Movement of Resident Rainbow Trout

Movement in Response to Temperature, Flow, Management Zone and Weirs in the Kings River Below Pine Flat Dam

Kings River Fisheries Management Program

Kings River Fisheries Management Program
April 2012

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ABSTRACT

Two hundred and fifty-nine adult rainbow trout implanted with radio transmitters were released into the Kings River tailwater fishery between October 2005, and January 2008 (KRFMP 2005, unpublished; KRFMP, 2009b, unpublished). Both small (227g – 907g) and large (907g or greater) trout were released in seven groups. The release sites were partitioned across two regulatory management zones and an exclusion zone as well as three irrigation demand periods replicated over two water years. The focus of our study was to determine if size-class, flow, temperature change or anthropogenic barriers (weirs) affected the movement of resident rainbow trout.

Results showed that the study population contained both sedentary and mobile trout. Trout were observed having traveled total distances ranging from a minimum of 0m to a maximum of 30,195m; upstream, downstream or a combination of both. No correlation was found amid dependent variables; direction, rate, or distance moved with independent variables; size class, water temperatures or flow, indicating that trout were not displaced from the fishery by changes in seasonal discharge. In addition, three of the five diversion weirs evaluated did not present an upstream obstacle to study trout of either size class. In all, no determinate cause for trout movement or relocation was identified among the tested variables.

1.0 INTRODUCTION

Salmonid movement refers to the distance traveled by an individual or group away from a stocking point or home range. A home range is defined as "that area traversed by the individual in its normal activities of food gathering, mating and caring for young" (Rogers and White, 2007; Burt, 1943). The movement of stream dwelling fish can be an important consideration when examining salmonid life history strategies. Movement to more suitable habitat may accompany the onset of changing environmental conditions such as discharge, temperature, disturbance, abundance of food, competition etc. (Pearson, 2005). In addition, movement of resident stream fish has profound implications for research (e.g., measuring production and habitat models) and management (e.g., habitat enhancement, special regulations and stocking hatchery fish.) (Gowan et al., 1994).

In accordance with the Kings River Fisheries Management Program (KRFMP) Framework Agreement, analyzing the movement of resident rainbow trout (*Oncorhynchus mykiss*) is pertinent to "determining the health and status of the fishery in the Kings River below Pine Flat Dam" as indicated by Program Element (k) *Development of Criteria/Monitoring*. The examination of this data also falls in logical progression with achieving the multi-species aquatic resource goals described in Exhibit A(i)(ii). In order to better understand the environmental effects of our current management strategies, the objectives of this study are to: 1) determine how trout size (large or small) effects movement, 2) determine the effects of varying seasonal flow on trout movement, 3) determine the effects of water temperature on trout movement, and 4) determine the effects of management zones on movement. The null hypothesis maintaining that the above factors have no effect on the movement of the study trout.

In addition, we proposed to examine the effects of anthropogenic barriers on trout movement. With the realization that examining the impacts of weirs on trout migration was beyond the capabilities of this study, we presented only a brief descriptive analysis. Trout residence time and habitat selection were also examined and presented independently at an earlier date (See: KRFMP, (2010); unpublished and KRFMP, (2011); unpublished).

2.0 STUDY AREA

The tailwater fishery created by the Pine Flat Dam is approximately 20km (12.3miles) long (Figure 1). Two regulatory management zones and an "Exclusion" zone exist between Pine Flat Dam and the Highway 180 Bridge. The Exclusion zone is located between Pine Flat Dam and the Army Corps of Engineers (ACOE) Bridge and is approximately 0.8km long. The ACOE Bridge stands atop of a small weir and marks the beginning of the tailwater fishery. The Put and Take zone, located between the ACOE bridge and the Cobbles (Alta) Weir, is approximately 8km long, and the Catch and Release zone, located between Cobbles Weir and the Highway 180 Bridge, is approximately 11km long.

