This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views in this report are the author's and do not necessarily represent the views of BPA.

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YAKIMA SPECIES INTERACTIONS STUDY

ANNUAL REPORT 1992

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Project Number 89- 105
Contract Number DE-BI79-89BP01483

AUGUST 1993

EXECUTIVE SUMMARY

The Yakima Species Interactions Study (YSIS) was initiated in September of 1989 by the Washington Department of Wildlife (WDW) to investigate species interactions among fish in response to proposed supplementation of salmon and steelhead in the Yakima Basin. The research has three main goals which are to resolve critical uncertainties about species interactions, develop an interactions monitoring plan, and provide information that could be used to increase the probability of success of increasing natural production of anadromous salmonids. Critical uncertainties associated with the Yakima Fisheries Project (YFP) include how supplementation will affect the resident rainbow trout population in the upper Yakima River. Experiments are continuing and a baseline monitoring approach begun to investigate the potential for (before supplementation), and detection of (during supplementation) interactions between rainbow trout and other species. Work to date has emphasized potential interactions between rainbow and steelhead trout. This report summarizes preliminary results of interactions research and monitoring through 1992.

Baseline monitoring of rainbow trout spawn timing and distribution, population size, age and siie structure, species associations, and genetic structure continued in the mainstem Yakima River and tributaries during 1992. Spawn timing peaked earlier in 1992 than in 1991, but was consistently earlier in low elevation areas than high elevation areas. Rainbow trout generally spawned between February and June. Sexually mature rainbow trout were collected throughout the upper Yakima Basin except for very high elevation tributaries. The pattern of trout abundance among five pre-established mainstem index sections differed between the fall, 1991 and fall, 1992, but the total estimated number of trout and biomass of trout in the 25.1 km of index sections surveyed was fairly similar. At least 18 species of fish were observed during population estimates in the mainstem Yakima River. Mountain whitefish were judged to be the most abundant species in four of the five mainstem sections sampled, and northern squawfish were present in all mainstem index sections. Mean fork lengths of trout were very similar between years in each of the index sections. Growth of trout in mainstem sections ranged from an average of 0.08 to 0.12 mm/day. Trout in the mainstem were rarely captured outside the index sections from which they were originally sampled except during the spring when some trout made spawning migrations into tributary streams.

In tributaries, rainbow trout accounted for the greatest proportion of salmonid density and biomass in index sections (generally 60-100%) and were broadly distributed throughout the basin. Rainbow trout densities were positively correlated with longnose dace and shorthead sculpin densities. Average population and biomass estimates of rainbow trout in tributary streams were different among tributaries and similar within tributaries between 1991 and 1992.' **Salmonid** density was- strongly correlated with pool area and an index of habitat complexity. Spring chinook densities were strongly correlated with torrent sculpin and **redside** shiner densities.

Genetic data collected to date suggests rainbow trout in the upper Yakima basin are structured into five population units. Many of the rainbow trout populations in the upper Yakima are a genetic admixture of wild and hatchery rainbow trout. Hatchery steelhead have contributed little if any genetic material to the rainbow trout population. The occurrence of genetic material from hatchery trout is greatest in low elevation tributaries and the **mainstem** Yakima River. Trout in high elevation tributaries and **mainstem** sections have little if any genetic **evidence of** past hatchery stocking. Steelhead and rainbow trout in the upper Yakima basin can be differentiated electrophoretically by alleles common to the hatchery trout.

Preliminary research results with steelhead and rainbow trout to date suggest that the potential for gene flow is high, the potential for **competition** is unclear, and the potential for predation on trout by hatchery steelhead juveniles is low. Gene flow is predicted because rainbow trout and steelhead spawners overlap in space and time, cases of interbreeding are'suspected,, and high numbers of precocial males were documented from hatchery releases.

Experimental releases of hatchery steelhead smolts in the Teanaway drainage were initiated during May, **1991** to develop methods for monitoring interactions,, and to provide **insight into** the potential for interactions between fish produced by . conventional hatchery procedures and other fish upon, implementation of the **YFP.** Results from experimental, releases of hatchery steelhead smolts during 1991 and 1992 **suggested that** competition between hatchery steelhead **and rainbow** trout might have occurred, although if competition occurred the impacts to trout were unclear. Agonistic behavior between rainbow trout and hatchery steelhead smolts was observed during 1991 and 1992, but impacts on growth or-population densities **were not** detectable with the methods used. Hatchery steeihead dominated most of **the** behavioral interactions with rainbow trout, 'presumably **because** hatchery'steelhead were larger than the rainbow trout. **Agonistic** interactions between hatchery steelhead and rainbow trout were . . . 69% of the total interactions observed before June 1, 1992, but only 21% of the total interactions observed after June 1, 1992. Rates of interactions (interactions/fish/minute) were higher in control streams than in paired treatment streams prior to June 1, 1992, but lower in one control stream and higher in another after June 1, 1992. Small scale displacements were observed in, concordance with agonistic behavior but large scale displacements were not observed. In addition, rainbow trout, wild steelhead presmolts, and wild steelhead smolts did not emigrate at accelerated rates from the North Fork Teanaway River during the peak of hatchery steelhead smolt emigration.

The impact of predation by the hatchery steelhead, used in these experiments, on rainbow trout appeared to be very small. No successful predatory attacks were observed during over 180 hours of snorkeling. A total of 55 residual hatchery steelhead were collected from habitats having coexisting young-of-the-year trout. Stomach samples from these steelhead contained no fish.

Identification of biological variables to be measured, techniques to measure those variables, and design of the monitoring plan are in various stages of development. Attempts have been made to identify and evaluate techniques that minimize stress on fish populations as well as produce reliable information. For example, the adverse effects of electrofishing can be overcome by using weirs to provide information on spawning characteristics of trout in tributary streams. A mosaic of experimental designs (e.g. Before-After-Control-Impact-Pairs, Before-After, Small scale within treatment experiments) can be used to monitor the rainbow trout and evaluate causes of observed outcomes. Acclimation pond locations and the type of biological variables to be measured are two important factors that can be used to determine which types of experimental designs should be used.

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INTRODUCTION

The Yakima Species Interactions Study (YSIS) was begun in September of 1989 to investigate species interactions among fish in response to proposed supplementation of salmon and steelhead in the Yakima Basin. Supplementation is defined as "the use of artificial propagation in the attempt to maintain or increase natural production while maintaining the long term fitness of the target population, and keeping the ecological and genetic impacts on non-target populations within specified biological limits" (BPA summary report series, 1992). Target populations are-the populations of fish that will be supplemented and non-target populations are all other populations of fish. One of the goals of the proposed Yakima Fisheries Project (YFP) is to test the strategy of supplementation in the Yakima Basin. In a review of published literature and unpublished projects about supplementation, Miller et al. (1990) concluded "Adverse impacts to wild stocks have been shown or postulated for about every type of hatchery fish introduction where the intent was to rebuild runs". In Steward and Bjornn's (1990) review of the published literature, they stated that "Genetic and ecological effects, and changes in productivity of the native stocks that can result from supplementation remain largely unmeasured." Uncertainties about the effects supplementation in the upper Yakima basin may have on wild fish was the impetus for the initiation of the present studies.

The YSIS has three main goals which are to: evaluate risks of ecological interactions to target and non-target populations (resolve critical uncertainties), contribute to the development of an interactions monitoring plan, and provide information that may be used to increase the probability that natural production of anadromous salmonids may be successfully increased. Information obtained will be used as the YFP planning process proceeds (adaptive management). A monitoring plan is being developed which will incorporate data collected both before and after implementation of the YFP. Monitoring enables managers to identify undesirable impacts, use new knowledge to adjust supplementation protocols, and gauge the extent to which supplementation is meeting performance objectives.

Work to date has focused on predicting the potential for species interactions and on collecting baseline data to enable monitoring of the effects of interactions between anadromous steelhead and resident rainbow trout (*Oncorhynchus mykiss*). Steelhead and rainbow trout received the highest priority for three reasons: (1) an important fishery for rainbow trout exists in the upper Yakima basin, (2) the ecological requirements of the early life history stages of both forms are similar, suggesting a high potential for interactions, and (3) the potential for gene flow and the accompanying effects, such as increased or decreased tendencies to migrate, is high-because they are the same species. Present and future work will increasingly address interactions among target species (e.g. steelhead x spring.chinook *[Oncorhynchus tshawytscha],* **steelhead** x steelhead) and between target and non-target species (e.g. spring chinook x rainbow trout, steelhead x bull trout [*Salvelinus confluentus*]).

Interactions between fish produced as part of the YFP and resident trout may be classified based on the rearing treatments in the hatchery, and whether fish were first generation or progeny of first generation hatchery fish. At least two types of treatment fish will be produced by the YFP (PSR 1992). One type, termed the optimal convention&l treatment (OCT) will be produced using the "best" conventional hatchery practices. The other type, or new innovative treatment (NIT), will be produced using innovative approaches in the rearing environment such as providing cover and using natural substrate in raceways, and feeding fish live foods. The goal of the new innovative treatment is to mimic the behaviors and appearances of-wild fish so that survival of hatchery fish is increased, and perhaps approaches that of wild fish (PSR 1992). The purpose of the two treatments is to test the hypothesis that survival and other related variables of fish produced using the two treatments is", different, and to afford an extension of research results from the YFP to other currently operated conventional hatcheries; Experimental releases of steelhead produced at the Yakima Hatchery were used in the current studies as surrogates to predict potential interactions between steelhead treated in the.. OCT fashion versus other fish. Hatchery steelhead produced by the Yakima Hatchery were probably not exactly like the fish that will be produced as part of the YFP so interpretation of the results should be tempered with this caveat.

Interactions between steelhead produced as part of the YFP and rainbow trout can also be characterized as: (1) interactions between first generation hatchery fish., and rainbow trout (type 1), and (2) interactions between naturally produced progeny of hatchery fish and rainbow trout (type 2). *For* instance, interactions between hatchery steelhead outmigrants, residuals, and returning adults; and wild rainbow trout are characterized as type 1 interactions. Type 2 interactions occur between all life history stages of naturally produced offspring of hatchery produced adults and wild rainbow trout. Critical differences between the two types of interactions are that progeny of hatchery fish will presumably behave more like wild fish than , their hatchery produced parents, and type 2 interactions include interactions between young steelhead that rear in the stream and wild rainbow trout. To date, YSIS has focused the most attention on assessing the potential for type 1 interactions.

The format of this report is substantially different than previous ones (Hindman et al. 1991; McMichael et al. 1992). The organization of this report follows the outline of objectives listed in the contractual **agreement** between the Washington Department of Wildlife (WDW) and BPA for interactions research activities. The report is divided to reflect two study phases (baseline and experimental). Study phases are further divided into objectives, sub-objectives, and tasks. Accomplishments, short-falls, findings, and recommendations, are described for each task. This report is intended to satisfy two concurrent needs: (1) provide a contract deliverable from WDW to BPA, with emphasis on identification of salient results of value in ongoing YFP planning, and (2) summarize results of research for interested parties.

This annual report summarizes data for the period between January 1, and December 31, 1992. Data collected during 1992 was compared to findings from previous years to identify general trends and make preliminary comparisons. For the purpose of this report, statistical analyses were not emphasized. Except where otherwise noted, the methods and general site descriptions were the same as described in previous reports **(Hindman** et al. 1991, **McMichael** et al. 1992). It is important to note that this report describes work in progress. Readers are cautioned that any preliminary conclusions are subject to future revision as more data and analyses are available.

BASELINE PHASE

Activities related to the collection of baseline information on resident fish above Roza Dam were very successful in 1992. Spawning surveys included the addition of migrant traps and rearing survey efforts were intensified to include all fish species in the study area. Information collected in 1992 provided the third year of baseline data on **salmonid** abundance and distribution in five sections of the **mainstem** Yakima River as well as in 14 index sections of tributaries. Some objectives in the statement of work were not fully achieved but in most cases modifications to equipment and/or operating procedure will rectify these problems. All fish iengths in this report were measured as fork lengths (FL).

Objective I: Determine **Spawning** Characteristics

Sub-Obj. **I.A:** Characterize resident trout spawning activity in Yakima River tributaries above Roza Dam.

Task I.A.l: Determine the temporal **and spatial** distribution of resident trout spawning in Yakima River tributaries above **Roza** Dam.

Accomplishments: Using a backpack electrofisher, spawning surveys were conducted from February 10 through June 30, 1992, with methods similar to those used in 1991 (McMichael et al. 1992). Surveys in pre-established index areas were conducted twice a month on 12 tributaries (Umtanum, Badger, Cherry, Wilson, Manastash, Taneum, Swauk, West Fork Teanaway, Middle Fork Teanaway, North Fork Teanaway, Big, and Cabin). Trout were classified as green, mature, or spent depending upon their reproductive condition (McMichael et al. 1992). Migrant traps (upstream and downstream) were installed in three tributaries to monitor juvenile and adult trout movement during the spawning season as well as emigration of smolts. A total of 288 trout (targeted number was 337) were sacrificed for genetic stock identification (GSI) and scale pattern analysis (SPA) from tributary areas. Samples were delivered for analysis to the Washington Department of Fisheries (WDF) on July 10, 1992.

Short-falls: Spawning surveys conducted with the electrofisher provided useful results but some problems existed with the technique. Sexual maturity of trout was determined for most samples, however, most of the mature fish were males (due to their extended duration of sexual maturity). Limited numbers of adult size trout were collected from Big and Cabin creeks so conclusions about peak spawn timing were not made. Effects of electrofishing on health (injury) and viability of fish and deposited ova was also a concern, particularly during the spawning season. Trapping on Cherry and Wilson creeks provided limited information. High debris loading, high flows, **bed-** scouring and small mesh size on the Cherry and Wilson creek traps contributed to the problems that were experienced. Planned trapping was not attempted on Manastash, Badger, and **Taneum** creeks because of the problems associated with the traps in Cherry and Wilson creeks.

Findings: Spawning occurred earlier (February and March) in lower tributaries (Umtanum, Badger, Cherry and Wilson creeks) and later in middle and upper elevation streams **(Manastash, Taneum,** Swauk, the Teanaway drainage)(Figure 1). This pattern was similar to that observed during 1991 **(McMichael** et al. 1992). Similar to 1990 and 1991, resident rainbow trout migrating from the **mainstem** of the Yakima River spawned in Umtanum Creek. The migrant trap near the mouth of Umtanum Creek worked very well in capturing fish of all sizes migrating both upstream and downstream. A total of 190 adult rainbow trout moved into Umtanum Creek to spawn between February 10 and April 30 (Figure **2)**. Trout were defined as adults when they were longer than the minimum length of mature fish captured in the same creek. Pulses in numbers of migrating fish appeared to be related to increases in water temperature. There appeared to be two size groups of trout in Umtanum Creek during-the spawning season (Figure 3). Large resident trout from the **mainstem** Yakima River did migrate into the Cherry/Badger creek complex and, to a lesser extent, into Wilson Creek. 'Unfortunately it was not possible **to** determine the total number and peak timing of spawning 'due to trapping inadequacies (Figures 4, 5, 6, and 7). Three adult steelhead were captured during tributary spawning surveys (Umtanum, Taneum, and Swauk creeks), **while two** more were observed by snorklers in the North Fork of the Teanaway **River.**

Recommendations: To avoid problems associated **with electrofishing** we recommend increased use of traps to determine the **timing** and-.. magnitudeof **mainstem** rainbow trout. spawning in **tributaries.** Picket we**irs** with 25 mm spaces and **20 mm** tubing'should be used to avoid the **problems** experienced with the trap design **tested** in. 1992. This construction should allow **operation in swift** tributaries with moderate debris loading and be considerably **more** effective with less **effort** than the wood and **hardware cloth (6** mm) **'W'** style weirs used in 1992. The increased use of traps will allow electrofishing effort to be minimized, **thus reducing** negative effects of sampling on spawning fish and **their deposited** gametes.

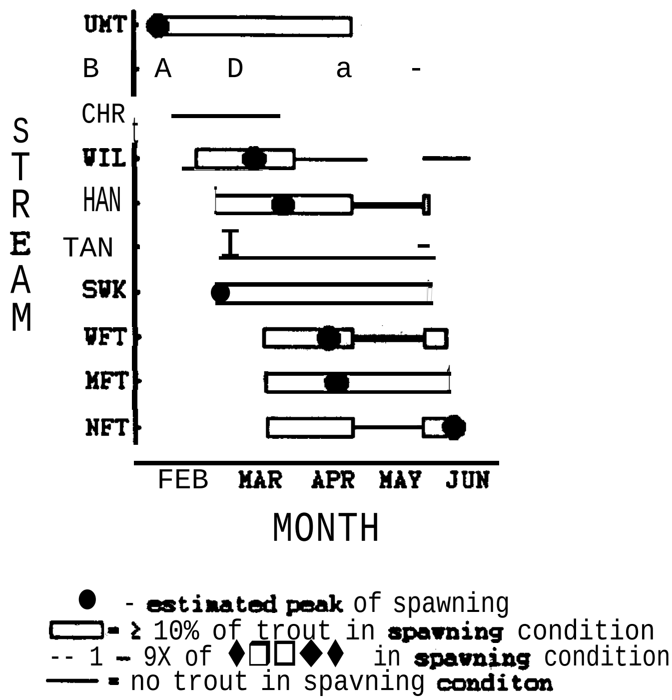


Figure 1. Spawning time of resident rainbow trout in tributaries to the upper Yakima River during spawning surveys in 1992. The peak of spawn timing was estimated as the time at which the highest percentage of trout were in spawning condition. UMT = **Umtanum** Cr., BAD = Badger Cr., CHR = Cherry Cr., WIL = Wilson Cr., MAN = Manastash Cr., TAN = **Taneum** Cr., **SWK** = Swauk Cr., WFT = W. Fork Teanaway R., MFT = M. Fork Teanaway River, NFT = N. Fork Teanaway R.

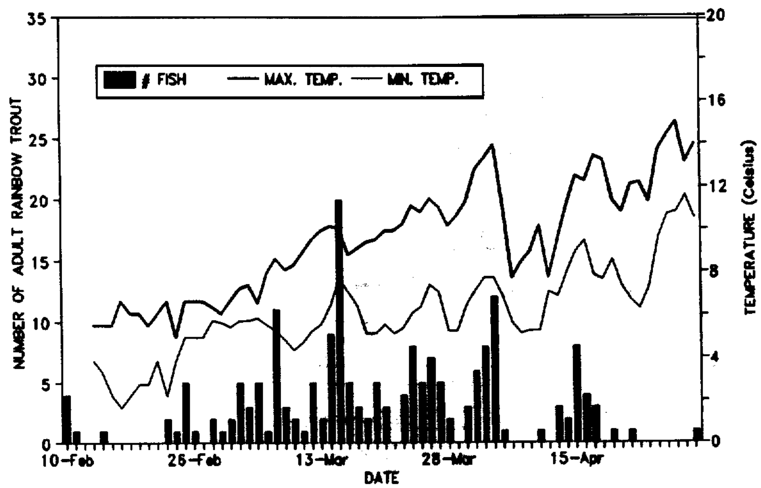


Figure 2. Number of adult **(>93 mm)** rainbow trout **(#** FISH) migrating upstream and captured in Umtanum Creek trap and daily maximum and minimum water temperatures between February 10 and April 30, 1992. Total fish sample size was 190.

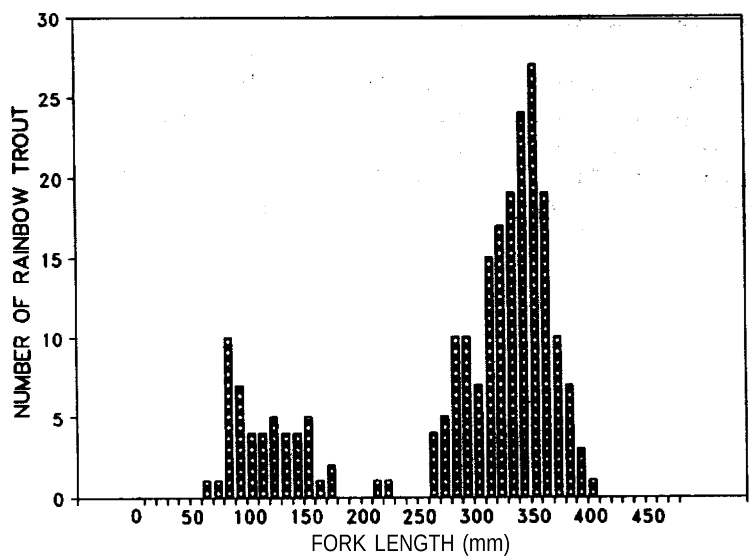


Figure 3. Length frequency histogram of upstream migrating rainbow trout captured in the Umtanum Creek trap between February 10 and April 30, 1992.

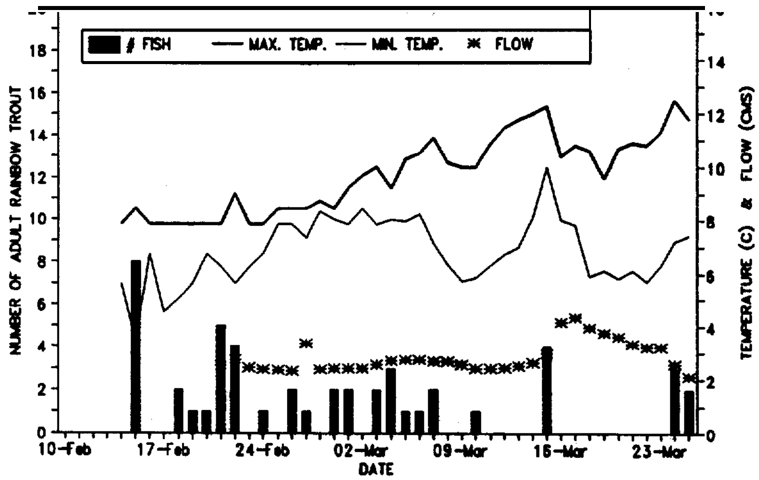


Figure 4. Number of adult (>134 mm) rainbow trout (# FISH) migrating upstream and captured in the Cherry Creek trap and daily maximum and **minimum** water temperatures and average flow for February 10 to March 25, 1992. Total fish sample size was 48.

