paradigm is incomplete, not lost. Ecology 83:1-13.

Schlosser, I.J. 1995a. Dispersal, boundary processes, and trophic-level interactions in streams adjacent to beaver ponds. Ecology 76:908-925

Schlosser, I.J. 1995b. Critical landscape attributes that influence fish population dynamics in headwater streams. Hydrobiologia 303:71-81.

Schmetterling, D.A. 2001. Seasonal movements of fluvial westslope cutthroat trout in the Blackfoot River drainage, Montana. North American Journal of Fisheries Management 21:507-520.

Schrank, A. J., and F. J. Rahel. 2006. Factors influencing summer movement patterns of Bonneville cutthroat trout (*Oncorhynchus clarkia utah)*. Canadian Journal of Fisheries and Aquatic Sciences 63:660-669.

Shemai, B., R. Sallenave, and D.E. Cowley. 2007. Competition between hatchery-raised Rio Grande cutthroat trough and wild brown trout. North American Journal of Fisheries Management 27:315-325.

Skalski, G.T., J.F. and Gilliam. 2000. Modeling diffusive spread in a heterogeneous population: a movement study with stream fish. Ecology 81:1685-1700.

Smithson, E.B. and C.E. Johnston. 1998. Movement patterns of stream fishes in a Ouachita highlands stream: an examination of the restricted movement paradigm. Transactions of the American Fisheries Society 128:847-853.

Solomon, D.J. and R.G. Templeton. 1976. Movements of brown trout Salmo trutta L. in a chalk stream. Journal of Fish Biology 9:411-423.

USFWS (U.S. Fish and Wildlife Service). 1995. Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*) recovery plan. Portland, Oregon.

Vannote, R.L., G. W. Minshall, K. W. Cummings, J.R. Sedell, and E. Gushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Science 37: 130-137

Young, M.K. 1995. Resident trout and movement: consequences of a new paradigm. Fish Habitat Relationship Technical Bulletin number 18.

Young, M.K., R.B. Rader, and T.A. Belish. 1997. Influence of macroinvertebrate drift and light on the activity and movement of Colorado River cutthroat trout. Transactions of the American Fisheries Society 126:428-437.

Young, M.K., and A.L. Harig. 2001. A critique of the recovery of greenback cutthroat trout. Conservation Biology 15:1575-1584.