Gould Weir, Dennis Weir and Fresno Weir are located within the Catch and Release management zone. Fresno Weir is the southernmost; standing 6.3km down the main channel from Cobbles Weir. The River abuts both private properties and public access areas.

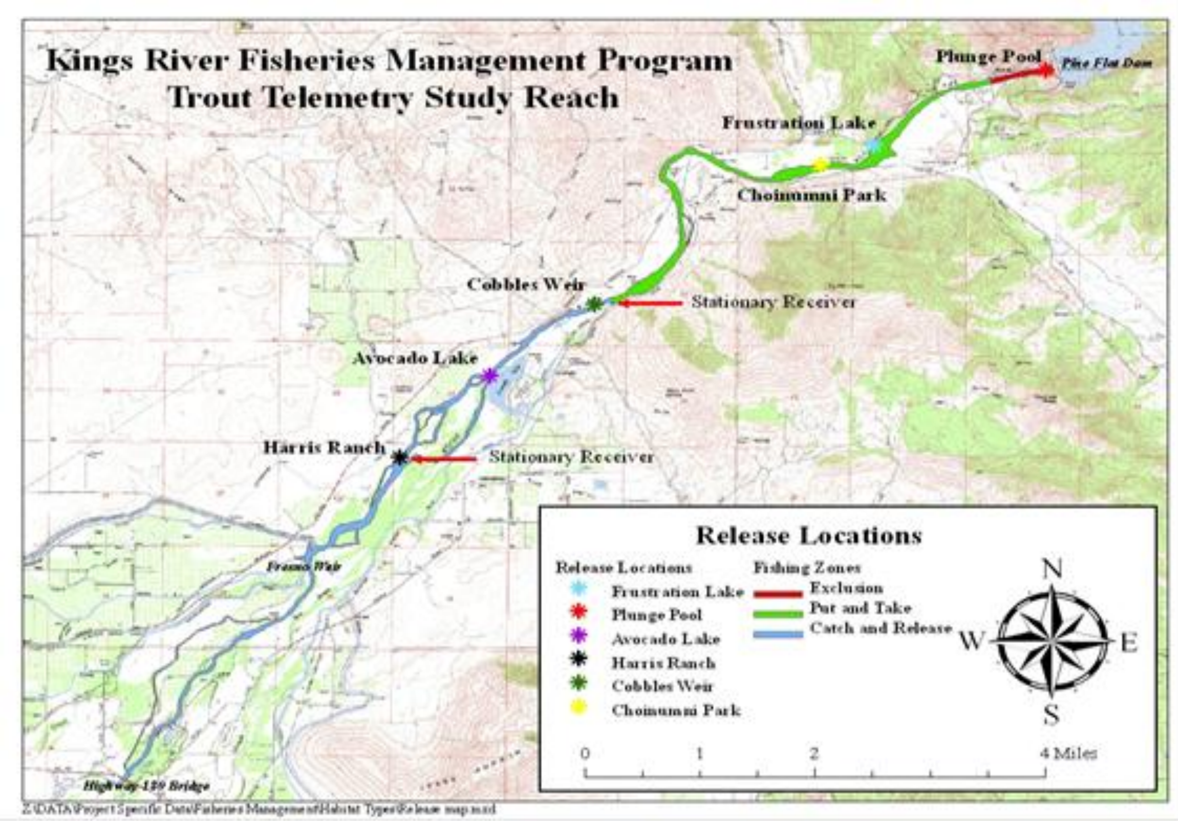


Figure 1: Tailwater fishery created by the Pine Flat Dam in eastern Fresno County. Two regulatory zones and an Exclusion zone are present in the study reach of the Kings River; Exclusion (red), Put & Take (green), and Catch & Release (blue).