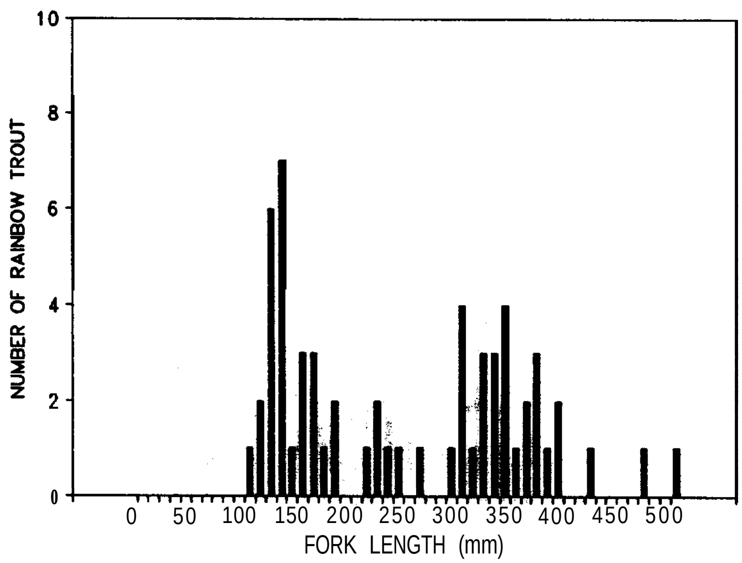


Figure 5. Length frequency histogram of upstream migrating rainbow trout captured in the Cherry Creek trap between February 10 and March 25, 1992.

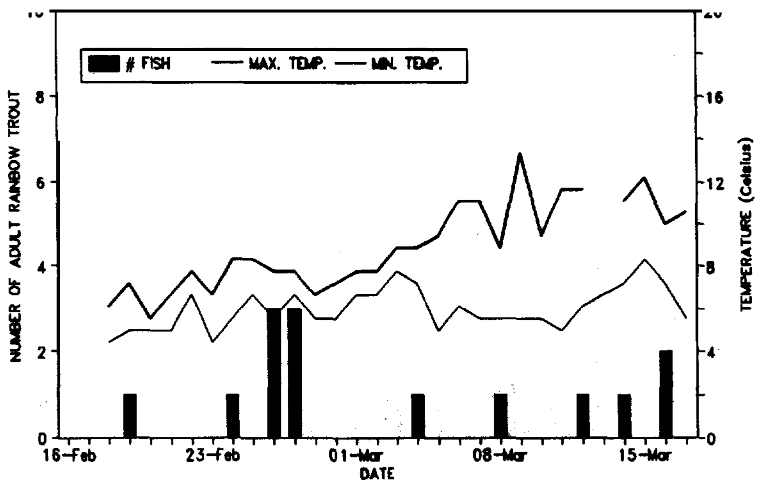


Figure 6. Number of adult (>167 mm) rainbow trout (# FISH) migrating upstream and captured in the Wilson Creek trap and daily maximum and minimum water temperatures for February 16 to March 18, 1992. Total fish sample size was 14.

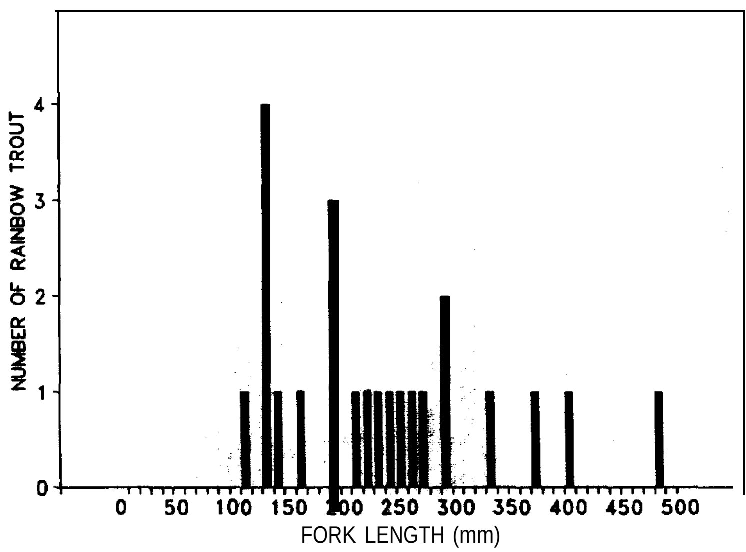


Figure 7. Length frequency histogram of upstream migrating rainbow trout captured in the Wilson Creek trap between February 16 and March 18, 1992.

Sub-Obj. **I.B:** Characterize resident trout spawning activity in the **mainstem** Yakima River above Roza Dam.

Task **I.B.1:** Determine the general temporal and spatial distribution of resident trout spawning in **the mainstem** Yakima River above Rosa Dam.

Accomplishments: As in 1991, spawning time of resident trout in large reaches of the Yakima River was determined by electrofishing pre-established index sections with the driftboat (sections 1 **- 5),** and backpack electrofishing and angling (sections 6 and 7) **(McMichael** et al. 1992). Sample sizes were generally about 30 to 50 fish per section per month. Two adult steelhead were collected in the Ellensburg section. A total of 157 rainbow trout (target was 175) were taken from **mainstem** sections for GSI and SPA analyses.

Short-falls: Periodic electrofishing in **mainstem** sections appears to be inadequate for determining exactly where rainbow trout spawn. In addition, short-falls associated with backpack electrofishing in tributaries (identified under Sub-Obj. **I.A)** apply to the use of driftboat electrofishing.

Findings: Sexually mature rainbow trout were found'throughout the entire length of the Yakima River between Roza and Keechelus dams. Similar to findings in 1991, spawning occurred slightly earlier in lower elevation reaches and later in the upper areas (Figure 8). No concentrations of spawning trout were detected in the mainstem.

Recommendations: Because the techniques currently being used are inadequate for determining exaatly where and **when** rainbow trout are spawning in the **mainstem** Yakima River, initiation of a radio telemetry study on spawning rainbow trout in the Canyon area of the Yakima River (between Ellensburg and Roza Dam) is recommended. This work would address important **questions** including the major task activity goal (temporaland spatial spawning in the mainstem), habitat utilization, and movement patterns of adult trout within the **mainstem** prior to and after spawning.

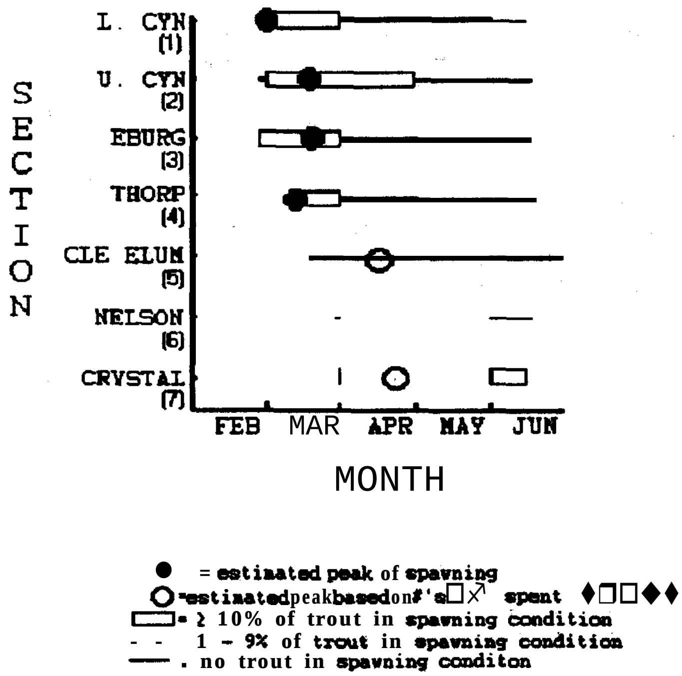


Figure 8. Spawning time of resident rainbow trout in the upper Yakima River during spawning surveys conducted in 1992. Section numbers appear in parentheses below the corresponding section name. The peak of spawn timing was estimated as the time at which the highest percentage of trout were in spawning condition, or as the percentage of trout that had already spawned-'(spent) in 1992. Peak spawn timing was not estimated for the Nelson section because of small sample sizes.

Sub-Obj. I.C: Develop a biological profile of resident trout spawning populations in tributaries and mainstem areas above Roza Dam.

Task I.C.1: Determine age composition, length-at-age relationships, age-fecundity relationships, sex ratio, and growth rates of adult resident trout.

Accomplishments: Data were collected during electrofishing and trapping efforts to generate length frequency, age structure, condition factor (length/weight relationship), sex ratio, fecundity, and movement information. Trout ages are being determined by WDF via subcontract.

Short-falls: Analysis of scales taken during spring sampling is not yet complete and thus discussion of trout age data was not included in this report. Sex was difficult to determine based on external characteristics except when adult trout were in spawning condition. In addition, female trout exuded gametes during a much smaller window of time than male trout. Thus, sex ratios were usually based on smaller sample sizes than the total number of fish collected.

Findings: Mean lengths of mature rainbow trout captured in the spring during electrofishing surveys were greater in most mainstem sections than in tributaries. Mean lengths of trout were greater than 300 mm in the lowest four mainstem sections (Figure 9). Upstream of the Thorp section, mean lengths of trout decreased but were still greater than 200 mm. Mean lengths of trout in tributary streams were generally under 200 mm except for low elevation tributaries such as Cherry and Wilson creeks (Figure 10). Due to the unavailability of age data, relationships between size and age or growth remain to be assessed.

Sex ratios were generally dominated by males. Due to the increased duration of sexual maturity in males, it is very likely that our sampling methods were biased towards males. In samples where a large proportion of the fish were in spawning condition (e.g. fish captured in the Umtanum Creek trap), the sex ratio was more evenly distributed between males and females (1.5 males:1.0 female). Fecundity of rainbow trout ranged from 76 eggs/female (159 mm) in Umtanum Creek to 3102 eggs/female (455 mm) in Wilson Creek. Fecundity increased with fish length according to the following relationships: mainstem (Fecundity = 500 + 1.4(fork length), P=0.03, df=24), and tributaries (Fecundity = -1292 + 8.6(fork length), P=0.0000, df=24).

Recommendations: In order to reduce sex ratio bias, electrofishing methods should be replaced with trapping methods in the tributaries. In addition, efforts to increase the timeliness of obtaining age information should be intensified.

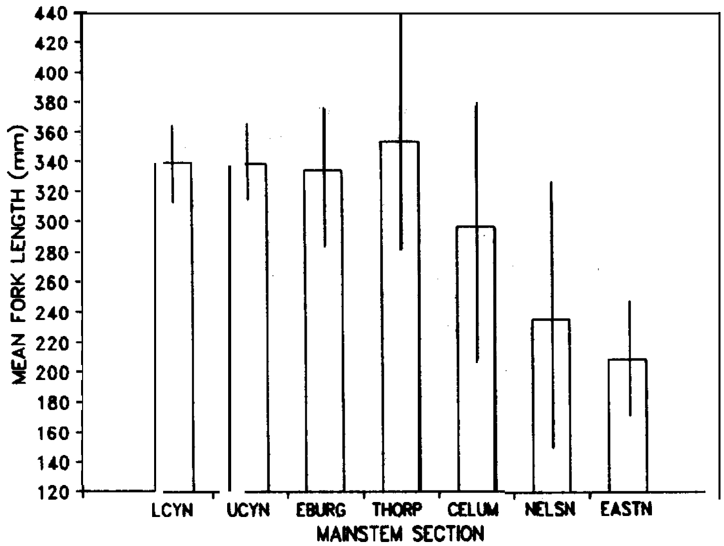


Figure 9. Mean fork length (mm) of rainbow trout that spawned in the **mainstem** Yakima River during 1,992 (reproductive condition classified as green, mature, or spent). Vertical lines represent ± 1 standard deviation.

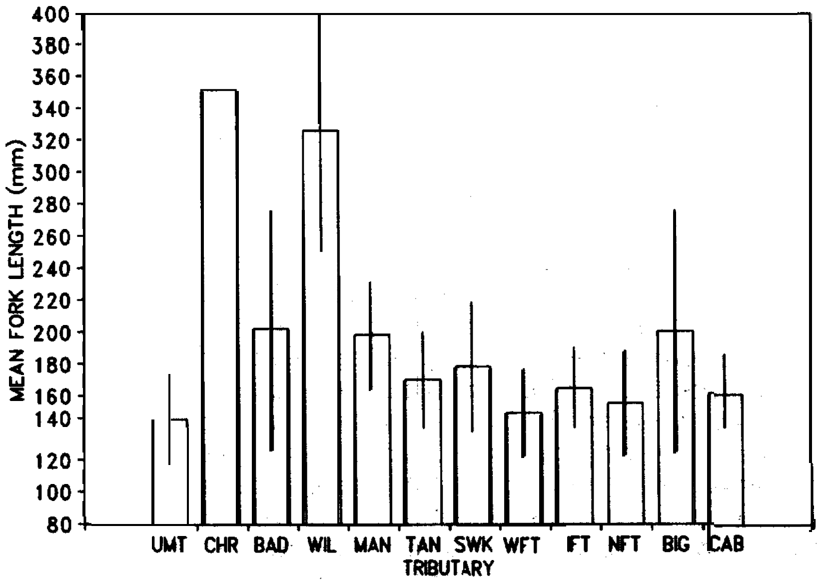


Figure 10. Mean fork length (mm) of rainbow trout that spawned. in tributaries to the **mainstem** Yakima River during 1992 (reproductive condition classified as green, mature, or spent). Vertical lines represent ± 1 standard deviation.

Task **I.C.2:** Obtain trout **samples** and **genetically assess** population **structure** and **lineage.**

Accomplishments: In this **report,** this **task and Task II.C.2 were** treated together because of the similarity of data obtained. The number of target fish collected for GSI and SPA was very close to target levels for spring spawning and fall rearing **samples** (Table **1).** Samples collected during **the spring** were **delivered to WDF on** July 10, 1992, and samples collected during the fall were delivered on November 12, 1992. WDF processed the **samples and** reported on the methods associated with the electrophoresis (Appendix A).

Short-falls: The abundance of rainbow trout in Cherry Creek appears to have declined since GSI sampling was initiated in 1990. Therefore, fish were not collected from Cherry Creek during the spring and fall to reduce potential impact on the Cherry Creek population.

Because it was difficult to collect large sample **sizes** of rainbow trout in spawning condition, **25% of** the **spring sample contained** rainbow trout that were of adult size but were not sexually mature. Much variation in scale patterns exist for rainbow **trout** collected from the upper basin (Curt Knudsen pers. **comm.) but no** formal analysis has been conducted to date.

Table 1. Target and actual numbers of samples collected for genetic stock identification and scale-age analysis **from** trout collected during the spring and fall of 1992 in the upper Yakima River and its tributaries.

Stream or section	Target[a]	T & p	-Fall
Tributaries			
Umtanum	40	39	35
Badger	33	28	33
Cherry	33	0	0
Wilson	33	23	25
Manastash	33	33	33
Taneum	33	33	33
Swauk	33	33	32
North Fork Teanaway	33	33	33
Middle Fork Teanaway	33	33	33
West Fork Teanaway	33	33	33
Wilson cutthroat trout		10.	
Taneum cutthroat trout		10	
Yakima **Mainstem**[b]			
Lower Canyon (1)	25	25	25
Upper Canyon (2)	25	25	25
Ellensburg (3)	25	20	25
Thorp (4)	25	15	25
Cle Elum (5)	25	22	22
Nelson (6)	25	25	19
Crystal (7)	25	25	24
Total	512	465	455

[a] Number of fish targeted for spring and fall, each.
[b] Number in parentheses indicates **mainstem** section number.

Findings: The following findings are abstracted from results reported in Appendix A. The population structure of rainbow trout in the upper Yakima basin appeared to be comprised of five genetic clusters (Figure 11). Fall (rearing) and spring (spawning) samples taken within a tributary were generally more similar to each other than to samples taken from different tributaries. Although the clustering algorithm places the most similar populations in the same cluster, most of the populations forming clusters were genetically distinct (Appendix A). Most of the rainbow trout populations in the upper Yakima are a genetic admixture of native rainbow trout and hatchery rainbow trout. Available data indicate that the influence of hatchery trout has been greatest in low elevation tributaries and the **mainstem**

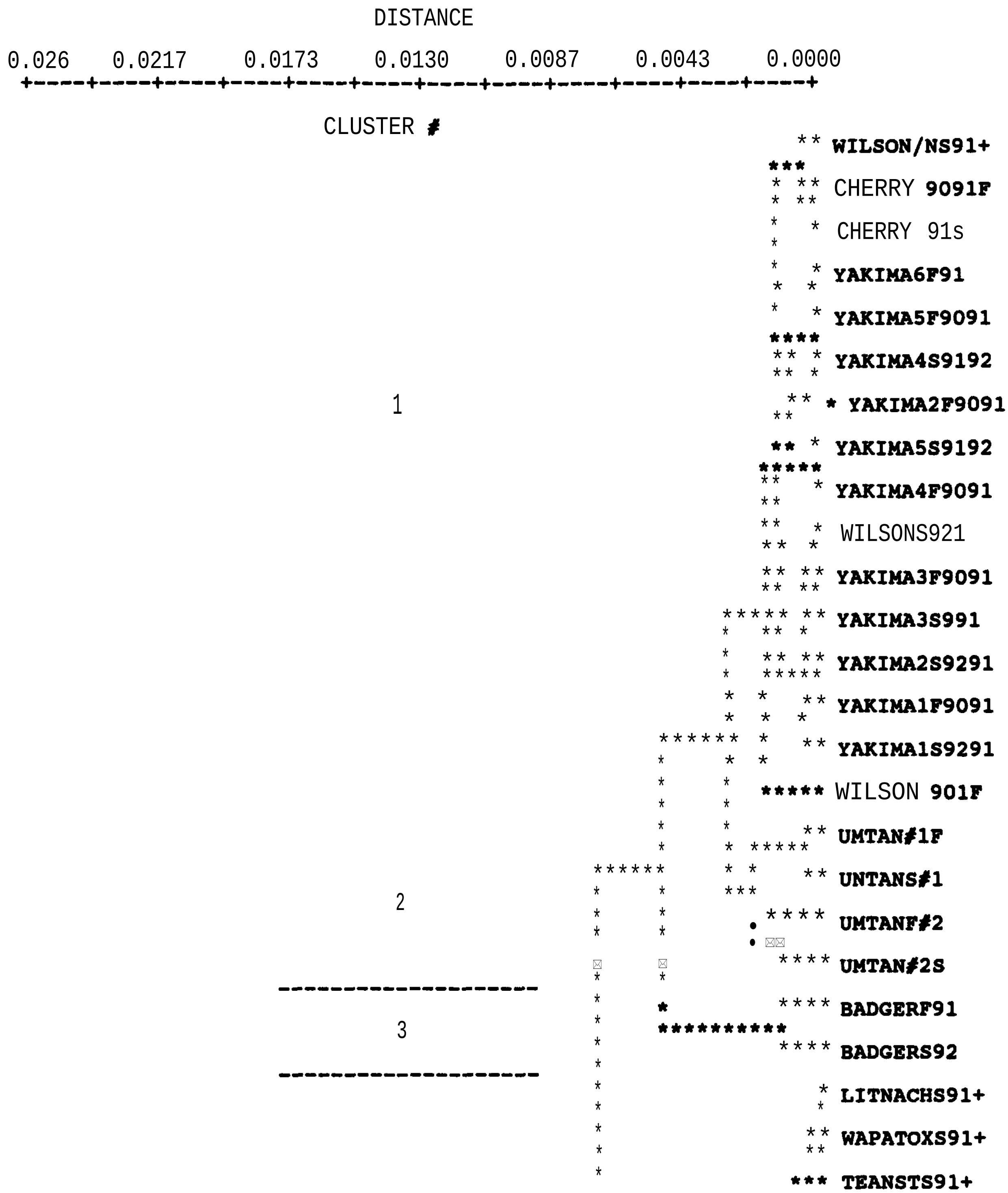
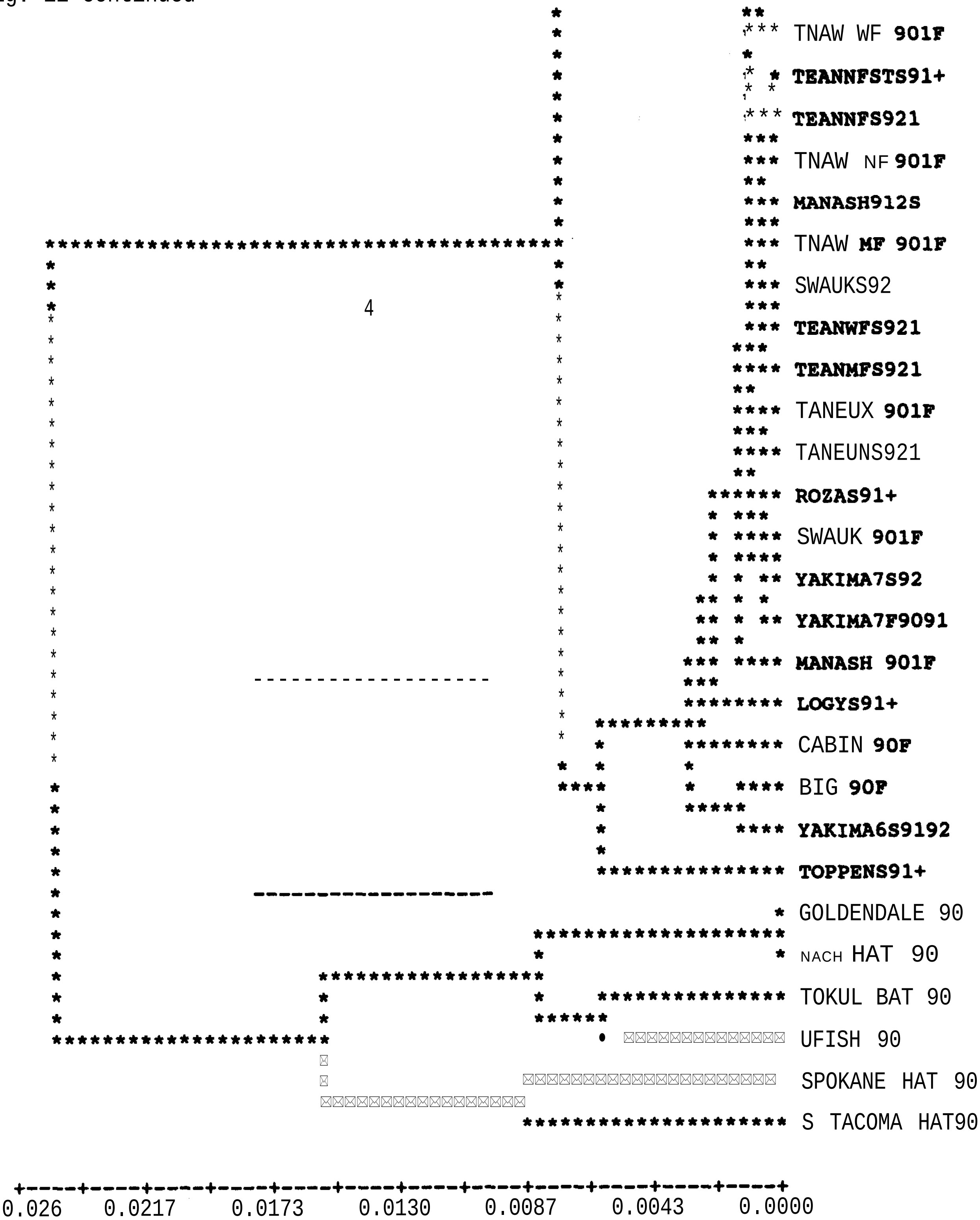


Figure 11. Cluster analysis of rainbow trout and steelhead **alleles** using unweighted pair group method and Nei (1978) unbiased genetic distance. Each collection is coded by place and time of capture. Steelhead samples end with a "+". Codes are further defined in appendix A.