3.0 METHODS

Two hundred and fifty-nine trout implanted with radio transmitters were released into the tailwater fishery between October 2005, and January 2008 (KRFMP 2005, unpublished; KRFMP, 2009b, unpublished). Due to the difficulty obtaining an adequate number of suitable sized “wild” trout directly from the river, 94% of the study trout were provided by the San Joaquin River Fish Hatchery. Each release group consisted of approximately forty trout. Release locations were stratified across the regulatory management zones in an effort to study the effects of the zones on movement of rainbow trout below Pine Flat Dam. Release timing corresponded with seasonal changes in stream flow conditions. More specifically, groups one and four were released during early non irrigation demand; groups two, five and seven were released in the late non irrigation demand period (just before flows increased) and groups three and six were released during irrigation demand (high flow period).

Daily flows measured in cubic feet per second (cfs) were obtained from records provided by the Kings River Water Association (KRWA). Hourly measurements of river temperature were recorded by Ryan temperature sensors located at the ACOE Bridge, Cobbles Weir and Fresno Weir. Water temperatures were summarized by mean daily temperature within each management zone. Put and Take zone temperatures were taken from the ACOE Bridge and Cobbles weir. Catch and Release zone temperatures were collected at Cobbles Weir and Fresno Weir. These temperatures were recorded in conjunction with flow data and corresponding dates of observed movement. In all, nine-hundred eighty-eight temperature days were recorded, excluding four days where the Ryan sensor was off-line at the ACOE Bridge.

Releases occurred at five locations along the Kings River. Two release sites were located in the Put and Take zone, and three release sites were located in the Catch and Release zone. Use of the Plunge Pool release site (located within the Exclusion zone) was discontinued after the second release. The decision to discontinue use of this site was made when it became evident that trout were not dispersing from this space into the study area in a manner similar to that observed at the other release sites. It was also determined that the Plunge Pool was not representative of the of the study reach, since trout could only move in a downstream direction. Use of the Frustration Lake release site (Put and Take zone) was discontinued after a single release due to the rapid disappearance of study trout. Fifty percent (5 of 10) of the trout released at this location went missing overnight and were never located. Finally, use of the Avocado Lake release site (Catch and Release zone) was discontinued after only a single release of two trout during the second round of releases. An attempt was made to utilize resident trout caught at this location however, all but two trout caught at this location exhibited signs of having been in a hatchery. Further attempts to catch resident trout were discontinued (KRFMP, 2010, unpublished). Data collected from the Avocado Lake release site and Plunge Pool were included in the summary analysis but Plunge Pool trout were excluded from the statistical analysis due to the non-representative nature of the release site as previously described.

Table 1: - Experimental design for stratified release groups (ENID = early non-irrigation demand, LNID = late non-irrigation demand, ID = irrigation demand).

Release Schedule for Telemetry Trout										
				Exclusion	Put & Take		Catch & Release			
Release Group	Release Month	Irrigation Demand	Size	Plunge Pool	Choinumni	Frustration Lake	Alta Weir	Avocado	Harris	Planted
1	October '05	ENID	Large = 18	4	0	5	9	0	0	n = 38
			Small = 20	6	0	5	9	0	0	
2	February '06	LNID	Large = 18	5	3	0	4	2	4	n = 38
			Small = 20	3	5	0	6	0	6	
3	June '06	ID	Large = 18	0	5	0	6	0	7	n = 36
			Small = 18	0	5	0	7	0	6	
4	October '06	ENID	Large = 17	0	5	0	5	0	7	n = 32
			Small = 15	0	4	0	5	0	6	
5	December '06	LNID	Large = 18	0	5	0	7	0	6	n = 38
			Small = 20	0	7	0	7	0	6	
6	June '07	ID	Large = 18	0	6	0	7	0	4	n = 37
			Small = 19	0	7	0	6	0	6	
7	January '08	LNID	Large = 20	0	5	0	7	0	8	n = 40
			Small = 20	0	8	0	5	0	7	

Trout positions were recorded via two stationary radio telemetry receivers and mobile receivers operated by an observer. The mobile receivers were equipped with GPS (see Equipment Selection paper; KRFMP, 2009a, unpublished). Attempts were made to relocate each study trout twice in a seven-day period. Once located, a bearing was recorded along the transect perpendicular to the trout's position and a digital photograph was taken for future reference. Additionally, upstream and downstream bearings were recorded when possible. Location of the seasonal observer was automatically recorded via the GPS receiver integrated in the radio receiver. Environmental data (i.e. habitat type, presence of terrestrial vegetation, etc…) were recorded on a standardized field data sheet (KRFMP, 2010, unpublished).