Fig. 11 continued



Yakima River (Figure 12). Trout in high elevation tributaries, such as the three forks of the Teanaway River and Big and Cabin creeks, had the lowest occurrence of genes from hatchery trout and, because of the low precision of calculating hatchery influence (Appendix A), hatchery influence may be close to zero in these streams.

Hybridization between cutthroat trout and rainbow trout was suspected in the upper Yakima River basin because a large number of trout had characteristics of both rainbow and cutthroat trout. None of the putative hybrids sampled from Badger Creek had alleles that were diagnostic for cutthroat, but putative hybrids sampled from other parts of the basin may have had low levels of these cutthroat alleles. This suggests that the majority of putative hybrids collected were genetically rainbow trout with coloration patterns (hyoid slashes) typical of cutthroat. All of the cutthroat trout collected were westslope cutthroat trout (*Oncorhynchus clarki lewisi*).

Steelhead populations could be distinguished from some of the rainbow trout populations primarily by the presence of alleles in admixed rainbow trout. For example, most steelhead were distinguishable from resident rainbow trout in the heavily admixed mainstem Yakima, but not from resident rainbow trout in tributaries where the genetic influence of hatchery rainbow trout has been small or nonexistent such as in the forks of the Teanaway River.

Recommendations: The number of samples taken during the spring should be reduced to those tributaries where differences have been shown to exist between fall (rearing) and spring (spawning) samples (e.g. North, Middle, and West forks of the Teanaway River) from past genetic sampling. This sampling design will reduce the impact to the trout population and enable continued collection of appropriate information.

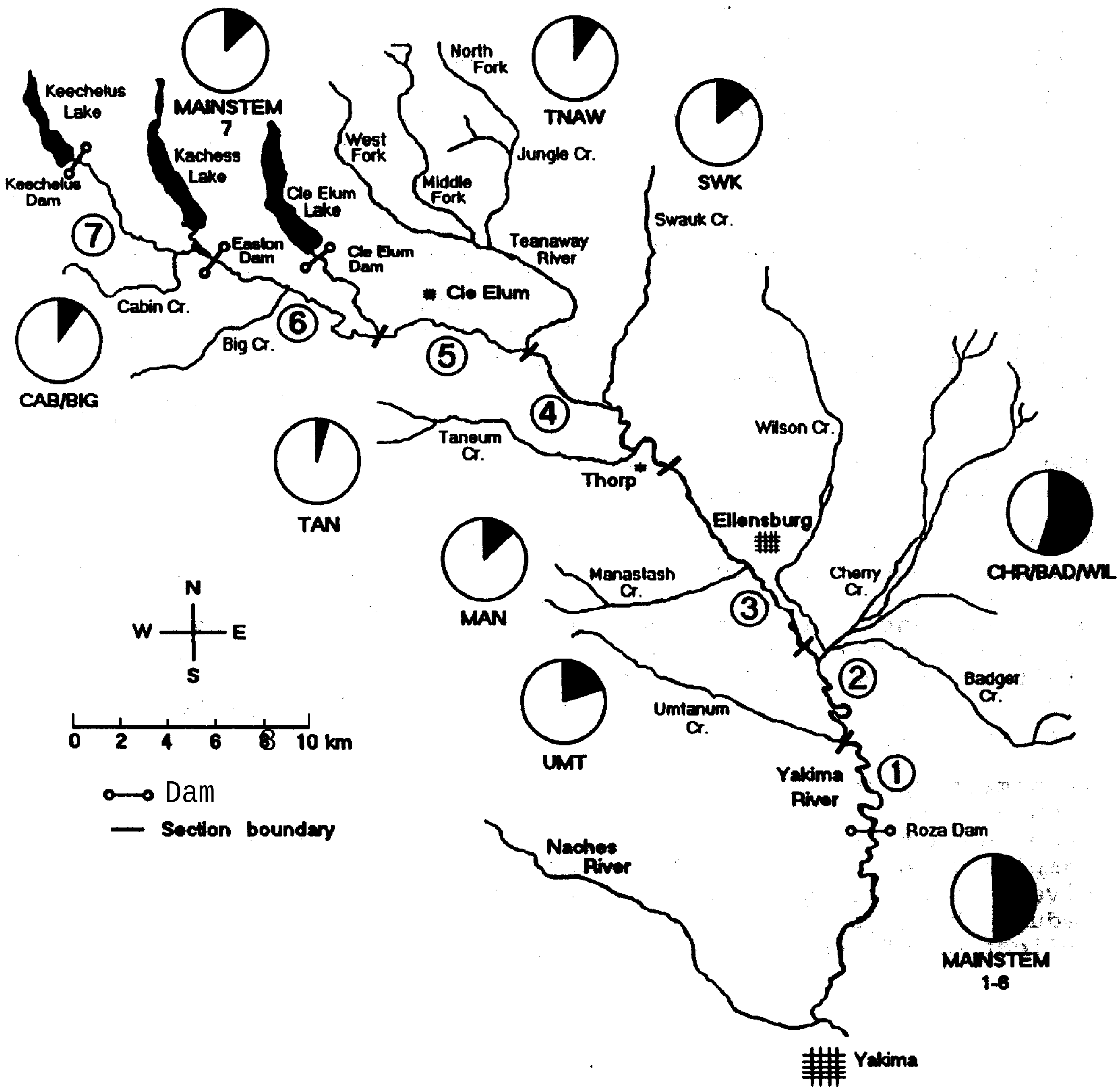


Figure 12. Map of the Yakima River basin showing preliminary estimates (pie diagrams) of the genetic contribution of hatchery rainbow trout (in black) currently represented in naturally produced rainbow trout populations. The presence of alleles from Goldendale Hatchery trout were compared to alleles from hypothetical, pure, rainbow trout to derive these estimates.

Sub-Obj. I.D: Estimate **the** current and future probability of spatial and/or temporal overlap between resident trout and steelhead spawners.

Task **I.D.1: Synthesize** information obtained **from** work on resident trout spawners (Sub-objectives **I.A, I.B,** and **I.C)** with that **available** from **NMFS radiotelemetry** studies and **YIN** studies of"steelhead.

Accomplishments: Available data from the present study and those of the National Marine Fisheries Service (NMFS), and the Yakima Indian Nation (YIN) have been compiled. Temporal and spatial spawning data for trout and steelhead have been compared. Preliminary projections, based on current utilization and habitat characteristics, have been made to determine the potential for overlap and hybridization between spawning steelhead and resident trout.

Short-falls: Due to the low number of returning steelhead during the study period and the low level of effort expended toward determining the timing and location of upper Yakima River steelhead spawning, estimates of the extent of spawning overlap between rainbow trout and steelhead were based on limited data. Most of the steelhead data were not based on observations of fish actually spawning, but were instead simply observations of fish during the broader spawning season.

Findings: Preliminary information indicate that the spatial and temporal overlap of spawning resident rainbow trout and steelhead and the potential for interbreeding is high assuming no assortative mating in sympatry (Figure 13). In 1992, a sexually mature female steelhead migrated into Umtanum Creek and exited the stream spent. This occurred during the peak of rainbow trout spawning activity in the creek. It is suspected that the **female** steelhead spawned with a resident rainbow trout because no male steelhead entered the stream through the trap that year. In addition, a spent female steelhead was collected adjacent to her redd, in association with mature male rainbow **trout in** Umtanum Creek during 1990. No other steelhead was collected in Umtanum Creek during 1990. Furthermore, during 1992, a steelhead redd and many rainbow trout redds were found within 200 m of each other in Big Creek during electrofishing surveys. The present spatial overlap illustrated in Figure 13 might represent minimums due to low steelhead abundance in the upper river. If, under **future conditions, the abundance of** steelhead were to increase **due to supplementation or natural recolonization, the extent of** spatial overlap would probably increase.

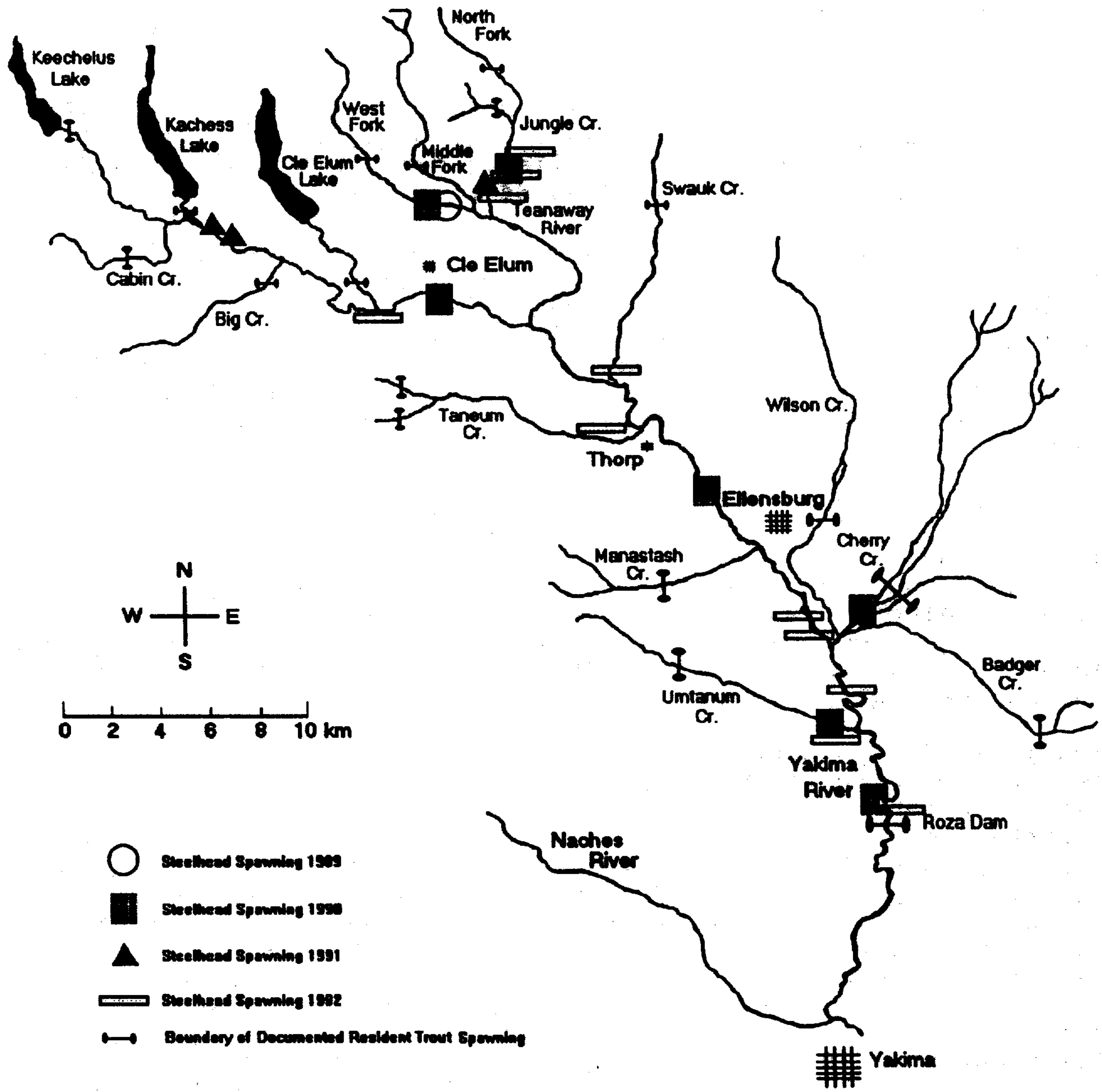


Figure 13. Map of the Yakima River basin showing the spatial distribution of spawning rainbow and steelhead trout within the upper Yakima basin. Data synthesized from WDW, YIN, and NMFS sources.

Objective II: Determine Rearing Characteristics

Sub-Obj. II.A: Characterize the distribution and abundance of resident trout rearing in tributaries above Roza Dam.

Task II.A.l: Conduct semi-quantitative population estimates in tributaries of the upper Yakima River above Roza Dam.

Accomplishments: Relative abundance of all species was conducted in the same sites as the trout population estimates. Results and methods for this task were combined with those of Task II.A.2 for the purposes of this report.

Task II.A.2: Conduat quantitative population estimate. surveys of trout rearing in tributaries above Rosa Dam.

Accomplishments: Using methods described by Hindman et al. (1991) and McMichael et al. (1992), sizes of salmonid populations were estimated once a year in index sites of 10 tributaries of the Yakima River above Roza Dam during the summer and fall of 1992. Some index sites were sampled during the summer and resampled during the fall to determine if variation in population size occurred between these two seasons. In addition, the feasibility of increasing the precision of population estimates was examined by performing enough electrofishing passes to get 90% depletion of the number of salmonids collected during the previous pass as opposed to 50% depletion used in previous years. Population size in index sites was estimated for the first time in four tributaries (Big, Swauk, Manastash, and Umtanum creeks), for the second time in one tributary (Jungle Creek), and for the third consecutive year in five tributaries (Cabin and Taneum creeks, and the Middle, North, and West forks of the Teanaway River). In addition to population estimates, measures of relative< abundance of all species present,, habitat area, stream discharge, water temperature, longitudinal streambed profile (thalweg depth), and gradient were recorded in the index sites. Relative abundance estimates for each species were calculated by adding the total number of individuals collected during the first two electrofishing passes and dividing by the habitat area. The standard deviation of thalweg depths was used as an index of habitat complexity (Kaufmann 1987). Semi-quantitative population estimates (Strange et al. 1989; McMichael et al. 1992) were conducted in three index sites of Badger Creek. Finally, all trout captured during electrofishing efforts were individually marked with anchor tags if they were greater than 175 mm long, and trout captured in the Teanaway River system were individually marked with visible implant (VI) tags if they were between 120 and 175 mm long.

Short-falls: Population size was only estimated for salmonids longer than 79 mm, because capture efficiency of small fish was low, and there appeared to be differential capture-efficiencies between salmonids greater than 79 mm and those less than 80 mm long. Most fish less than 80 mm were age 0+ (see task II.C.l).

High flow conditions in Badger Creek prevented estimation of population size using the multiple removal techniques applied in other streams. However, when discharge in Badger Creek decreased in December, relative abundance of all species was estimated+ using a single-pass electrofishing census (Strange et al. 1989). Population estimates for the lowest elevation section of Swauk Creek (SWK1) were made using snorkeling rather than electrofishing methods because the stream was dry except for two pools. Consequently, estimates were made in the two pools because they were the only available habitat (surface area of the two pools combined was 69 m^2).

Findings: Average density and biomass of all salmonids greater than 79 mm was different among tributaries in 1992, and similar within tributaries between 1991 and 1992 (Figures 14 and 15). During 1992, Taneum and Swauk creek had the highest salmonid density and biomass among the tributaries and Cabin Creek and the North Fork of the Teanaway River the lowest. Densities and biomasses of salmonids within individual index sites were more variable between years than averages for three index sites within a tributary between years. A strong positive correlation between population density and biomass occurred during all three years sampled (1990, $r=0.62$, $P=0.017$; 1991, $r=0.99$, $P<0.000$; 1992, $r=0.98$, $P<0.000$). Mean length of rainbow trout sampled in Yakima River tributaries appeared to be relatively similar between years and among tributaries (Figure 16), although the length-at-age of these fish may have been quite different (see task II.C.1). Furthermore, the condition factor of tributary-rearing rainbow trout appeared to be similar within tributaries between years:' (Figure 17).

Seasonal variation of salmonid density in tributaries of the' Yakima River was investigated by re-sampling several tributary{ index sites during the summer and fall. Population density-estimates did not appear to differ significantly between seasons based on index site re-sampling. Individually marked fish were infrequently recaptured between seasons and years, suggesting they may have moved from index sites between sampling efforts, died, or that there was high tag loss in tagged fish.

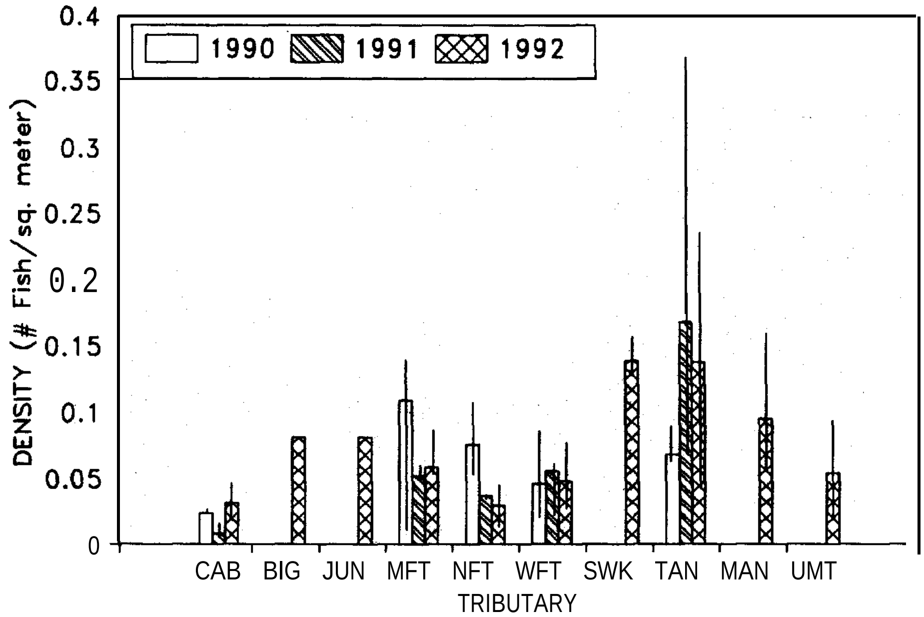


Figure 14. Average salmonid densities in three index sites within each of ten tributaries of the Yakima River during summer/fall of 1990, 1991, and 1992. Vertical lines are ranges in density for tributaries with more than one index site.

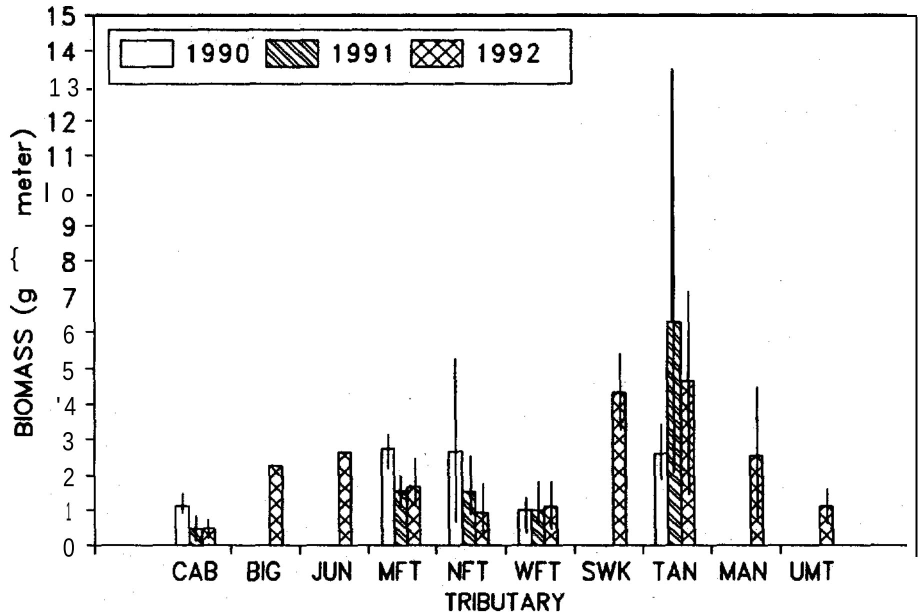


Figure 15. Average salmonid biomasses in three index sites within each of ten tributaries of the Yakima River during summer/fall of 1990, 1991, and 1992. Vertical lines are ranges in biomass for tributaries with more than one index site.

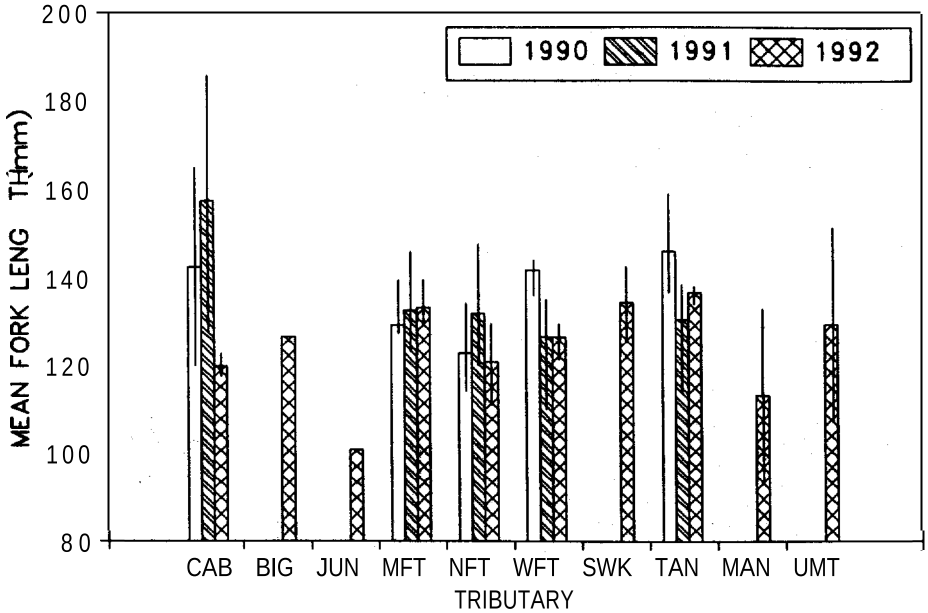


Figure 16. Average length (greater than 79 mm fork length) of rainbow trout in three index sites in ten tributaries of the Yakima River during summer/fall 1990, 1991, and 1992. **Vertical** lines are ranges in mean lengths for tributaries with more than one index site.

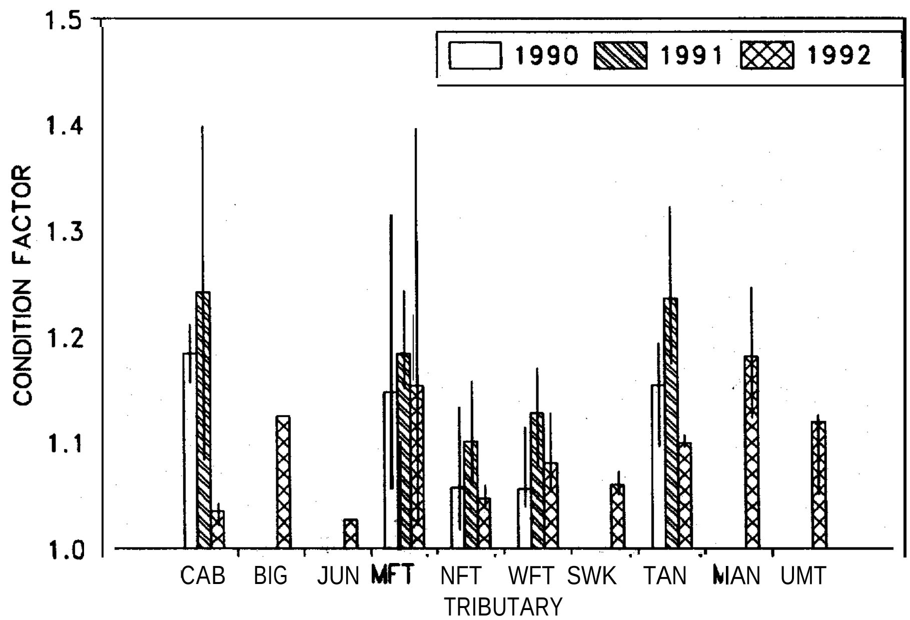
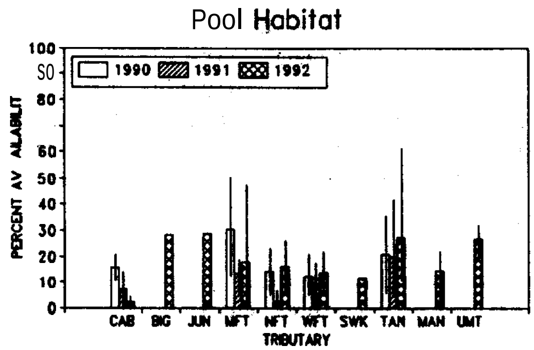


Figure 17. Average condition of rainbow trout (greater than 79 **mm** fork length) in ten tributaries of the Yakima River during summer/fall **1990,** 1991, and 1992. Vertical lines are **ranges** in average condition factor for tributaries with more than one index site.

Efforts were made to increase the precision of population estimates by multiple removal electrofishing methods **(Zippin** 1958) based on a 90% depletion curve as opposed to a 50% depletion curve. However, the precision gained using this method was considered insufficient to justify the time spent on additional electrofishing passes. Furthermore, the increased likelihood of electrofishing-induced mortality during additional passes, and the variability in electrofishing capture efficiency associated with changes in water temperature between passes (Reynolds 1983) may nullify the increase in efficiency contributed by this more precise technique.

Salmonid density was positively correlated to pool area and an index of habitat complexity (standard deviation of thalweg depths). There was a significant relationship between pool area and population density for 1991 (r-0.77, **P=0.001)** and 1992 **(r=0.58, P=0.004)** but not for 1990 **(r=0.28,** P-0.33). Pools were generally less than 30% of the available habitat (Figure 18). A strong positive correlation between population size and habitat complexity existed in 1992 **(r=0.85, P=0.0001).** Habitat complexity was not measured prior to 1992.

In general, rainbow trout accounted for the greatest proportion of **salmonid** density and **biomass in** tributaries of the Yakima River during 1992 (generally 60 to **100%),** and were broadly distributed throughout the basin, while other **salmonid** species (e.g. cutthroat, bull, and brook trout (6. ***fontfnalis);*** mountain whitefish ***(Prosopium williamsoni),*** spring chinook salmon) were observed less frequently (0 to 40% of **salmonid** density) and within a more limited distribution (Table 2). Rainbow trout were captured in all 10 tributaries sampled, and ***were*** observed in 26 of 27 index sites. This species appeared to inhabit a diversity of physical habitat types, and was found in association with many **salmonid** and non-salmonid species. **In** particular, there were strong positive correlations between rainbow trout and **longnose dace (*Rhinichthys*** cataractae) densities (r-0.50, **P=0.02),** and between rainbow trout and shorthead sculpin ***(Cottus confusus)*** densities **(r=0.64,** and **P=0.002).** Cutthroat trout, eastern brook trout, and bull trout were typically observed in high elevation tributary sections (sections 2 and 3 of tributaries). Cutthroat trout and eastern brook trout densities were positively correlated **(r=0.96, P<0.0000).** Although brook trout densities were strongly correlated with sculpin (unknown spp.) species density **(r=0.53,** P= **0.01),** this was not true for cutthroat trout or bull trout. Conversely, spring chinook salmon were typically observed in low elevation index sites of tributaries, in close association with other non-salmonid species, but not other **salmonid** species. Spring chinook were strongly correlated with torrent sculpin (C. ***rhotheus)* (r=0.58, P=0.005)** and with **redside** shiners ***(Richardsonius balteatus)* (r=0.76, P<0.0000),** but were most abundant where there were only low numbers of rainbow trout (see section **SWK1).** Although these analyses are preliminary, they a)



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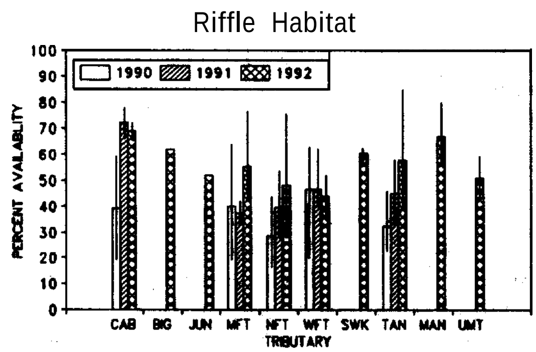

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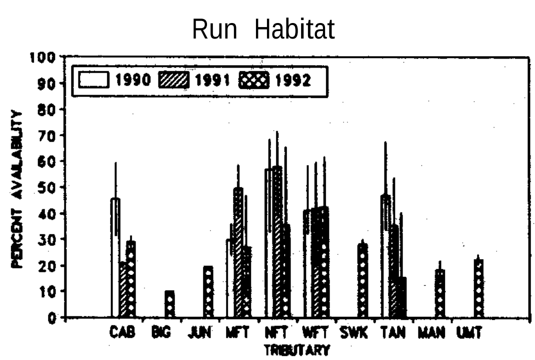


Figure 18. Percent availability of a) pool, b) riffle, and c) run habitat types in tributaries of the Yakima River during 1990, 1991, and 1992. Vertical lines are ranges in percent availability for tributaries with more than one index site.

Table 2. Relative density estimates ($\#/100\ m^2$) for all species by section in eleven tributaries of the **Yakima** River sampled during summer/fall 1992. Individual fish were sorted by species, and summed **across** two electrofishing passes within each 100 m study section.

Species[1] / Site[2]	RBT	CUT	EBT	HYB	BULL	SPC	HSH	SPD	LND	TOS	SHS	UNS	MWF	LSS	BLS	RSS	SQW	STB	LMP
CAB1	1.27	0	0.3	0	0	0.5	0	0.6	0.2	1.3	13.8	0	0	0	0	0	0	0	0
CAB2	3.3	1	0	0	0	0.4	0	0	0	0	11	0.2	0	0	0	0	0	0	0
BIG	12.7	0.5	0	0	0	0	0	0.8	0	2.8	13.5	22.4	0	0	0	0	0	0	0
JUN	98.9	0.5	0	0	0	0	6.3	0.5	3.1	6.3	6.3	0	0	0	0	0	0	0	0
MFT1	9.7	0	0	0	0	0.2	0	0.2	3.1	6.6	11.5	0	0	0	0	0	0	0	0
MFT2	a.8	0	0	0	0	0	0	0	19.2	3.7	0	13.6	0	0	0	0	0	0	0
MFT3	9.5	0.2	0	0.2	0	0	0	0	0.5	6.2	0	10	0	0	0	0	0	0	0
NFT1	7.9	0	0	0	0	0	0.1	0	13	2.5	6.5	0	0	0	0.2	0	0	0	0
NFT2	1.9	0	0	0	0	0	0.2	0	1.3	10	8.1	0	0.3	0	0	0	0	0	0
NFT3	2.1	2.1	0	0	0.4	0	0	0	0	0	9	0	0	0	0	0	0	0	0
WFT1	9.6	0	0	0.7	0	0	0	0.9	20.3	4.7	12.2	0	0	0.5	0	0	0	0	0
WFT2	7.8	0	0	0	0	0.2	0	3.4	10.4	8.9	0	9.4	0	0	0	0	0	0	0
WFT3	a.2	0	0	0	0	0	0	0.3	2.3	a.2	0.8	5	0	0	0	0	0	0	0
SWK1[3]	10.1	0	0	0	0	7.2	0	289.9	0	0	0	1.4	0	0	173.9	59.4	1.4	0	0
SWK2	58.5	0	0	0	0	0.5	0	0.5	40.6	10.6	63.3	0	0	0	0	0	0	0	0
SWK3	28.4	1.8	0	0	0	0	0	0	8.5	10	32.8	20.3	0	0	0	0	0	0	0
TAN1	25	0.3	0.2	0	0	0	0	0	0	1	9.7	0	0	0	0	0	0	0	0
TAN2	10.7	0	0.7	0	0	0	0	0	0	1.2	0	455	0	0	0	0	0	0	0
TAN3	5.2	1.4	2.1	0	0	0	0	0	0	1.6	4	22.6	0	0	0	0	0	0	0
MAN1	7.7	0	0	0	0	1	0	11.2	14.7	21.7	4.1	16.6	0	0	0.3	0.6	0	0	0
MAN2	3.9	1.1	2.5	0	0	0	0	0	0	6.1	2.5	86.4	0	0	0	0	0	0	0
MAN3	0	9.5	7.1	0	0	0	0	0	0	0	0.3	36.1	0	0	0	0	0	0	0
BAD1[3]	3.2	0	0	0	0	0	0	0	0	0	0	0	2.5	0	0.4	0	6.6	0.4	0.4
BAD2[3]	4.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BAD3[3]	34.7	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
UMT1	52	0	0	0	0	0	0	2.9	0	0	0	15.4	0	0	0	0	0	0	0
UMT2	1.6	0	0	0	0	0	0	31.2	0	0	0	9.9	0	0	0	0	0	0	0

[1] Species abbreviations as follows: RBT= rainbow trout, CUT= cutthroat trout, EBT= eastern brook trout, HYB= putative hybrid, BULL= bull trout, SPC= spring chinook salmon, HSH= hatchery steelhead, SPD= speckled dace, LND= longnose dace, TOS= torrent sculpin, SHS= shorthead sculpin, UNS= unknown sp. of sculpin, MWF= mountain whitefish, LSS= largescale sucker, BLS= bridgelip sucker, RSS= redside shiner, SQW= squawfish, STB= stickleback, and LMP= brook lamprey.

[2] Tributary names have been abbreviated as follows: CAB = Cabin Creek, BIG = Big Creek, JUN= Jungle Creek, MFT = Middle Fork of the Teanaway River, NFT = North Fork of the Teanaway River, WFT = West Fork of the Teanaway River, SWK = Swauk Creek, TAN = Taneum Creek, MAN = Manastash Creek, BAD = Badger Creek, and UMT = Umtanum Creek. Sections are numbered by increasing elevation within each tributary.

[3] Alternate relative abundance estimate techniques (snorkeling and single pass electrofishing) were used in these sections due to adverse flow conditions.

provide an initial assessment of species association patterns. For example, cutthroat trout and brook trout were found in close association during 1991 **(r=0.93, P<0.0000)** and 1992. Similar to 1992, the relative abundance of spring chinook salmon was strongly correlated with relative abundance of **redside** shiners **(r=0.97, P<0.0000)** during 1991.

Recommendations: Population densities should continue to be estimated in the five tributaries that have been sampled during the past three years to continue description of natural variation of **salmonid** densities through time. Furthermore, the continuation of sampling in two tributaries sampled for the first time during 1992 (Swauk and Umtanum creeks), should facilitate understanding of variability in trout abundance as a function of elevation in the basin. Thus, a longitudinal gradient within the basin would be formed between Cabin Creek at the highest elevation and Umtanum Creek at the lowest elevation. By including a mixture of index sites that would be sampled through time and space both spatial and temporal variation in population densities could be monitored.

Because a large amount of annual variability within index sites in tributary rearing survey estimates has been observed, another population estimate procedure may be needed which may minimize effects of fish movement and changes in local habitat conditions. A feasibility study in the North Fork of the Teanaway River should be conducted to determine a preferred method of sampling population densities. Methods such as those outlined by **Hankin** and Reeves (1988) which sample a larger proportion of the habitat than current methods should be evaluated.

Sub-Obj. **II.B:** Determine the general distribution and abundance of resident trout rearing in the **mainstem** Yakima River above Roza Dam.

Task II.B.l: Conduct population **estimates** in the **mainstem** of the Yakima River above Rosa Dam.

Accomplishments: Population estimates were completed during September and October for five pre-established sections of the Yakima River (McMichael et al. 1992). Using a driftboat electrofisher, trout were captured, marked during two successive nights, and then recaptured one week later during two successive nights. For the first time since the studies began, abundances of all other fish species observed *were* visually estimated.

Short-falls: The precision of estimating fish species densities other than trout is low,, because of the difficulties associated with visual estimation while electrofishing and netting (only trout are netted).

Findings: Densities of trout among **mainstem** index sections appeared to be distributed differently between 1991 and 1992 (Figure 19). In 1991, trout were distributed evenly among the four sections where estimates were calculated. In 1992, trout densities decreased in an upstream direction, with the exception of the Cle Elum section. Although the distribution of trout abundance appeared to be different between 1991 and 1992, the total estimated number and biomass of trout in the 25.1 km of river sampled were fairly similar. Total trout population and biomass estimates were 5,587 trout weighing 1088.1 kg in 1991, and 5,078 trout weighing 1018.7 kg in 1992. Comparisons **between** estimates from 1990. and those in 1991 and 1992 **were** not **included** because the techniques and equipment **differed between** *the* **two** time periods (McMichael et al. 1992). Over 98% of: all the trout captured in 1992 were rainbow trout. Cutthroat trout were-- captured infrequently in 1991 and 1992, but were captured in all of the **mainstem** sections except the Ellensburg section in 1992, and in the Cle Elum and Thorp sections in 1991. Eastern brook trout and a bull trout were captured in the **Cle Elum section** in 1992 .

At least 18 species (sculpins were identified **only** to **genus and** therefore represent a single **"species" for the purposes of** this part of the report) of fish were observed **during population** estimate activities. Mountain whitefish **were judged** to be 'the most abundant fish species present in four of the five **mainstem** sections sampled. Suckers **(largescale (*Catostomus macrocheilus*)** and bridgelip ***(C. columbianus))*** *were* the most **abundant species** in the lower canyon section but were also **among the most** abundant species in other sections. Rank abundance of **spring** chinook was among the top five in all of the sections. Northern squawfish

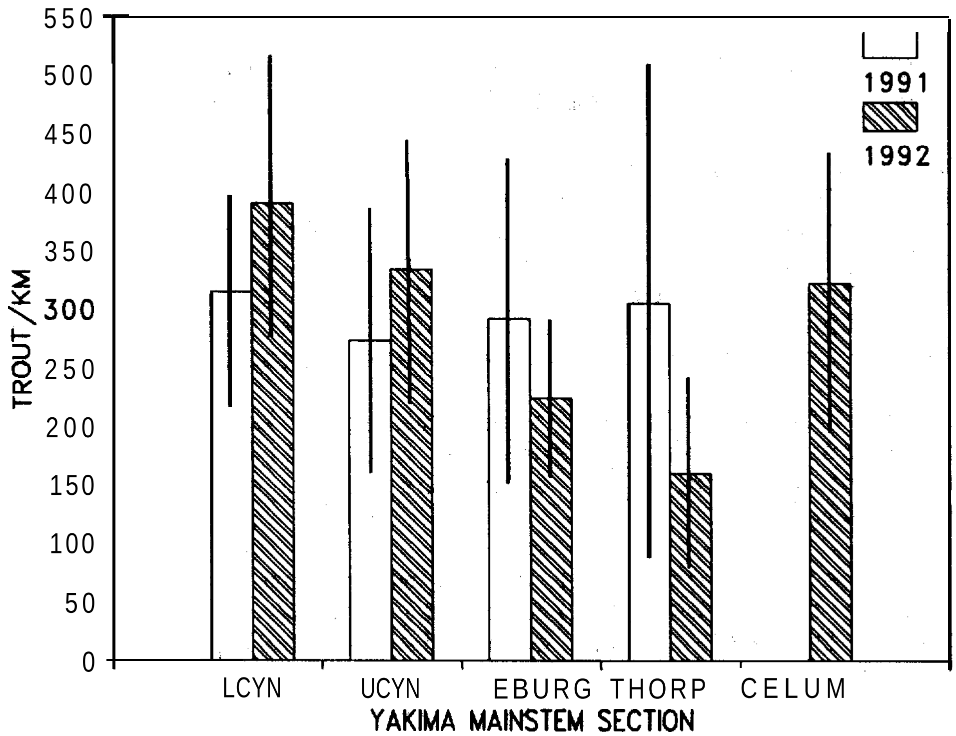


Figure 19. Population estimates of trout in five sections of the Yakima River during the fall of 1991 and 1992. LCYN = lower canyon, UCYN = upper canyon, EBURG = Ellensburg, THORP = Thorp, and CELUM = Cle Elum. Vertical lines represent ± 1 standard deviation.

(Ptychocheilus oregonensis) were collected in all five sections of the Yakima River. Three exotic species (pumpkinseed ***(Lepomis gibbosus)***, yellow perch ***(Perca flavescens)***, and carp ***(Cyprinus carpio))*** were observed in the upper canyon section although very few individuals were observed. Since 1992 marked the first time in which the relative abundances of these species was quantified, no comparisons from previous years *were* possible.

Recommendation: In order to better determine the abundance of non-trout species and their ecological relationship to salmonids, more effort should be applied to quantifying the distribution and abundance of these fish.

Sub-Obj. **II.C:** Develop a biological profile of resident trout rearing in tributaries and **mainstem** areas above Roza Dam.

Task **II.C.1: Determine age** composition, length-at-age relationships, growth rates, and movement patterns **of** rearing populations of resident trout. **(For** additional information about biological profiles of trout rearing in tributaries see Task II.A.2).

Accomplishments: Various methods were used to clarify movement patterns and generate information about fish growth. These included electrofishing in the **mainstem** Yakima River and its tributaries **(McMichael** et al. **1992),** trapping in Wilson, Cherry, and Umtanum creeks in the spring, and analysis of angler tag reports. Trapping was attempted for the first time during **1992** in Wilson and Cherry creeks, and for the whole spawning season. for the first time in Umtanum Creek. Age data is available only for fish collected in the fall of 1990 and 1991. Over 7,500 trout have been tagged and released since early 1990. Electrofishing efforts and angler tag reports have yielded a total of 109 tagged fish recaptures in tributaries and 422 in the mainstem.