Using the telemetry data, a point location map was produced in ArcMap. This was accomplished by placing the layer of point observations over a scaled base map as a feature class. The attribute table was referenced to identify and isolate individual trout and the (ArcMap) measuring tool was used to measure the distance in meters moved between points. The first measurement taken for each trout was the distance moved away from its stocking point, with each successive movement measured independently. Movements less than 10meters up or down stream were considered negligible and were excluded from the statistical data. The dates, distances and direction (Longitudinal: upstream/downstream or Lateral: instream/outstream) moved for each individual fish were retrieved from the table and documented accordingly. By isolating the individual locations of study trout we were also able to identify which trout crossed upstream over weirs and on which dates.

4.0 ANALYTICAL PROCEDURES

Descriptive statistics were used to describe the movement habits of resident trout, including minimum, maximum and mean distance and dispersal rate. Movements across diversion structures (i.e. weirs and canal head gates) were also quantified, however data collected from the weir sites was insufficient for use in statistical analysis.

Due to the non-normal distribution of our sample population, the Wilcoxon Signed-rank test was used to test for significance ($P \leq 0.05$). Longitudinal movements were chosen as the nominal variables, and tested separately with flow, temperature, size class and management zones. This was later repeated using lateral movements as the nominal variables and flow as the measurement variable. Lateral movements were defined as instream (toward river center), outstream (toward river bank) or equivalent (an equal location opposite the river midline). Flow was divided into three classes: < 249cfs, 250 – 999cfs, and >1,000cfs. Temperature was divided into four classes: < 11^{o}C, 11^{o}-14.9^{o}C, 15^{o}-18^{o}C (optimal) (Moyle, 2002) and >18^{o}C. Two size-classes were tested; Large (907g or greater) and Small (227g to 906.9g) and two management zones were tested; “Catch and Release” and “Put and Take”.

5.0 RESULTS

Trout frequently swam both up and down stream; with many also observed changing lateral position within the river. The mean upstream distance was 291 meters (955 feet) and the mean downstream distance was 360 meters (1,181 feet). Total distance traveled by an individual trout ranged from a minimum of 0m to a maximum of 30,195m (18.8 miles). Of the 259 tagged trout 69% (180 trout) moved greater than 10m (33 feet) from their release point. The mean dispersal rate of greater than 10m was ten days.

Throughout the study discharge from Pine Flat Dam ranged from 100cfs to 13,322cfs. Although trout were generally mobile, rates of discharge had no significant effect ($p > 0.050$) on longitudinal or lateral movements of study trout (Tables 2-3). When analyzed by release group no significant differences appeared amongst groups with the exception of group 5 which had a p-Value of 0.050 (Table 4).

In the Put and Take zone, mean daily water temperature was 12.5^{o}C. Of the 985 days measured 152 (15 %) of those days fell within the optimal range for trout growth and 750 (77 %) of those days were in the suboptimal range. Temperature did not significantly effect ($p > 0.050$) the upstream or downstream movement of resident rainbow trout (Table 5) (Appendix).

In the Catch and Release zone, mean daily water temperature was 12.7^{o}C. Of the 988 days measured within the zone 147 (15 %) of those days fell within the optimal range for trout growth and 764 (77 %) of those days were in the suboptimal range. Temperature did not significantly effect ($p > 0.050$) upstream or downstream movement of resident rainbow trout (Table 5) (Appendix).