Shortfalls: Current methods of detecting fish movement were not designed to determine continuous movement of fish so precise estimates of movement were not possible. Traps in Wilson and Cherry creeks were insufficiently designed to function effectively during numerous periods of high debris loadings, thus data obtained were of limited value. Analysis of scale samples is behind schedule.

Findings: Movement data from the past three years of electrofishing and angling tag recoveries shows that most (89%) of the 109 trout recaptured in tributaries were tagged in tributaries, although fish tagged in the **mainstem** were **found in** Cherry and Wilson creeks, as well as the Cle Elum River (Table **3).** Most of the 422 tagged **trout (97%)** that were recaptured in the **mainstem** had been tagged in the mainstem. The other 3% were tagged in the following tributaries during electrofishing surveys: Umtanum, Badger, Cherry, Manastash, Swauk, and Big' creeks.

Trapping efforts in Umtanum and Cherry creeks showed that movement between the **mainstem** and these two tributaries did occur (for more information see Task I.A.l). Of the 22 tagged fish migrating into Umtanum Creek during the spawning ***season*** in 1992, 82% had been tagged in the Yakima River **mainstem** and the other 18% had received tags during electrofishing spawning surveys in Umtanum Creek in 1990 and 1991 (were repeat spawners in 1992). In 1992, a total of 333 untagged trout less than 217 mm long

Table 3. Cumulative (cum.) and annual (1992) information on movement and cumulative information on growth rates of tagged rainbow trout that were recaptured in tributary and mainstem Yakima River study sections from 1990 to 1992 electrofishing surveys and angler tag returns.

Stream or Section	No. Recaptured 1992	No. Recaptured Cum.	Percent recaptured from Tributaries 1992	Percent recaptured from Tributaries Cum.	Percent recaptured from Mainstem 1992	Percent recaptured from Mainstem Cum.	Growth rate[a] (mm/day)
Tributaries							
Umtanum	0	6	0	100	0	0	0.02 (5)
Badger	2	3	100	100	0	0	0.03 (2)
Cherry	0	12	0	42	0	50	0.13 (2)
Wilson	18	46	83	93	17	7	0.12 (24)
Manastash	6	6	100	100	0	0	0.19 (4)
Swauk	3	3	100	100	0	0	0.01 (3)
Taneum	4	6	100	100	0	0	0.03 (4)
Teanaway[b]	8	21	100	100	0	0	0.06 (12)
Cle Elum	2	2	0	0	100	100	c
Big	1	1	100	100	0	0	0.09 (1)
Cabin	'1	2	100	100	0	0	C
Trib. Total / Mean	45	109	88	89	12	11	0.09 (57)
Mainstem							
L. Canyon	206	274	1	2	99	98	0.12 (125)
U. Canyon	37	69	0	3	100	97	0.08 (30)
Ellensburg	23	30	4	10	96	90	0.12 (25)
Thorp	9	23	11	4	89	96	0.12 (13)
Cle Elum	13	22	8	5	92	95	0.11 (18)
Nelson	1	1	0	0	100	100	C
Crystal	3	3	0	0	100	100	C
Mainstem Total / Mean	292	422	2	3	98	97	0.11 (214,)

[a] Numbers in parentheses are sample sizes used for growth rate estimates.
[b] North and Middle forks of the Teanaway River combined.
[c] Length data not available for recaptured fish.

emigrated from Umtanum Creek while the trap was bsing operated, indicating that some trout produced in Umtanum *Creek* spend part of their life in the **mainstem** Yakima River. In addition, 14 fish that had been tagged at the trap during 1991 and 1992 were recaptured during **mainstem** electrofishing surveys in **the summer-**fall, 1992. Three adult trout that were tagged moving upstream through the Cherry Creek trap in March *were* recaptured during **mainstem** electrofishing surveys in the summer-fall, 1992. It appeared that most of the adult trout that moved from the **mainstem** to the tributaries did so during the spawning season. It is likely that most of the trout moved back into the **mainstem** during this time as well. Thus, immigration and emigration to and from spawning areas appeared to occur over a relatively short time span.

Mean trout growth rates (calculated using data from individually tagged and recaptured fish from 1990 to 1992) varied widely among tributaries, ranging from 0.01 mm/day in Swauk Creek to 0.19 mm/day in Manastash Creek (Table 3). Variation in growth rates may be from sampling artifacts (young fish generally **grow faster** than old ones), genetic differences, or environmental differences. Trout growth rates in **mainstem** areas were more consistent, ranging from 0.08 mm/day in the upper canyon section to 0.12 mm/day in the Thorp section (Table 3). The mean growth rate of trout in all tributaries combined was **0.09** mm/day, which was slightly lower than the **mainstem** mean of 0.11 mm/day.

Length-at-age of trout collected in the fall of **1990** was smaller in tributaries than in **mainstem sections,** except for Cherry and Wilson creeks (Table 4, Appendix B). Trout that were collected for scale analysis represented the **size range** of the fish sampled, but may not have represented the true proportional abundance of each age class. For this reason, no analysis of percent composition of trout by age class was conducted. For this report, tributaries and **mainstem** sections were grouped because of small sample sizes (Table 4). Tributary **and mainstem** groupings **(n=4** and 2 respectively) were made according to presumed similarities in fish growing conditions which were based primarily on geography and water temperature. Mean size of fish within the Cherry/Wilson group and the **mainstem** (sections 1-5) *were* similar to one another, **as** were fish within the **Manastash/Taneum/Swauk** and Teanaway groups. Age 0+ fish in Cherry/Wilson and the **mainstem** for example, had mean lengths of 132 mm and 174 mm respectively. In contrast, age 0+ fish in **Manastash/Taneum/Swauk,** all forks of the **Teanaway River, and** Umtanum Creek had mean lengths of 67, 65, and 60 mm respedtively. Trout length data collected during population estimates in the **mainstem** during the summer-fall of 1990, 1991, and 1992 are summarized in Figure 20. Only trout sampled in the lower canyon section tended to exhibit an apparent consistent increase in mean length between years, from 27i mm in 1990, to 278 mm in 1991, to 281 mm in 1992. The mean length of trout in the upper canyon,

Table 4. Length-at-age of rainbow trout collected for SPA during 1990 in the **mainstem** Yakima River and tributaries, and during 1991 in the **mainstem** only. A cross-section of trout size classes was collected. Trout collected from areas that had presumed similar growing conditions, based on geography and water temperature, were grouped to increase sample sizes.

Group		**Age** 0+	**1+**	**2+**	**3+**	**4+**	**5+**
UMT	N	6	39	2			
	Mean	60	105	152			
	Range	(49-75)	(69-138)	(140-185)			
CHR	N	20	24	10	4		
WIL	Mean	132	260	312	376		
	Range	(98-190)	(175-370)	(225-366)	(336-397)		
MAN	N	21	99	21			
TAN	Mean	67	132	160			
SWK	Range	(55-85)	(96-187)	(134-215)			
NFT	N	40	62	39	2		
MFT	Mean	65	124	152	196		
WFT	Range	(48-85)	(90-194)	(123-191)	(185-206)		
MAIN.	N	1	22	20	2	2	1
l-5	Mean	174	253	273	334	386	385
1990	Range		(147-260)	(170-356)	(327-340)	(356-416)	-
MAIN.	N	2	88	52	19	5	
l-5	Mean	126	201	279	332	352	
1991	Range	(92-160)	(143-271)	(203-342)	(261-405)	(323-390)	
MAIN.	N	6	4				
6-7	Mean	171	214				
1990	Range	(1X-230)	(156-305)				
MAIN.	N	3	30	7	1		
6-7	Mean	104	168	222	235		
1991	Range	(100-108)	(124-252)	(172-302)	-		

Ellensburg, and Thorp sections all appeared **to decrease over the** last two years; whereas the Cle Elum section, after a dramatic apparent decrease between 1990 (282 mm) and 1991 (237 mm), appeared to increase (239 mm) slightly in 1992. In 1990, trout in the Cle Elum section appeared to have the greatest mean **length** of all the **mainstem** sections, but for each of the past two years trout in the lower canyon were apparently the longest.

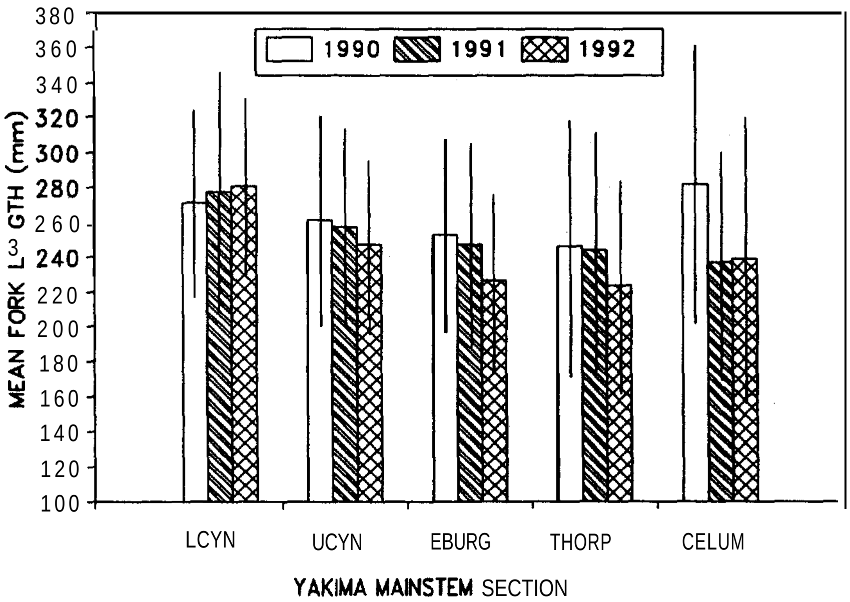


Figure 20. Mean fork length (mm) of fish captured during fall population estimates in five Yakima River **mainstem** sections. Vertical lines represent ± 1 standard deviation. LCYN = lower canyon, UCYN = upper canyon, EBURG = Ellensburg, THORP = Thorp, and CELUM = Cle Elum.

Recommendations: A technique used to monitor the continuous movement of trout, such as radio telemetry, should be adopted so that movements that are critically important to trout (e.g. **spawning migrations) can be understood.** In addition, the magnitude of trout moving into and **out of tributary** streams **and** the associated biological characteristics of those fish should be studied using a trap design suitable for the streams to be trapped. Scale samples taken from fish during 1992 and before should be aged and analyzed.

Task II.C.2: **Genetically** assess population **structure** (resident vs. **anadromous)** of trout **populations** rearing above Roaa Dam.

Accomplishments and Findings: See description under Task I.C.2.

Sub-Obj. II.D: Estimate the current and future probability of spatial and temporal overlap in rearing areas utilized by resident trout and steelhead above Roza Dam.

Task II.D.1: Synthesize information generated from work on resident trout (Sub-Objectives II.A, II.B, and II.C) with that available from other workers on steelhead.

Accomplishments: Typically, rainbow trout and steelhead juveniles are not distinguishable from one another in the field except during the spring when steelhead smoltify. Therefore, steelhead rearing distributions were inferred from data collected during the spring. Data from 1991 and 1992 spawning surveys and trapping efforts (Task I.A.l and I.B.l) were utilized to identify the spatial overlap of resident trout and juvenile steelhead. smolts. Fish movement information from Roza, Prosser and McNary dams was obtained from the YIN and WDF.

Short-falls: The occurrence of overlap at large spatial scales (e.g. stream reach and tributaries) as demonstrated by these studies does not preclude partitioning at, smaller spatial scales. Analysis of overlap at the channel unit and microhabitat spatial scale was beyond the scope of the data collected. Because overlap at these smaller spatial scales has not-been examined, the full extent of spatial overlap cannot be addressed. Discrimination of juvenile steelhead and resident trout is difficult in the field. This is so even during the spring period of smoltification and emigration when it might be expected that discrimination would be easiest. In addition, resident trout can display coloration that is characteristic of smolts during the spring and fish which resemble the coloration of resident trout may actually be steelhead pre-smolts. The- occurrence of fish that were classified as either smolts or rainbow trout when tagged and were then later recaptured above Roza Dam or at Roza, Prosser, and McNary dams suggests that during the spring, some steelhead and rainbow trout may have been incorrectly identified (Table 5). Misidentification of fish that were tagged as rainbow trout was low (1%), but if sizes of rainbow trout tagged. (most rainbow trout that were tagged were larger than 175 mm) were more representative of the sizes in the population then misidentification may have been higher. The percent of recaptured fish tagged as smolts that were recaptured as rainbows was 33%, although the sample size was quite small. In addition, the location at which a smoltified fish is captured may not reliably indicate where it had reared, since smolts may have already begun seaward migrations.

Table 5. Number of steelhead smolts **(N=52)** and resident rainbow trout **(N=5,894)** tagged and recaptured by WDW above Roza Dam, including tagged fish reported in migrant sampling at Roza, Prosser and **McNary** dams. Smolts were identified by silvery color, absence of parr marks, dark pigmentation of fins and the streamlining of overall form.

	Taaaed smolts		Taaaed rainbows	
RECAPTURED	As Smolts	As Rainbows	As Smolts	As Rainbows
Above Roza	0	1	1	553
At **Roza**[a]	2	0	0	1
At **Prosser**[a]	0	0	3	0
At Mc **Nary**[b]	0	0	1	0
TOTAL	2	1	5	554

'Data from Yakima Indian Nation
[b]**Data** from Washington Department of Fisheries

Findings: The potential for spatial overlap between steelhead and resident trout during the rearing period would be expected to be high if steelhead abundance increases in the upper Yakima River. Even though steelhead abundance in the upper Yakima River is low, spatial overlap is high. All of the spring electrafishing surveys in the tributaries and **mainstem Yakima** River in which steelhead smolts were captured also had rainbow trout or steelhead pre-smolts'(Figure 21). In addition, other resident trout (brook and cutthroat trout) were also present in some of the surveys (Figure 21). Spatial overlap between resident trout and juvenile steelhead occurred in the entire **mainstem** Yakima River and the lower elevation'portions of most tributaries (Figure 22). Instances of temporal overlap within the same habitat unit was also documented, but observations were few due to the way data was collected.

Recommendations: In order to better define spatial overlaps between, and densities of, juvenile steelhead and rainbow trout, techniques should be developed to facilitate identification of juvenile steelhead and rainbow trout during non-migratory periods.

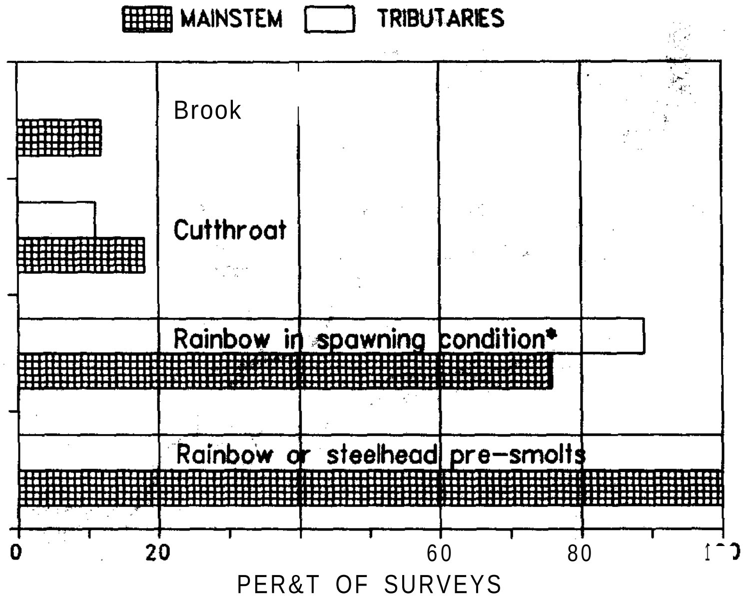


Figure 21. Percent of spring **electrofishing surveys** from.1990 to 1992 in which steelhead smolts were present and that also had resident trout included in the sample. * Rainbow in spawning condition refers to sexually mature or recently spent trout and represents a resident life history. The total number of spring electrofishing surveys in which smolts were observed and the number of smolts observed were: **Mainstem - 17/44;** tributaries **- 9/18.**

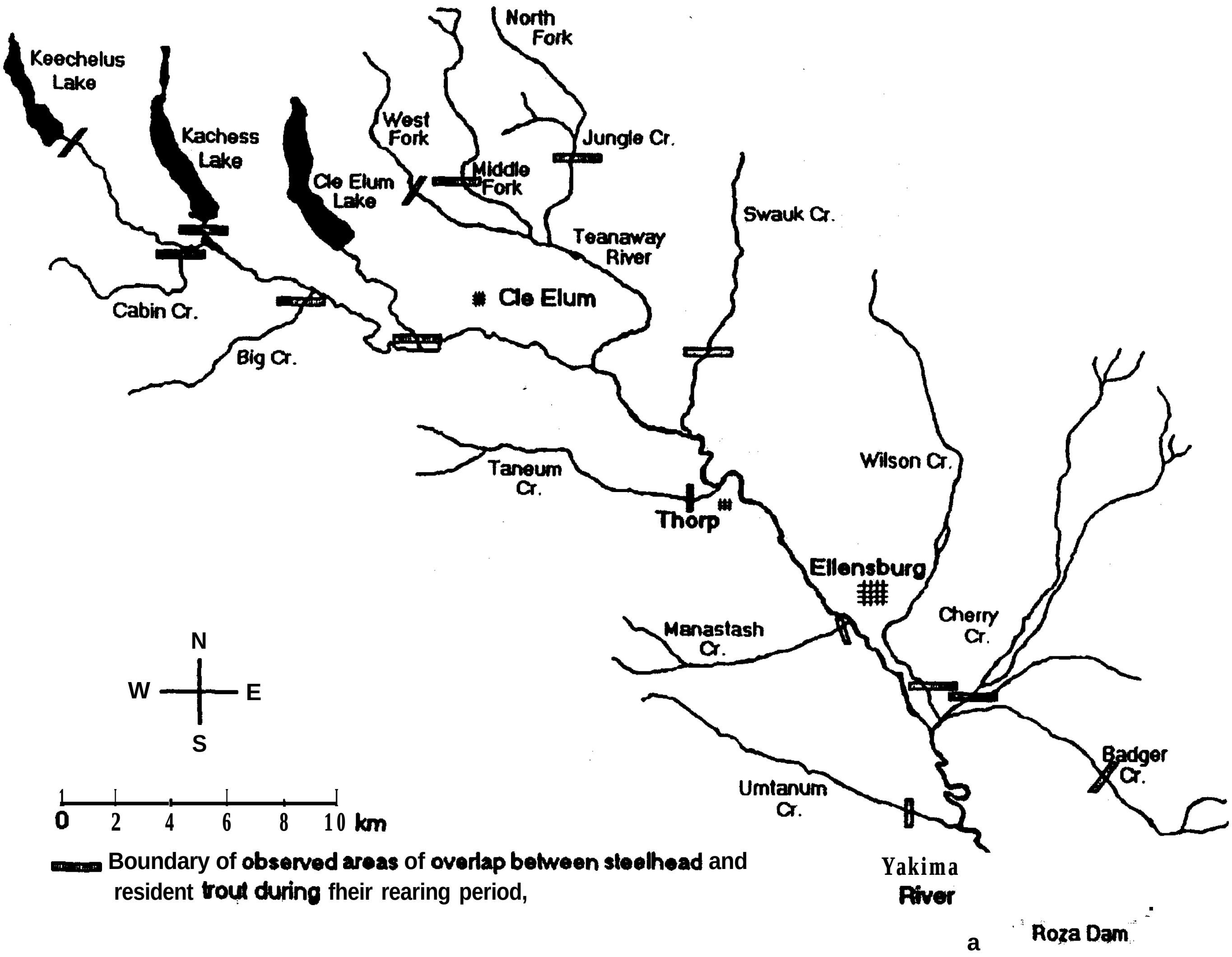


Figure 22. Spatial overlap between juvenile wild steelhead and resident trout in the upper Yakima Basin. Number of steelhead smolt observations = 198.

EXPERIMENTATION PHASE

Efforts related to this aspect of the project consisted of coordinating, performing, and evaluating the second season (of four years total) of experimental hatchery steelhead smolt releases in the Teanaway basin. Evaluation included monitoring the movement and interactive behavior of salmonids observed, analyzing data from 1992 sampling, and preparing an annual report for FY 1991. Steelhead broodstock for the production of experimental fish for the 1993 and 1994 releases were collected at Prosser Dam.

The general experimental design for this phase of the project centered on the use of two treatment streams (supplemented, hatchery steelhead introduced) and two reference or control stream (unsupplemented, no hatchery steelhead introduced). Hatchery-reared steelhead smolts were released into Jungle Creek, a tributary to the North Fork of, the Teanaway River (Figure 23). Thus Jungle Creek (referred to hereafter as T_T to represent a small tributary treatment stream) was used as one treatment stream. The North Fork of the Teanaway River (referred to hereafter as M_T to represent a large treatment stream) was considered the other treatment stream because the hatchery fish moved into the North Fork as they exited Jungle Creek. Jack Creek (referred to hereafter as T_C to represent a small tributary control stream) was used as one control., stream. The other control stream was the Middle Fork of the Teanaway River (referred to hereafter as M_C to represent a larger tributary control stream). Both Jungle (T_T) and Jack (T_C) creeks flow into the North Fork of the Teanaway River (M_T). Hatchery steelhead were prevented from immigrating into Jack Creek from the North Fork of the Teanaway. Underwater behavioral observations were conducted at fixed index sites in treatment and control streams in an attempt to assess the extent and outcome of agonistic interactions among hatchery steelhead, resident trout, and naturally-produced juvenile spring chinook salmon. The hatchery-reared steelhead used in this study were progeny of hatchery and wild adult steelhead collected at Prosser Dam on the lower Yakima River. The juvenile steelhead were reared at the Yakima Hatchery and at the Nelson Springs Raceway. It is possible that steelhead smolts produced by YFP facilities would behave differently than those used in this study. The results from this study, however, do provide valuable information on interactions between hatchery-reared steelhead smolts and resident trout. The general study methods were similar to those reported in the FY 1991 annual report (McMichael et al. 1992).

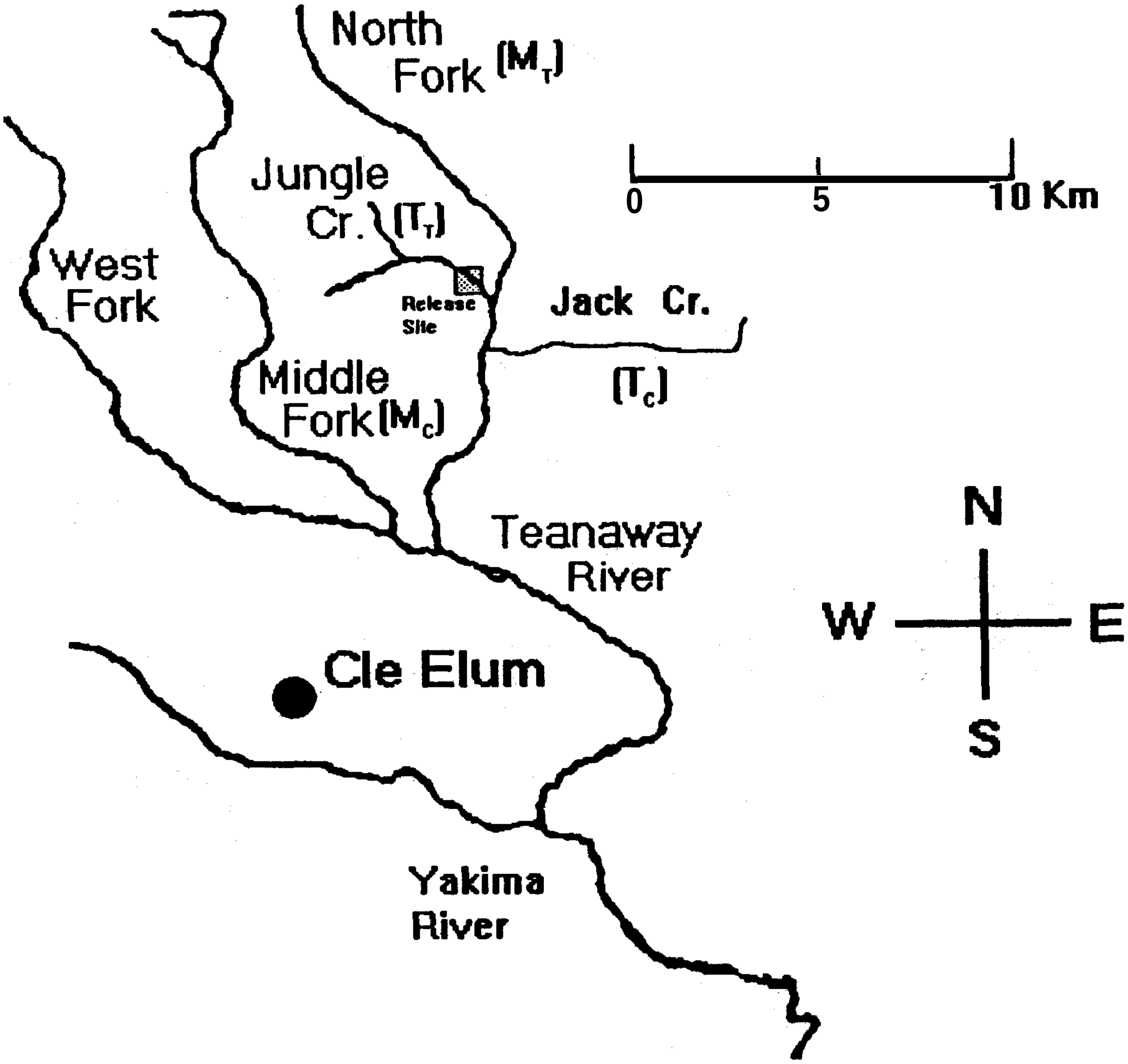


Figure 23. Map of the study area for the smolt release study of the experimentation phase. The upper Teanaway River basin is shown with the treatment and control streams **labled.**

Objective III. Assess-acts of hatchery steelhead **smolt** releases on resident **trout.**

Sub-Obj. **III.A.** Determine whether hatchery steelhead (HSH) smolt releases impact trout in the treatment stream.

Underwater observations (snorkeling) were performed in T_T and T_C from May 1 to October 7 and in M_T and M_C **from** May 13 to October 7. For the period between **May 1** and 28 [considered to be the **HSH** smolt outmigration period (Wagner et al. **1963)],** the numbers of each species of fish observed, **as well** as the number **and rate of** behavioral interactions are summarized in the upper portion of Table 6. The lower half of Table 6 shows corresponding data for June 3 through October 7, 1992 (which relates to task III.B.2).

Task **III.A.1.** Determine whether **HSH smolt releases** displace resident **trout/steelhead.**

Accomplishments: Underwater behavioral observations were useful for examining small scale (within a 1 m^2 area) physical displacement of trout by HSH. Some such small scale displacements were observed. Mid-scale displacements (out of a small tributary) were monitored with downstream migrant traps in T_T and T,. Screw trap data provided useful information on larger-scale (out of a drainage) displacements **(M_T and M_C).**

Short-falls: Poor water visibility **caused by** high turbidity during spring run-off delayed sampling **in two (M_T** and **M_C)** of **four** study streams for the -first 10 **days of the observation period.** However, turbidity **was low enough in T_T and T_C creeks** that **they** were sampled for the entire period.

Table 6. Data from underwater observations of fish in control (T, and M_C) and treatment streams (T_T and M_T) in the Teanaway River basin between May 1 and May 28, and between June 3 and October 7, 1992.

Stream	Obs. Time (min)	Number of fish observed[a] RBT	CUT	EST	SPC	HSH91	HSH92	TRT/m	HSH/m	Interactions No.	Int/f/m[b]
Mav 1 to Mav 28											
T_T	1559	113	11	0	0	19	3215	0.08	2.21	136	18.3
M_T	419	20	0	0	0	0	217	0.05	0.45	20	30.8
T_C	520	207	19	6	0	0	0	0.42	0.00	29	27.6
M_C	467	67	1	0	0	0	0	0.16	0.00	21	35.3
June 3 to October 7											
T_T	288	91	0	0	0	0	116	0.31	0.39	50	161.9
M_T	951	347	0	0	6	0	363	0.36	0.46	68	37.4
T_C	219	112	11	18	0	0	0	0.63	0.00	15	79.4
M_C	1053	721	5	0	41	0	1	0.74	0.00	123	61.6

[a] RBT = rainbow trout or wild steelhead presmolt, CUT = cutthroat trout, EBT = brook trout, SPC = spring chinook salmon, HSH91 = hatchery steelhead released in 1991, HSH92 = hatchery ateelhead released in 1992. TRT/m = total number of trout observed per minute, HSH/m = total number of HSH observed per minute.
[b] Int/f/m = Number of interactions observed per fish (all salmonids combined) per minute (x 10^{-4}).

Findings: During the first two weeks following releases of HSH, resident trout were displaced in the treatment streams (T_T and M_T). A displacement was defined to have occurred when a fish moved away from a relatively fixed location due to another fish's actions. Physical contact was not a requirement for a displacement classification (some fish were "crowded out" without physical contact taking place). The incidence of displacement decreased over time as emigration progressed and several displaced trout were observed returning to apparent preferred locations. Displacement was not detectable at a large or mid-scale, but was apparent within a small scale (e.g. within a pool). Displacement was less apparent in 1992 than it was in 1991, possibly due to the higher rate of HSH smolt emigration in 1992. Hatchery steelhead emigrated quickly after they were released (80% of the fish captured emigrating from M_T were captured within four days following the first release). The rate of wild steelhead and trout emigration did not increase following HSH releases, suggesting that wild salmonids were not being displaced over large spatial scales (Figure 24). The number of interactions per fish per minute (all salmonids combined) was, in most cases, higher in the control streams than it was in the treatment streams (Table 6).

The traps at the mouths of T_T and T_C provided information on the migration of trout out of these small streams during the period of HSH releases and through mid-summer. The T_T trap was not installed until the third release of hatchery steelhead. Very few trout emigrated from T_T while many more exited T_C (Table 7). Flow in T_C was intermittent by July 29 and it was dry by August 12, which may account for the larger number of resident fish leaving. Two HSH apparently **passed** the weir panels in T_C and were subsequently recaptured moving downstream through the trap. Flow in T_T was slightly higher during this period which may indicate that, for the latter part of the summer, T_C may not be an adequate control for T,.

Table 7. Data for salmonids trapped moving downstream past the mouths of T_T and T_C creeks between May 5 and August 12, 1992.

Species Group[a]	T_T (Jungle Creek)			T_C (Jack Creek)		
	No.	Length FL(mm)[b]	SD	No.	Length FL(mm)[b]	SD
RBT	7	78	34.6	104	98	31.8
WSH	1	151		0	-	
HSH	407	179	23.4	2	204	36.1

[a] RBT = rainbow trout and steelhead presmolts, WSH = wild steelhead smolts, HSH = hatchery steelhead.
[b] Mean fork length.

Recommendations: Monitor displacement rates out of **the release** stream **(T_T) when** HSH are released to enumerate outmigration of resident trout that may be displaced by hatchery steelhead.

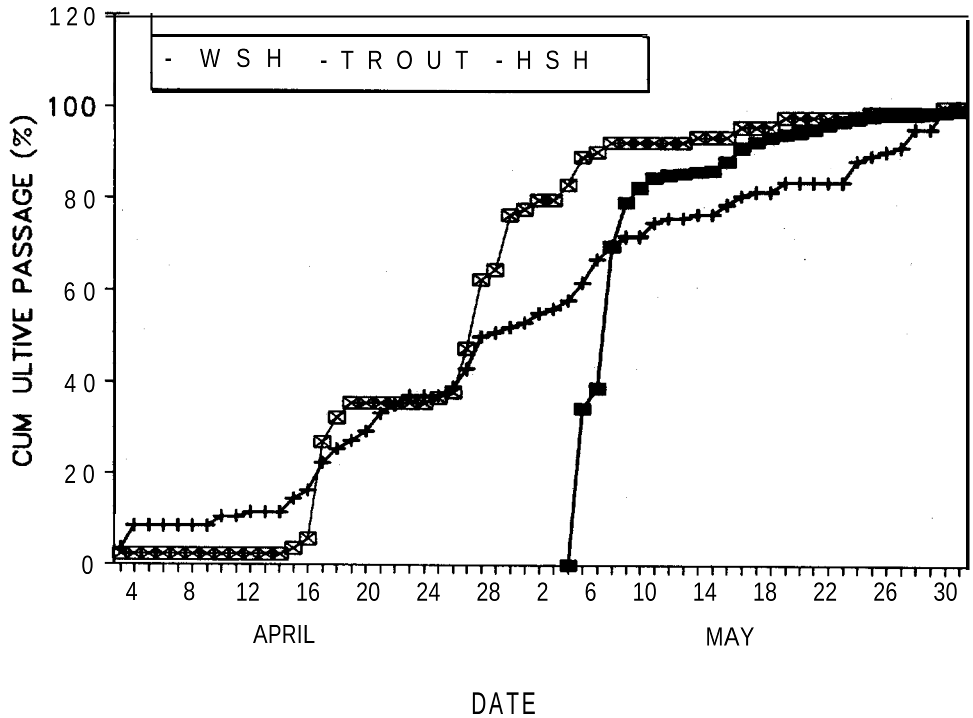


Figure 24. Cumulative passage of wild steelhead (WSH), resident trout and steelhead presmolts (TROUT), and hatchery steelhead (HSH) at the screw trap near the mouth of the North Fork of the Teanaway River (M_T) from April 4 through May 31, 1992. The first release of hatchery steelhead took place on May 3. The second and final releases were on May 5 and 10, respectively.

Task **III.A.2.** Assess the extent and outcome of agonistic interactions **between HSH smolts** and **resident** trout.

Accomplishments: Over 200 agonistic encounters were observed by direct underwater observations (snorkeling) between-May 1 and 28. Dominance-subordinance relationships were observed during these encounters.

Short-falls: High densities of **HSH** near the release site made it difficult for samplers to differentiate between some hatchery and wild fish. The quality of fin marks applied to hatchery steelhead released in 1992 was poor, making it difficult to positively identify some **hatchery** fish. Fish that were not identified as to hatchery or wild origin were not included in the analyses.

Findings: Size influenced on the outcome of agonistic interactions. Larae fish dominated smaller fish in all of the encounters observed in 1992. In 1991, large fish dominated smaller fish in 69% of the cases. In both years **hatchery** steelhead were on average larger than wild **steelhead, which** in turn were larger than resident trout or wild steelhead presmolts (Figure 25).

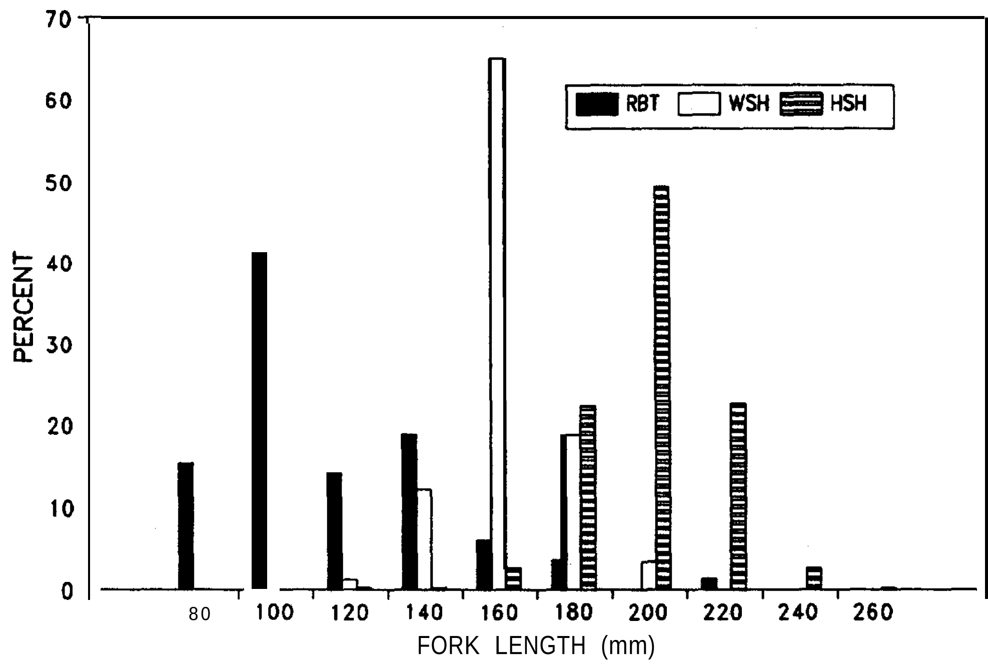


Figure 25. Length frequency histogram of rainbow trout (and wild steelhead presmolts) (RBT), wild steelhead smolts (WSH), and hatchery steelhead smolts (HSH) captured at the screw trap operated near the mouth of the North Fork of the Teanaway River **(M_T)** between April 4 and Way 31, 1992.

In control streams (T_C and M_C) most interactions were among rainbow trout, and between cutthroat and rainbow trout. The majority of interactions observed between May 1 and 28 in the treatment streams (T_T and M_T) were between hatchery steelhead and resident trout (Figure 26). Interactions observed consisted of aggressive displays, threats, chases, nips, and butts. Sixty-nine percent of the interactions observed during May involve& hatchery steelhead and resident trout. Hatchery steelhead dominated resident trout in 99% of those interactions. During 1991, HSH also dominated resident trout *in* most contests however; more reversals (where resident trout dominated hatchery steelhead) were observed during 1991 (45%) than in 1992 (4%):

Recommendations: Underwater observations should be continued as they have been done in the past. More emphasis should be placed on determining the impacts these encounters have on variables such as growth.

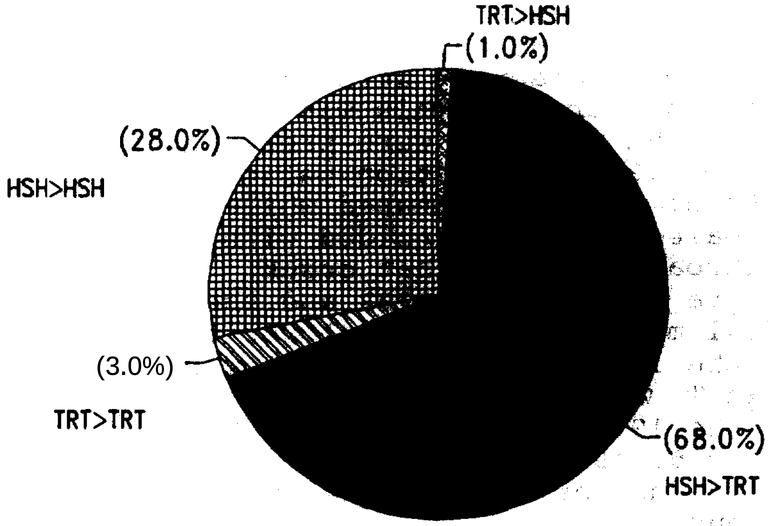


Figure 26. Dominance-subordinance relationships between resident trout (TRT) and hatchery steelhead (HSH) expressed as percentages of total aggressive encounters in T_T and M_T combined), between May 1 and 28, 1992. The group preceding the > symbol denotes the dominant group (e.g. HSH>TRT = hatchery steelhead were dominant over resident trout).: Total number of agonostic encounters was 153.

Task III.A.3. Determine whether precocious HSH smolts interbreed with resident trout.

Accomplishments: The occurrence of interbreeding was explored during snorkeling survey activities. The proportion of HSH that were precocial males was quantified by examination of two of the three release groups sampled (each N = 50) at the time of their release into T_T. Precocity was determined using methods described in McMichael et al. (1992).

Short-falls: No observations of attempted mating between precocial HSH and other fish were made. However, our methods were primarily targeted at examining other behavioral interactions. Incidence of precocialism was not determined for the fish released on May 5.

Findings: Precocial male HSH accounted for 2% and 0% of the fish sub-sampled on the May 3 and May 13 release dates, respectively. No precocial males were observed attempting to interbreed with resident trout in any stream. 'This. was similar to 1991, when a total of 4% of the HSH released were precocial males. During the latter part of the 1991 outmigration period (May 29 to June 14) however, over 26% of the HSH captured while exiting T_T were sexually mature males. This coincided with the spawning time of rainbow and cutthroat trout in that *creek.* No sexually mature resident trout were observed in 1992 and the incidence of residual precocial male HSH was much *lower* than the previous year, therefore the likelihood of gene flow between HSH and resident trout in T_T was probably lower in"1992 than in 1991. A female HSH from the 1991 release group (HSH91) was observed on an active redd on May 5, 1992, however, the presumed mate was not identified. It is unclear whether the other fish was another HSH or a resident trout.

Recommendations: All three release groups should be sampled to determine the percentage of precocial male steelhead released in 1993. Investigate relations between the incidence of precocialism and residualism rates.

Task III.A.4. Compare food habits between HSH smolts and resident trout during the steelherd outmigration period.

Accomplishments: Staff and students at Central Washington-. University (CWU) performed this task and task III.B.3 through a direct contract with BPA and results will be reported separately: by CWU. WDW staff provided coordination and logistical support.

Sub-Obj. III.B. Evaluate the incidence of residualism by HSH and determine impacts to rearing resident trout.

Task III.B.l. Determine the distribution and **relative** abundance of hatchery steelhead residuals in **the** Teanaway drainage.

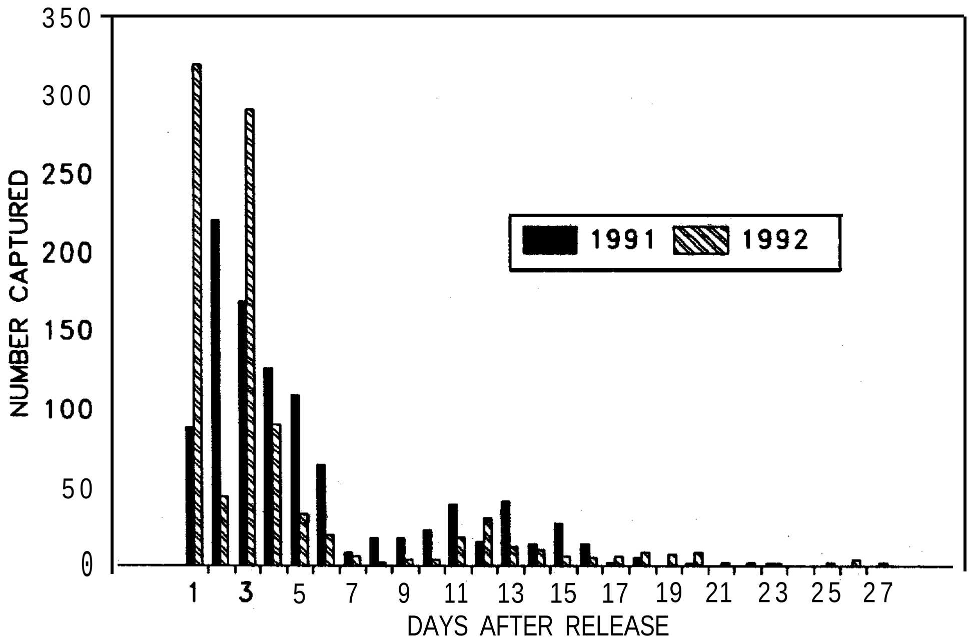
Accomplishments: Distribution of residual HSH was determined by snorkeling and/or electrofishing at various locations, and relative abundance was determined by trapping, underwater observations, and population estimates. The population estimates used for this phase of the study, with the exception of Jungle Creek **(T_T),** were the same as those reported in the Baseline Section of this report.