The results of size class were analogous to those above with no significant distinction made between the longitudinal movements of large and small trout in relation to water temperature (Table 6).

Although fishing pressure is present throughout the year, fishing management zones also had no significant effect ($p > 0.050$) on the movement of resident rainbow trout (Table 7).

Table 2: - Effects of flow on upstream/downstream trout movement (m)

LONGITUDINAL MOVEMENT & FLOW				
Flow (cfs)	**n**	**Days**	**Observations**	**Significance**
< 250 cfs	48	154	114	P = 0.473
≥ 250 - ≤ 999 cfs	115	553	377	P = 0.576
≥ 1,000 cfs	152	396	773	P = 0.378

Table 3: - Effects of flow on instream/outstream movement (m)

LATERAL MOVEMENT & FLOW				
Flow (cfs)	**n**	**Days**	**Observations**	**Significance**
< 250 cfs	21	154	63	P = 0.680
≥ 250 - ≤ 999 cfs	58	553	152	P= 0.525
≥ 1,000 cfs	91	396	430	P=0.229

Table 4: - Effects of flows on trout movement (m) by release group

MOVEMENT by RELEASE GROUP		
Release Group	**n**	**Significance**
Group 1	38	P = 0.456
Group 2	38	P = 0.619
Group 3	36	P = 0.517
Group 4	32	P = 0.437
Group 5	38	P = 0.050
Group 6	37	P = 0.565
Group 7	40	P = 0.736

Table 5: - Effects of temperature on trout movement (m)

TEMPERATURE & MOVEMENT					
	Days				
Temperature ºC	**P&T**	**C&R**	**n**	**Observations**	**Significance**
< 11	428	352	112	673	P = 0.656
11 - 14.9	332	412	101	323	P = 0.383
15 - 18	152	147	98	234	P = 0.111
>18	76	77	15	28	P = 0.195

Table 6: - Effects of size class on trout movement

MOVEMENT BY SIZE CLASS		
Size Class	**n**	**Significance**
Large	110	P = 0.138
Small	87	P = 0.153

Table 7: - Effects of management zone on trout movement (m)

MANAGEMENT ZONE & MOVEMENT		
Zone	**n**	**Significance**
Put & Take	75	P = 0.919
Catch & Release	165	P = 0.922

Twenty-one trout were documented as having crossed a weir in an upstream direction at least once during the study. Of these, one small trout and six large trout crossed over the ACOE weir into the Exclusion zone. Three small trout and eight large trout crossed Cobbles (Alta) Weir and three large trout crossed Dennis Weir. No trout were documented migrating upstream of Gould Weir, however it was observed that during high flows some trout were able to bypass the weir via the Avocado split or the Harris Ranch confluence. No trout were documented crossing Fresno weir in an upstream direction.

6.0 DISCUSSION

Rainbow trout in this study demonstrated behaviors analogous to trout in similar studies on other rivers (Burrell et al. 2000; Hilderbrand and Kershner, 2000; Gowan et al. 1994). Most individual trout in mark-recapture experiments typically remain near the point of first capture, however a variable percentage is also known to disperse (Hilderbrand and Kershner, 2000). Although previously dismissed, this trend in dispersal has been observed in multiple reports since 1958 (Gowan et al, 1994). Many resident trout populations contain both sedentary inhabitants as well as long range movers. Such irregular dispersal patterns have been attributed to competition avoidance or a founder effect in most cases. At this time we can draw no conclusions about the factors prompting movement within our own resident trout population.

6.1 Temperature

Temperature is an important factor in the life history of salmonids. Even slight changes in water temperature may affect respiration, metabolism, growth, fecundity and stress levels. The optimal temperatures for growth of rainbow trout are around 15^{o} – 18^{o}C, a range that corresponds to temperatures selected in the field when possible (Moyle, 2002). Because fish are poikilothermic (cold-blooded) they will often move into more favorable areas of a stream to regulate body temperature (Thompson and Larson, 2004). In this study no connection was made between the movement of rainbow trout and changes in river temperatures.