Short-falls: The relative abundance of residual hatchery steelhead was difficult to gauge primarily because the capture efficiencies of the traps at the mouths of the North and 'Middle forks of the Teanaway River were difficult to calculate. Trapping efficiency tests were of limited value due to small sample sizes and use of some fish that residualized between the release sites and the traps.

Findings: Hatchery steelhead smolts released in the Teanaway drainage in 1992 emigrated at a faster rate **than HSH** released in 1991. In addition, the emigrationrate **of** the first two release groups was much higher than that for the final group in 1992 (Figure 27). The coefficient of variation for migration rate of the 1991 release group was lower' (147) than that for the 1992 group (232). This indicates that **in 1991** fish **mig**rated out of the system more gradually than the fish released **i**n 1992. Very rough and preliminary estimates of residualism **based on** outmigration trapping suggest that approximately 35% of the hatchery steelhead released in 1992 did not emigrate from the NFT before June 1. Similarly, the estimate for the same period in 1991 was 38%.

Based on fish observation rates during snorkeling (Figure **28),** population estimates conducted in index sites by **electrofishing** (Table **8),** and the rate of HSH **outmigration** as **determined by** numbers of fish captured at the screw traps in the **Teanaway** basin, the incidence of residualism appeared to be fairly similar between 1992 and 1991. However, the distribution of residuals appeared to be restricted to a smaller area in 1992 than it was the year before. For example, no hatchery steelhead were captured in the NET 17 km upstream of the mouth of Jungle Creek (population index site number 3) in 1992, although they were present there in 1991 (Table 8). Anglers fishing for trout in the area during both years corroborated this conclusion. Residual hatchery steelhead were reportedly caught in two of the **M_T** tributaries upstream of the point where they entered **M_T** from **T_T**

(Jungle Creek) in 1991 while no such reports were received in 1992. The densities of HSH in the treatment streams, as inferred from snorkel observation rates, decreased through the summer (Figure 28).



FIRST RELEASE ON DAY 0; N = 15, 000
SECOND RELEASE ON DAY 2; N = 11, 000
THIRD RELEASE ON DAY 9; N = 5, 500 (1991), N = 9, 000 (1992)

Figure 27. Number of hatchery steelhead smolts captured at the mouth of M_T (the North Fork of the Teanaway River) 'versus the number-of days after the first release in 1991 and 1992. Fish were captured in a traversing fyke net in 1991 and a rotary screw trap in 1992.

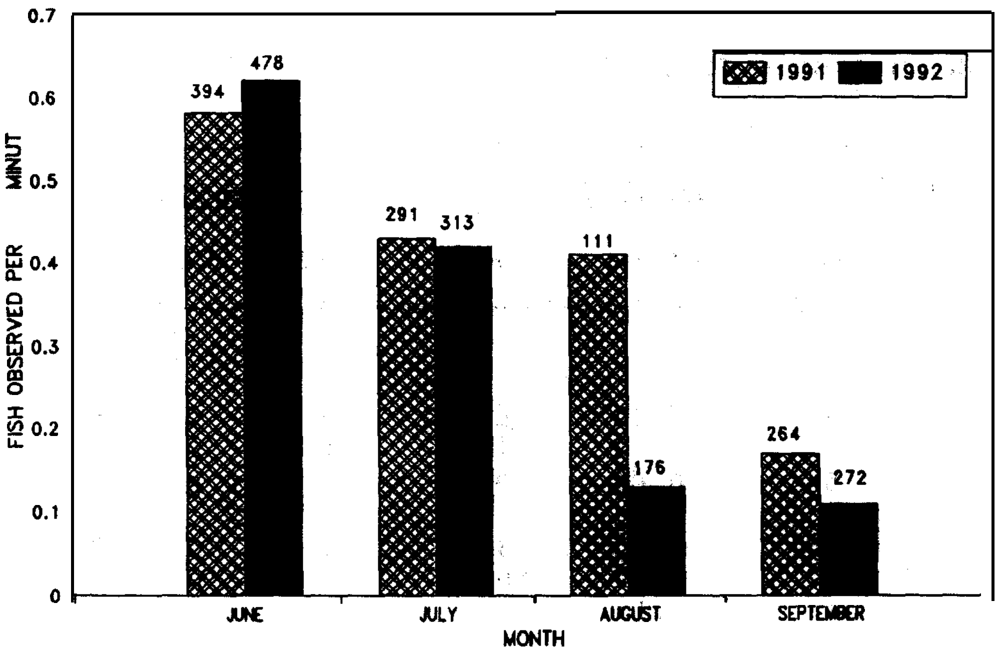


Figure 28. Observations of residual hatchery **steelhead** during snorkeling activities in the summer and early **fall** of 1991 and 1992. Data represent T_T (Jungle Creek) and M_T (North Fork of the Teanaway River) combined. The number of minutes of observation is shown above each bar.

Population estimate data from **1991** and 1992 are presented for the one site in T_T, and three sites each in the M_T and M_C forks of the Teanaway River (Table 8).

Table 8. Salmonid biomass, density, and percent (of total number) composition data for index sections in the Middle (M_C) and North (M_T) forks of the Teanaway River for 1990, 1991, and 1992, and for one site in Jungle Creek (T_T) in 1991 and 1992. Data were collected in the fall of each year. No estimate was conducted in Jungle Creek in 1990.

Stream and Section	Biomass (g/m^2)	Density (#/m^2)	Percent* of density RBT	CUT	BUL	CS	HSH
1990							
M_C 1	2.4	0.13	55	0	0	45	0
M_C 2	3.4	0.11	92	1	0	7	0
M_C 3	2.5	0.08	98	2	0	0	0
M_T 1	0.6	0.05	32	0	0	68	0
M_T 2	2.0	0.07	100	0	0	0	0
M_T 3	5.3	0.11	12	77	11	0	0
1991							
M_C 1	1.4	0.06	100	0	0	0	0
M_C 2	1.2	0.05	96	4	0	0	0
M_C 3	2.2	0.06	100	0	0	0	0
M_T 1	1.2	0.04	90	0	0	0	10
M_T 2	0.9	0.03	89	0	0	0	11
M_T 3	2.6	0.04	17	78	0	0	6
T_T	2.4	0.06	40	0	0	0	60
1992							
M_C 1	1.1	0.05	96	0	0	4	0
M_C 2	1.4	0.05	100	0	0	0	0
M_C 3	2.5	0.08	97	3	0	0	0
M_T 1	0.8	0.03	96	0	0	0	4
M_T 2	0.3	0.01	67	0	0	0	33
M_T 3	1.8	0.04	30	60	10	0	0
T_T	2.6	0.08	13	6	0	0	81

[a]**RBT** = rainbow trout, CUT = cutthroat trout, BUL = bull trout, CS = chinook salmon, HSH = hatchery steelhead residuals.

Hatchery steelhead comprised a large proportion of the biomass of salmonids in the population index sites in M_T and in T_T in the fall of 1992 (Table 8). Hatchery **steelhead** were more numerous than **trout in the latter stream** duringth8 **fall** population estimates in both 1991 and 1992. **In** 1991 and 1992, HSH comprised 60 and **81%,** respectively, of the total number of salmonids in the T_T index site. No HSH were **captured** in population index **sites in** the M_C in 1991 or 1992 (Table 8). Some HSH residuals from the 3991 releases emigrated in 1992 as **smolts.** A tagged HSH that was **released** into T_T in 1991 was captured emigrating from M_T on **April 16,** 1992 and was **captured** again in the Juvenile Passage Facility at Roza Dam on May 2, 1992. Another residual HSH was captured in the Ellensburg **section** of the **mainstem** Yakima River on September 24, 1991 during electrofishing mark-recapture population estimate sampling, and was subsequently captured by the Yakima Indian Nation at Roza Dam on April 28, 1992. Both of these HSH were classified as smolts (based on external characteristics) when observed at Roza Dam. Six residual HSH from the 1991 releases were captured during **mainstem** Yakima River population. estimates in the fall of 1991 and **three** residuals from the 1992 **releases** were **captured** during similar activities in the fall of 1992. These data were initially collected to address Task II.B.l. in the Baseline Section of this report.

The hatchery **steelhead released** in 1992 **had been reared** at approximately 33% of the **density** of the **1991** release **groups.** The fish for the first two releases in **1992** wer8 reared at the Nelson **Springs Raceway and reached** a size of 6.0 fish/lb; (mean weight **=** 76 **g),** whereas the final **release** group **was reared** -at **the Yakima** Hatchery and were released at.8 **size** of **8.5** f **ish/lb. (mean** weight = 53 g). The 1991 **release** groups were the **progeny of** wild Yakima steelhead collected at **Prosser** Dam, while the 1992 release group were from wild and hatchery **origin (first generation** offspring of wild Yakima **steelhead)** parents **collected** at **Prosser** 'Dam. It is unclear what factors, other than rearing density, may have accounted for the apparently **superior** performance (with regard to outmigration rate **in particular) of the 1992** release group. The HSH released in the first two groups **in 1992 appeared** slightly smaller than those **released in** 1991 **(mean** fork **length** in 1991 **=** 201 mm, 1992 = 196 mm). The mean size of fish in the final release group was smaller in 1991 (10.0 fish/lb., 45 **g** mean weight) than in 1992 (8.5 fish/lb., 53 **g** mean weight). The overall average size of the fish released appeared larger in 1991 (6.2 fish/lb., 73 **g** mean weight) than in 1992 (6.6 fish/lb., 69 **g** mean weight).

Recommendations: Trapping efficiency should be more accurately assessed so that outmigration estimates will be more useful as a means of determining the percentage of hatchery steelhead that do not emigrate from M_T in 1993.

Task III.B.2. Assess the extent and outcome of agonistic **interactions** between **HSH** residuals and resident fish.

Accomplishments: Underwater observations were successful for determining the extent and outcome of agonistic interactions between HSH and resident fish during the period studied. A total of 256 agonistic interactions were observed during 21.2 hours of direct observation between June 3 and October 7. Hatchery steelhead present after June 1 were defined to be residuals for this analysis.

Short-falls: It is not known to what extent agonistic interactions may have affected trout growth or population size.

Findings: The observed numbers of interactions per fish per minute were higher in all study streams after June 1 than between May 1 and 28 (Table 7). Warm water temperatures as well as decreased available living space during low flow conditions may have been related to much of the increased aggression. Resident trout were observed competing for cold water seeps in the M_C when stream temperatures exceeded 24 **°C.** Seep areas were identified using a hand-held thermometer while snorkeling. Nearly 80% of the interactions observed were within allopatric groupings of HSH or rainbow trout. The percentage of the interactions that occurred between hatchery steelhead and resident trout was considerably lower (21%) after June 1 (Figure 29) than it was between May 1 and 28 **(69%) (Figure 26).** The outcome of the sympatric agonistic contests observed, however, still favored the larger HSH during both periods. Mean fork length of HSH appeared to be 50 to 75 mm larger than resident trout during the study period (Figure 30). In M_C, juvenile spring chinook salmon dominated rainbow trout in over 85% of their sympatric contests. The chinook salmon were, on average, larger than the age 0 resident trout they were dominating. No three-way contests **were** observed due to the spatial segregation of HSH, resident trout, and juvenile spring chinook (i.e. all **three** groups were not observed in the same location at the same time).

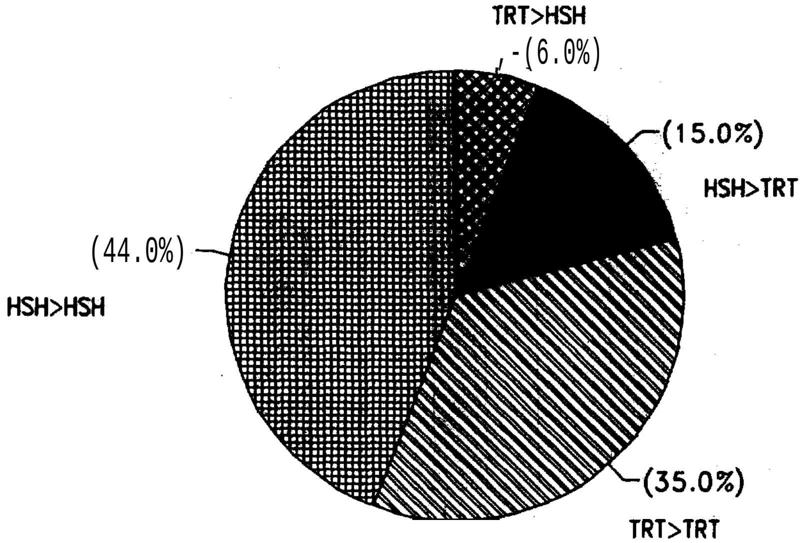


Figure 29.. Dominance-s&ordinance relationships between resident trout (TRT) and hatchery steelhead (HSH) expressed as percentages of total-aggressive encounters in T_T (Jungle Creek) and M_T (the North Fork of the Teanaway Rives) combined, between June 3 and October 7, 19.92. The group preceding the > symbol denotes the dominant group (e.g. HSH>TRT = hatchery steelhead were dominant over resident trout). Total number of agonistic interactions between salmonids was 113.

Recommendations: In addition to continuing ongoing underwater observations, experiments to measure the effects of competition between HSH, rainbow trout, and spring chinook salmon on performance and survival-related traits (e.g. growth) should be designed and implemented. This ii, necessary to more directly assess the impacts of competition on population fitness parameters.

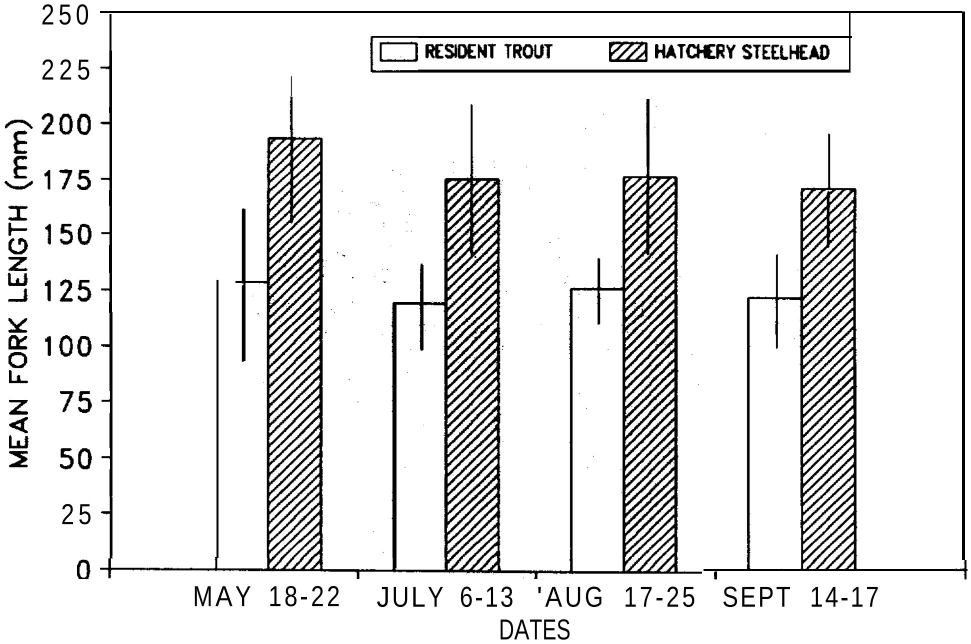


Figure 30. Mean fork lengths (mm) of resident trout and hatchery steelhead in M_T (the North Fork of the Teanaway River) between mid-May and mid-September, 1992. Sample sizes for each period were between 10 and 30 fish per group. (data from Scott Urakawa and Paul James, CWU). Vertical lines represent ± 1 standard deviation.

Task III.B.3. Assess overlap in food habits between residual steelhead and resident trout.

Accomplishments: Staff and students at Central Washington University performed this aspect of the work (and task III.A.4) through a direct contract with BPA and results will be reported. separately by CWU. In coordination with CWU, the occurrence of predation on newly emergent resident trout by HSH was examined by WDW.

On July 6, 1992, samples of HSH residuals were collected in M_T (N = 26) and in T_T (N = 29) to determine whether HSH were preying upon newly emerged sympatric trout fry. At the time of sampling emergent trout fry were about 40 - 60 mm in length. Gastric lavage was used to extract stomach contents from HSH for examination. No fish were observed in the stomach contents of any HSH sampled. Researchers at CWU also found an absence of young trout in the diet of HSH on other surveys.

Sub-Obj. **III.C.** Facilitate, coordinate, and assist efforts to collect adult steelhead broodstock for the research steelhead production project.

Task III.C.l. Coordinate with **WDW, YIN, NMFS** and others as necessary to ensure that **sufficient numbers** of **broodstock** to create research *fish* for **interactions** studies are collected.

Accomplishments: Coordination meetings and conference calls were well-attended by all parties and cooperation was very good. A priori, an agreement was reached between WDW, YIN, and WDF concerning the operation of the trap at Prosser Dam for collection of steelhead broodstock.

Short-falls: In 1991, even though exceptional numbers of steelhead returned (in comparison to the 10 year mean), so few fish used the denile and right bank ladders at Prosser Dam that the target number of hatchery broodstock was not reached. Through December 1992, the number of fish returning appeared lower than in 1991. To bolster numbers of broodstock available, small numbers of wild steelhead were collected following consultation with YIN, YFP genetics specialists, and other WDW staff.

Findings: Steelhead broodstock were collected at Prosser Dam between mid-September and December 31, 1991. A total of 22 hatchery-origin steelhead were collected at the right-bank fish trap. It appears that the number of eggs collected should be nearly sufficient to produce the necessary number of smolts for species interactions research in the Teanaway drainage in 1993. In 1992, the Prosser Dam adult trap was operated from September 14 through December 15. The adult collection goal for the 1992 cycle was 24 fish (12 females:12 males). An attempt was made to use scale patterns of adult wild steelhead to reduce the number of non-target **Satus** Creek steelhead that were inadvertently retained for broodstock. The National Marine Fisheries Service, with assistance from the Yakima Indian Nation, used radio telemetry to locate the spawning areas of over 100 steelhead in 1991-92. By using the scales collected from the fish in their study we attempted to find distinguishing scale patterns that might enable us to distinguish between fish that spawned in **Satus** Creek and those that spawned in the **Yakima or Naches rivers.** Many hours of scale reading and comparison with data from fish bound for known locations failed to provide a screening tool we were confident in. Additional methods may be employed in early **1993 if sufficient numbers of broodstock are not obtained at** Prosser Dam.

Recommendations: This portion of the study is complete.

DISCUSSION

Predicting potential interactions

Preliminary research results with steelhead and rainbow trout to date suggest that the potential for gene flow-is high, the potential for competition is unclear, and the potential for predation on trout by hatchery steelhead juveniles is low. These predictions are based on interactions (type 1 and type 2) that might occur between combined YFP steelhead treatments (both OCT and NIT) versus rainbow trout. The potential for different impacts from both OCT and NIT treatment groups on the rainbow trout are not discussed in this report.' Where appropriate, a distinction was made between the potential for interactions between the two steelhead treatment group* and resident rainbow trout.

The distribution of spawning rainbow trout and steelhead in space and time was similar, suggesting that the potential for gene flow existed. Although overlap increases the potential for gene flow it does not demonstrate that it occurs. Assortative'mating mechanisms are not uncommon among spawners in sympatry (Turner 1986). Incidental information was available however, suggesting that gene flow probably occurred. In 1990 and 1992, female steelhead presumably spawned with one or more male rainbow trout in Umtanum Creek. In addition, many precocial male steelhead from experimental releases in the Teanaway basin in 1992 were observed at release time and later, and a residualized steelhead from the 1991 release was observed on a redd during 1992 in Jungle Creek (T_T). Although the potential for gene flow appeared to be high the effects of this interbreeding on steelhead and rainbow trout are unknown. The effect of interbreeding on both forms of *O. mykiss* might include shifts in migration tendencies, growth, and other fitness related characters.

Genetic risks exist to both steelhead and rainbow trout as a result of past stocking with hatchery rainbow trout and presumed future stocking of hatchery steelhead (Busack 1990; Busack et al. 1991). Risks of hatchery introgression between steelhead and rainbow trout may be highest for steelhead spawning in mainstem sections 1-6 and low elevation tributaries, and highest for rainbow trout in high elevation tributaries. Genetic data indicate that the influence of past *trout* stocking is highest in rainbow trout in'mainstem sections 1-6 and in low elevation tributaries such as Cherry, Wilson and Badger creeks. In addition, steelhead may interact genetically with rainbow trout in mainstem sections 1-6 and low elevation tributaries because spatial and temporal overlap currently is greatest. The genetic structure of rainbow trout in high elevation tributaries 'appeared to have been least influenced by past stocking of hatchery trout and might thus be most affected by gene flow from hatchery steelhead.

The potential for competition to occur between steelhead and rainbow trout was suggested by a high degree of spatial and temporal overlap during the juvenile rearing period. Incubation and emergence of rainbow trout and steelhead probably overlapped in space and time because wild steelhead and rainbow trout adults spawned at similar times and in similar areas. Wild steelhead smolts were captured in areas that contained various age classes of rainbow trout during the spring. A high incidence of residualized hatchery steelhead were observed in the North Fork Teanaway River (M_T) and residualized hatchery steelhead were also captured in the mainstem Yakima River as far down as the Canyon section. Adult fish may compete for spawning habitat during the spring because of the temporal and spatial overlap. Although, overlap occurs at many rainbow trout and steelhead life history stages, actual competition, which is "when a number of animals (of the same or of different species) utilize common resources the supply of which is short; or if the resources are not in short supply, competition occurs when the animals seeking that resource nevertheless harm one or other in the process" (Birch 1957) can not be demonstrated without controlled field experiments.