6.2 Flow

No significant relationship was found between the longitudinal or lateral movements of resident trout in conjunction with categorical flows. In a similar study, Gido et al. (2000) reported that during periods of high flow, resident fish would move laterally into areas of slower moving water or into undercut banks as opposed to moving up or down stream to seek refuge from strong currents. After no correlation was found between categorical flows and longitudinal movement, we tested our data to see if trout on the Kings were doing the same. Results showed that increased flows did not prompt trout to seek refuge in slower waters closer to the bank.

6.3 Management Zone

Most waters stocked with fish are not regularly evaluated for their fish populations, angler use, or trends in their native biota (Moyle et al., 1996; Bahls, 1992). Due to limited literature, no model has been established which describes what a “normal” distribution of trout within a stocked tailwater fishery should look like. No difference in movement was detected amongst rainbow trout between the management zones tested. Moyle (2002) stated that hatchery-raised rainbows are ill adapted for survival in streams and are likely to die of starvation or stress within a few weeks if not caught. In systems where hatchery trout are regularly stocked in high use areas, it may be hypothesized that trout that are not caught-out may experience an early and increased rate of mortality; as opposed to leaving to find more hospitable grounds. Predation has also remained unexamined. Many studies similar to ours have been prompted by angler reports of decreasing trout populations in other rivers. Further study is needed.

6.4 Release Group

There were no significant differences found amongst the seven release groups in regard to trout movement, with the exception of release group five. Release group five was released in December 2006 during the late non-irrigation demand period. With a minute yet significant p-Value of 0.050 it is difficult to distinguish which variables contributed to groups five’s slight margin of significance.

6.5 Weirs

Dams are a well-known obstacle to natural salmonid movement, however smaller structures such as bridges, culverts, low water crossings, and weirs have also been implicated in blocking fish passage. Fish can have trouble getting past if a slope of a culvert is too steep or long, a weir is too high, or if there is no pool below the obstacle where fish can begin their leap out of water (Thompson and Larson 2004; NMFS 2001). There are also factors including the size of an adult fish and physical attributes which affect its ability to jump. Adult rainbow trout can exhibit burst speeds of between 6.4 – 13.5 ft/sec and jump to maximum vertical distances of 2.8 feet (Saila, et al, 2005). Descriptive analysis from this study demonstrated that trout in the lower Kings are able to bypass the ACOE, Cobbles and Dennis weirs. At this time, insufficient data exists to determine if Gould's and Fresno Weirs are impediments to upstream migration.

SUMMARY

In natural systems cost-benefit most often determines an organism's decision to expend energy. As rainbow trout expend energy to move away from an established home range or stream section, a quantifiable benefit must exist (Rogers and White, 2007). In analyzing the significance of the tested variables we have found that mature rainbow trout are not being forced from the study area by increased seasonal flow. As this study failed to isolate a significant causation for trout movement, it has confirmed our null hypotheses that flow, water temperature, size class, and management zones are having no significant impact on trout movement within the tailwater fishery. These study results will be analyzed in succession with acquired resident time and habitat selection data and used toward future adaptive management strategies by the Kings River Fisheries Management Program.

References

Burrell, K. et al. (2000). Seasonal Movement of Brown Trout in a Southern Appalachian River. Transactions of the American Fisheries Society 129:1373-1379, 2000.

Cocherell, et al. (2010). Distribution and Movement of domestic rainbow trout, Oncorhynchus mykiss, during pulsed flows in the South Fork American River, California. Springerlink.com

Fayard, J.; Klein, K. and F. Lefevre. (2009). Long Distance Dispersal and the Fate of a Gene from the Colonization Front. Journal of Evolutionary Biology: 22 (2009) 2171 – 2182

Gido, K.; Larson, R. and Ahlm, Lief. (2000). Stream-Channel Position of Adult Rainbow Trout Downstream of Navajo Reservoir, New Mexico, Following Changes in Reservoir Release. North American Journal of Fisheries Management 20:250-258, 2000.

Gowan, C. et al. (1994). Restricted Movement in Resident Stream Salmonids: A Paradigm Lost? Canadian Journal of Fisheries and Aquatic Science, Vol. 51, 1994.

High, B. and Meyer, K. (2009). Survival and Dispersal of Hatchery Triploid Rainbow Trout in an Idaho River. North American Journal of Fisheries Management 29:1797-1805, 2009.

Hilderbrand, H. and Kershner, J. (2000). Movement Patterns of Stream-Resident Cutthroat Trout in Beaver Creek, Idaho-Utah. Transactions of the American Fisheries Society 129:1160-1170, 2000.

Kings River Conservation District. (2005). Pilot-scale Telemetry Investigation to Evaluate Behavior and Dynamics of Rainbow Trout Inhabiting the Kings River Downstream of Pine Flat Dam. Unpublished, In-House Report.

(KRFMP) Kings River Fisheries Management Program. (1999). Framework Agreement. Unpublished Document.

(KRFMP) Kings River Fisheries Management Program. (2010). Residence Time of Rainbow Trout: Habitat Selection, Behavioral Movement, and Fate of Adult Rainbow Trout within the Kings River Downstream of Pine Flat Dam. Unpublished Document.

(KRFMP) Kings River Fisheries Management Program. (2011). Habitat Selection: Habitat Selection, Behavioral Movement, and Fate of Adult Rainbow Trout within the Kings River Downstream of Pine Flat Dam. Unpublished Document.

Mellina, E. et al. (2005). Seasonal Movement Patterns of Stream-Dwelling Rainbow Trout in North-Central British Columbia, Canada. Transactions of the American Fisheries Society 134:1021-1037, 2005.

Moyle, Peter. (2002). Inland Fishes of California; revised and expanded. University of California Press. Berkley and Los Angles California.

Moyle, P. and Nichols, R. (2006).Ecology of Some Native and Introduced Fishes of the Sierra Nevada Foothills in Central California. Source: Copeia, Vol. 1973, No. 3, (Aug. 28, 1973), pp. 478-490. American Society of Ichthyologists and Herpetologists, URL: http://www.jstor.org/stable/1443113, Accessed: 07/07/2008 13:20

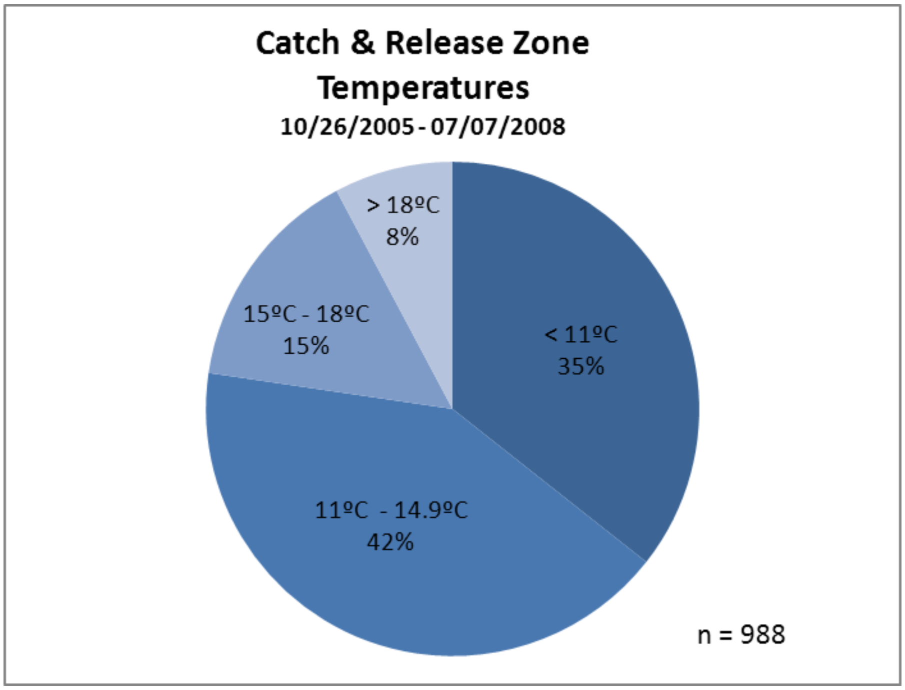
Rogers, K. and White, G.; Ed. Guy, C. and Brown, Michael.(2007). Analysis of Movement and Habitat Use from Telemetry Data; Ch 14. Analysis and Interpretation of Freshwater Fisheries Data. American Fisheries Society. Bethesda, Maryland.

Saila, S.B.; Poyer, D.; and D. Aube. (2005). Small Dams and Habitat Quality in Low Order Streams. Wood-Pawcatuck Watershed Association. Hope Valley, RI.

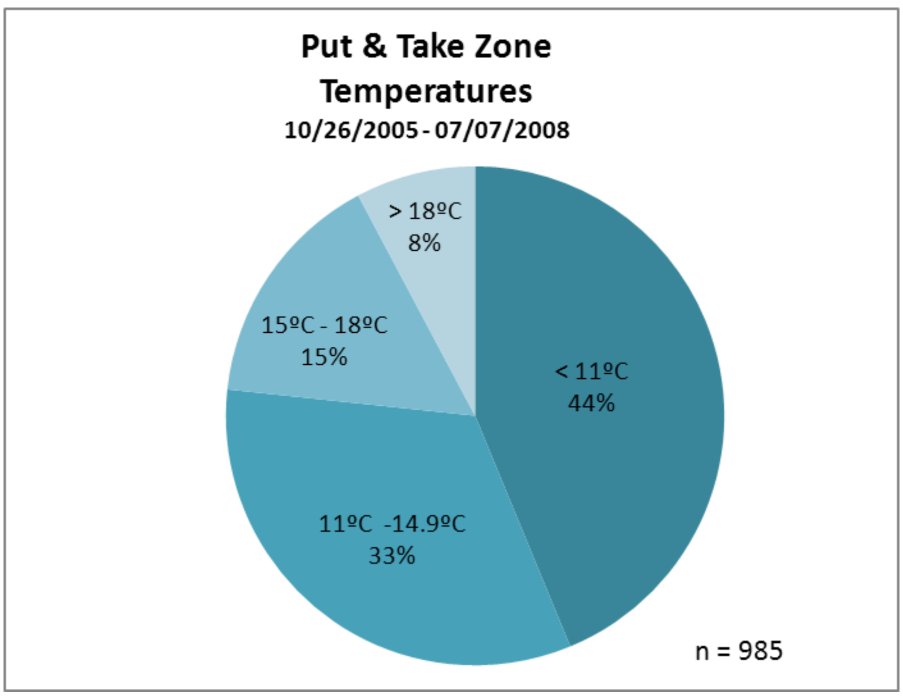
Simpson, G. (2006). Movement of Catchable Rainbow Trout after Stocking in Rapid Creek. South Dakota Department of Game, Fish and Parks. Report No. 06-05. Retrieved June, 2010 from: e.library.sd.gov/sodakLIVE-Docs/content/GFP/GFPdoc.067.pdf

Thompson, L. and Larson R. (2004). Fish Habitat in Freshwater Streams. Reference Article, Publication 8112. Regents of the University of California Division of Agriculture and Natural Resources.

Appendix



Division of temperature days within the Catch and Release management zone. Optimal temperatures for trout growth = 15° - 18° C.



Division of temperature days within the Put and Take management zone. Optimal temperatures for trout growth = 15° - 18° C.