Results from experiments in the Teanaway basin suggest that competition for food and/or space appeared to occur between hatchery steelhead released in the North Fork Teanaway drainage, which may-mimic OCT fish, and wild rainbow trout, but the actual effects from these interactions were unclear. Agonistic behavioral interactions between rainbow trout and hatchery steelhead were observed in 1991 and 1992. Hatchery steelhead dominated most of the interactions with rainbow trout, presumably because hatchery steelhead were larger than the rainbow trout. Small scale or local physical'displacements were observed in concordance with agonistic behavior but large scale displacements were not observed.

In general, the effects of agonistic interactions and small scale displacements on performance characteristics are unclear because the magnitude of the effect was very difficult to detect given high natural variability of densities and size structure and the small number of replicate observations thus far. Rainbow trout densities in index sections of the North Fork Teanaway River (M_T) have declined every year since 1990. Rainbow trout densities in the Middle Fork Teanaway River (M_C) also declined between 1990 and 1991, but increased slightly between 1991 and 1992. In both streams, declines in densities between 1990 and 1991 may have been the result of a flood that occurred in the fall of 1990. The ratio of Middle Fork to North Fork rainbow trout densities was greatest in 1992 suggesting the potential for cumulative impacts of hatchery releases to the trout population. Mean fork lengths and condition factors of rainbow trout in the North and Middle forks of the Teanaway River did not show clear trends that could be definitely attributed to competition.

Predation by the hatchery steelhead used in these experiments and by wild rainbow trout on rainbow trout was negligible. The incidence of piscivory by hatchery steelhead and wild rainbow trout in the Teanaway basin to date has been extremely low (Scott Urakawa, CWU, pers. comm.). Very few of the hatchery steelhead and rainbow trout collected in the Teanaway basin contained fish in their stomachs and none have contained salmonids (Scott Urakawa, CWU, pers. comm.). Stomach samples of 55 residual hatchery steelhead collected from habitats with coexisting young-of-the-year trout contained no fish. No successful predatory attacks were observed during over 180 hours of snorkeling. Although predation by hatchery steelhead and rainbow trout in the Teanaway basin may not be frequent, predation in other parts of the upper Yakima basin may be more probable. Rainbow trout in the mainstem Yakima River and low elevation tributaries are much larger than rainbow trout and hatchery steelhead in the Teanaway basin and thus may be more likely to prey on fish.

In general, the susceptibility of rainbow trout to disease may increase with the addition of hatchery fish. In 1991, residualized hatchery steelhead in Jungle Creek (T_T) displayed a high incidence of *Saprolegnia*, a fungal infection (McMichael et al. 1992). Wild fish in the treatment stream also had fungal infections but wild fish in the control streams did not. Fish in the treatment stream may have been infected because hatchery fish were released into the system. *Saprolegnia* is commonly present in natural streams, and was probably not introduced into the Jungle Creek by the hatchery fish. On the release date, no infections were apparent from observations of experimental fish released into Jungle Creek (T_T). It may be that increased densities in the creek (T_T) from the addition of hatchery steelhead contributed to increased stress levels and higher susceptibilities of rainbow trout to *Saprolegnia*. In contrast to results found in 1991, no hatchery fish or wild fish *were* observed with *Saprolegnia* in 1992.

Observed fish species other than rainbow trout that might interact with target species in the upper Yakima River include northern squawfish, mountain whitefish, redside shiner, longnose dace, torrent sculpin, and shorthead sculpin. Northern squawfish are known predators on salmon and steelhead and were found in mainstem sections 1-5 and in some low elevation sections of tributary streams. Mountain whitefish inhabit slightly different habitats in the mainstem Yakima River than target species, but their density and biomass were deemend to be so high that they could have influenced the amount of available food for target species. In tributaries to the Yakima River, spring chinook densities were positively correlated with **redside** shiner and shorthead sculpin densities. **Redside** shiners may outcompete chinook salmon and steelhead in warm water **(Hillman 1989a,** Reeves et al. 1987) and torrent sculpin are potentially voracious predators on young salmon. ***Oncorhynchus mykiss*** densities *were* positively correlated with shorthead sculpin and **longnose dace** densities. **Longnose dace** may interact with steelhead in ways similar to those of speckled **dace** (Li et al. **1992),** and shorthead sculpins have been shown to be voracious predators on young chinook salmon and steelhead **(Hillman** 1989b). Agonistic interactions between chinook salmon and rainbow trout, and cutthroat trout and rainbow trout, were observed during underwater surveys in the Teanaway drainage.

Monitoring Plan - Current status

Variable identification, experimental design, and methods for implementation of a rainbow trout monitoring plan are in various stages of development. Identification of variables that may be affected by interactions with supplemented species and that reflect the status of the rainbow trout population is being conducted. These variables might include trout density, **size-at-**age, growth, distribution (spawning and rearing), spawn timing, and movement. In addition, biotic and **abiotic** variables are being selected that may help explain the natural fluctuations in variables described above. These variables might include northern squawfish density, sculpin density, temperature, discharge', and stream morphology.

Many designs can be identified for use to monitor and evaluate interactions between target species and rainbow trout depending upon the spatial position of releases within a basin. For streams on which acclimation ponds are proposed, a **Before-After-**Control-Impact-Pairs design (BACIP) **(Stewart-Oaten** et al. 1986; 1992) with small scale within-treatment experiments **(SSWT;** e.g. Li et al. 1992) can be implemented. Only tributaries that are planned to be supplemented and that have adequate control streams available could be selected for this design. *Five* streams in the upper Yakima basin (Jungle, Jack, Stafford, and Taneum creeks, and North Fork Teanaway River) could potentially serve as treatment streams (YFP DEIS 1992). Streams that are potential paired treatment\controls for this design are North Fork Teanaway River\Middle Fork Teanaway River, and Taneum Creek\Swauk Creek. If possible, treatments in the North Fork Teanaway River and Taneum Creek should be conducted in two different **years to add** partial **"time-treatment"** controls (Walters et al. 1988). In areas where no large scale control and treatment areas are possible a Before/After (BA) with **SSWT** design might be applied. Sections adjacent to acclimation ponds along the **mainstem** Yakima

River are candidates for this design. Selected areas not mentioned in the above designs could **be monitored with a BA** design. **Broad** scale trends in monitoring variables **will** be detected using the BA design. Possible causes for **the trends** could be evaluated using an analysis of the correlation among variables on rainbow trout versus other physical and biological variables (e.g. target species densities, abundance of non-target species, water temperature, water flow) and examination of SSWT and BACIP results.

Attempts are being made to identify and evaluate interactions sampling techniques that minimize stress on fish populations as well as produce reliable information. For example, where possible, electrofishing should be replaced by other methods because of the harm that electrofishing can have on fish populations **(McMichael** In press). Moreover, other methods may allow less subjective interpretation of results. The use of weirs may be more favorable than electrofishing for determining certain spawning characteristics of rainbow trout in tributaries because the risk of injury to fish is smaller and the interpretation of results is less subjective. Electrofishing activities involving spawning fish poses risks of injury to spawning adults as well as newly deposited gametes, whereas risks to fish that are passively trapped are reduced. Spawn timing, sex ratio, size structure, age structure, and number of migrating spawners can be evaluated more objectively using weirs than with electrofishing methods. Some of the disadvantages of using weirs include; sampling is restricted to migratory populations of trout, sampling does not identify the areas within **a** tributary where trout spawn, weirs themselves may hinder or delay fish movement, and they can be vulnerable to failure from adverse stream conditions or improper design. Although weirs may be preferable to electrofishing for determining certain aspects of rainbow trout spawning in tributaries, the type of weir design that is used may influence the degree of success achieved relative to sampling objectives.

Different degrees of success were experienced using three different weir designs in 1992. Weirs placed in a **"W"** formation and having both upstream and downstream migrant collection capabilities were unsuccessful in trapping high proportions of fish in Cherry and Wilson creeks because of high discharges, high debris loadings, and erodible substrate. Traps in a **"V"** formation, also having upstream and downstream migrant collection capabilities were very successful in capturing high proportions of migrating fish in Umtanum Creek. The greater success in Umtanum Creek was probably attributable to the low discharge and debris loading, and large substrate encountered there. Downstream **"V"** traps used in Jungle and Jack creeks were also successful for reasons similar to those encountered in Umtanum Creek. Screw traps used in the North and Middle forks of the Teanaway River successfully captured some outmigrants but problems with trap efficiency calibration limited the application of the results. New information on trap design and operation will be pursued to facilitate better collection of data in the future.

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ACKNOWLEDGEMENTS

Work reported in this document was made possible by assistance from volunteer workers, agency personnel, and private landowners. We would like to thank the numerous anglers who returned information about tagged rainbow trout. Information about the diet of rainbow trout and hatchery steelhead was provided by Scott Urakawa. Bill Sharp, Mike Kohn, Mark Johnston, and Joel Hubble of the Yakima Indian Nation provided data, personnel support, and equipment. Eric Hockersmith of the National Marine Fisheries Service provided information about spawning locations of steelhead trout. Steve Martin reviewed various drafts of the report. Many landowners allowed us access to do our sampling, but special thanks are extended to the landowners at the Zirkle Orchards and the Eaton farm for allowing us to install traps on their property.

Appendix A

PATTERNS OF GENETIC DIVERSITY IN YAKIMA RIVER RAINBOW TROUT: Initial analysis of 1990, 1991 and spring 1992 collections

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INTRODUCTION

The electrophoretic analysis of rainbow trout, **Oncorhynchus** mvkiss, collected from the **mainstem** Yakima River and tributaries above Roza Dam is part of the baseline phase of the Yakima River species interactions studies. The purpose of this work was to provide a baseline genetic profile of wild-spawned **rainbow** trout populations, to determine the patterns of genetic diversity and stock structure among these populations, and identify differences between these populations and steelhead and hatahery rainbow trout strains.

In addition, I wanted to determine if rainbow trout **X** cutthroat trout hybrids were present in any of the collections. Hybridization was suspected in some fish because of the presence of red-orange hyoid slashes, a characteristic of cutthroat trout. Westslope cutthroat trout, **O. clarki lewisi** may be native to'the Yakima and Yellowstone cutthroat trout, **O. c. bouvieri,** have **been** stocked into the Yakima River (Crawford 1979).

METHODS

Rainbow trout were collected from seven **mainstem** locations in the Yakima River and nine tributaries above Roza Dam during the spring and fall of 1990, 1991, and the spring of 1992 (Table 1). The collected fish were either dissected in the field (most adult specimens) or frozen whole at ultra-low temperatures (-80%) and transported to the Washington Department of Fisher&es *(WDF)* Genetic Stock Identification Laboratory. Muscle, 'heart,- eye *and* liver were dissected from each juvenile and placed into 12 X 75 mm test tubes. Total length, weight, and 12 scales from the preferred area were taken. The fish were **photographed** and refrozen for storage. Cutthroat trout **and obvious** hatchery rainbow trout were excluded from the collections: I **combined all** spring and fall **collections** from eaah **location** because of-the small number of samples collected in each year.

To assess whether some stream collections inadvertently contained cutthroat trout, or whether some rainbow **trout** were **inadvertently** excluded from some collections, ten cutthroat trout were collected from both Taneum and Wilson creeks. In **addition,** fourteen putative hybrids were collected from **Badger** *Creek.*

Electrophoresis followed the methods of Aebersold et **al. (1987).** The electrophoretic protocol, enzymes screened, and alleles observed during this study (and other studies on rainbow **trout and steelhead by** WDF) are listed in-Table 2. Genetic nomenclature follows the conventions of Shaklee et **al.** (1990).

BIOSYS-1 (Swofford and Selander 1981) was used for the statistical analysis of the electrophoretic data. The G-test program that was used to test for significant differences in allelic counts among selected collection pairs was written by R. Waples and revised by C. Busack. I tested the hypothesis that the pair of collections being tested differed no more than two random samples taken from the same randomly mating population. Included in the analysis were some steelhead collections **from** the Yakima River that served as reference samples.

To estimate the percentage of hatchery origin genes in the wild collections, C. Busack wrote a program that calculated the percentage of two parental stocks in a third collection. I chose twelve alleles at eleven loci that appeared to have the largest allelic differences between the Goldendale hatchery strain and a hypothetical native Yakima Rainbow trout collection. For example, none of the WDW hatchery rainbow trout strains have any **LDH-B2*76** alleles. Whereas, a native Yakima River rainbow trout would be in the inland group of rainbow trout and have a high frequency of this allele (I chose 0.4). This method was just a first cut at estimating the hatchery influence at various collection locations.

RESULTS and DISCUSSION

I based this analysis on the products of 43 loci. Three loci were monomorphic, **mAH-2*,** PGDH*, TPI-2* (other monomorphic loci were excluded from the analysis). The average heterozygosity and percentage of polymorphic loci are slightly higher than past studies due to the exclusion of monomorphic loci from this analysis. However, the values are useful for comparisons among the populations (sampling locations and times are listed in Table 3) in this study (Table 4). In general, the highest percentage of polymorphic loci and average heterozygosity occurs in the Umtanum and in the lower Yakima River **mainstem** collections. The WDW hatchery rainbow trout strains had the lowest polymorphic loci values. In contrast, the average **heterozygosities** were similar between the wild and hatchery collections.

Genetic differences within streams

I had enough samples from Umtanum Creek to test for allelic differences between two stream sections in both the fall and spring collections. Significant differences were found **(P<0.01)** between sections in both fall and spring collections. I also tested for significant allelic differences between fall and' spring collections within stream locations. Seven of eighteen comparisons were significantly different (Table 5).

Genetic differences among collections

I calculated the unbiased genetic distance (Nei 1978) and performed cluster analysis using unweighted pair group method. I identified five major groups of rainbow trout in the Yakima River above Roza Dam (Figure 1). The first group consists of Yakima mainstem collections in sections 1-6 (except spring section 6) and Wilson and Cherry creeks. The Umtanum spring and fall collections form the second group and two Badger Creek collections form the third group. The fourth group consists of Yakima River tributaries between Cle Elum and Ellensburg as well as selected steelhead from the Yakima River. The fifth group contained the collections from Cabin and Big creeks as well as the spring collections from Yakima mainstem section 6. None of the groups are very similar to WDW hatchery strains.

Native vs nonnative gene pools at locations

Numerous allele frequency differences exist between the WDW hatchery rainbow trout strains and Yakima River collections (Phelps 1992). The allele frequencies at the eleven loci used to estimate the percentage of hatchery influence is presented in Table 6. In general, the collections that comprise the first dendrogram group, Yakima mainstem and lower tributaries appear to have the greatest proportion of hatchery rainbow trout genes. The Manastash, Swauk, Taneum, and Teanaway tributaries appear to have been least affected by past hatchery stocking.

Cutthroat trout in collections of rainbow trout

The twenty cutthroat trout standards were identified as westslope cutthroat trout based on characteristic alleles (Leary et al. 1987). All of the fourteen putative hybrids from Badger Creek were pure rainbow trout. None of the fish had any evidence of cutthroat trout at any of the six diagnostic loci expressed in muscle and heart tissues. Allelic variation characteristic of rainbow trout was also observed at many loci.

I checked the spring 1992 collections for alleles characteristic of westslope cutthroat trout and found some indication of past hybridization and backcrosses to rainbow trout. Another potential explanation would be rare allelic variation in rainbow trout that is electrophoretically indistinguishable from alleles typical of westslope cutthroat trout. I will examine the presence of westslope cutthroat trout alleles further during 1993.

CONCLUSIONS

Significant genetic diversity exists in rainbow trout in the Yakima River above Roza Dam. This diversity appears to be due to natural stock structure and the result of interbreeding with hatchery rainbow trout. The red-orange hyoid slashes are a polymorphism within rainbow trout in Badger Creek. Unintentional inclusion of cutthroat trout in the collections is not a problem currently, but exclusion of some rainbow trout in past samples may have occurred.

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Table 1. Location and number of rainbow trout collected for electrophoretic and scale pattern analysis from the Yakima River (Spring 1990 - Spring 1992).

	Total Fish For Electrophoretic Analysis				
Stream	Spring 1990	Fall 1990	Spring 1991	Fall 1991	Spring 1992
1. AE Umtanum Cr.	32	50	33	33	39
2. AG Cherry	24	50	6	33	0
AF Wilson	19	17	33	33	23
AH Badger	0	0	32	33	28
3. AI Manastash	2	50	33	33	33
AL Taneum	13	50	33	33	33
AK Swauk	5	50	33	33	33
4. AP NF Teanaway	2	50	33	33	33
AO MF Teanaway	0	50	33	33	33
AN WF Teanaway	0	50	33	33	33
5. Cle Elum River	0	0	0	0	0
Cabin	0	25	0	0	0
Big	2	50	1	0	0
6. AZ Yakima R. (sec 7)	0	13	0	20	25
7. AY Yakima R. (sec 6)	0	0	10	20	25
AK Yakima R. (sec 5)	0	14	20	20	22
8. AW Yakima R. (sec 4)	1	14	20	20	15
AV Yakima R. (sec 3)	2	14	20	20	20
9. AU Yakima R. (sec 2)	5	14	21	20	25
AT Yakima R. (sec 1)	9	14	32	20	25
* WDW Naches Hatch. rainbow	53	--	--		
* UFISH catch-out pond		38	--		
* Westslope cutthroat					20
TOTAL	169	613	426	470	465

References: Hindman memo to Phelps & Knudsen 26 April 1991 (1990 collections), Olson memo to Phelps & Knudsen 10 Dec. 1991 (Fall '91 collections). The Yakima River mainstem section numbers are reversed from previous reports.

Table 2. Allele **mobilities** of **rainbow trout** and steelhead genetic variation observed at each **locus** on **different** tissue and buffer combinations (WDF **7 September 1992). [] = NMFS** allele not **identified** in populations WDF has studied. **NS=** not **scorable** on this **tissue/buffer** combination. **() = suspect variation** not **used in analysis. %% =** no allele for this number/letter **code. (* = scorable** in **muscle** tissue **biopsy, ? =** only some samples **scorable)** . .

Locus		Buffer	Rainbow trout relative ● lle40 mobilities A 1	B 2	C 3	D 4	E 5	F 6	G 7	H 8	I 9
sAAT1,2	**M**	Tris-Gly	100		**112**	**90**			**88**		
*	**M**	RW	**100**		**109**	**92**		101	88		
	M	CAM6.1	100		125	NS	113				
	HM	**CAME6.8**	100		125	95		**103**			
	H	EBT	100		114	90			**88**		
sAAT-3	E	Tris-Gly	100		69	**[109]**					
	L	CAME6.8	100								
	L	RW	100								
sAAT-4	L	**CAME6.8**	100								
	L	RW	100		105	110					
* **mAAT-1**	**MH**	**CAME6.8**	-100		**-110**						
	M	**CAM6.1**	-100		-110						
	M	Tris-Gly	-100		-119						
mAAT-2	**MH**	**CAME6.8**	-100		(-90)						
	M	CAM6.1	-100		(-90)						
mAAT-3	**M**	CAM6.1	-100								
	MH	**CAME6.8**	-100								
ACR	**H**	EBT	100								
	M	Tris-Gly	100								
* ADA-l	**M**	**CAME6.8**	100		**85**	**81**	**104**	105	113		
*	E	**CAM6.8**	100		**93**	**(#2)**	102 104	**105**	**113**		
	M	Tris-Gly	100								
* ABA-2	**M**	Tris-Gly	100		106	90	**110**				
*	**M**	CAuB6.8	100		NS		**105**				
ADH	L	CAM6.1	-100		-78						
	L	CAMB6.8	-100		-78	-50		-128			
	L	RW	-100		**- 5**						
	L	Tris-Gly	-100		**-21**	**%%**	**72**	**-171** 90			
sAH	L	CAm6.8	100		85						
	L	**CAM6.1**	100		**85**						
	L	Tris-Gly	100		**85**						
* **mAH-1**	**HM**	**CAME6.8**	100		**55**						
* **mAH-2**	**HME**	**CAME6.8**	100		**(186)**						
* **mAH-3**	**HM**	**CAME6.8**	100		**122**	**(114)**					
* **mAH-4**	**HM**	**CAME6.8**	100		**115**						
*AK	**M**	**CAME6.8**	100								
* **AK1**	**M**	CAHEN6.8	null		**100**	(cathodal **zone below** AK)					
ALAT	**M**	**CAME6.8**	100		105		**88**				
*	**M**	Tris-Gly	100		106	111	**91**				
* CK-Al	**M**	RW	100		67	75					
	M	CAME6.8	100		**50**						
*	**M**	**RW** ˆly	100		**67**	75					
* CK-A2	**M**	**CAME6.8**	100 100		(108)						
	M										
*	**M**	Tris-Gly	100								
CK-B	**E**	Tris-Gly	100			**[97]**					
CK-Cl	**E**	Tris-Gly	100		105	(98)					
	M	**CAME6.8**	100		105						
CK-C2	**E**	Tris-Gly	100								
	M	**CAME6.8**	100								

Table 2. (cont.)

Rainbow trout relative allele mobilities

Locus	T	Buffer	1	2	3	4	5	6	7	8	9	10	11	12
			A	B	C	D	E	CF		H	I	J	K	L
DIAl	E	CAx6.8	100	109	(128)									
* ESTD	LM	RW	100	102										
*	M	Trie-Gly	100											
EST-2	L	RW	100	110	(105)									
FBALD-3	E	Tris-Gly	100											
FBALD-4	E	Tris-Gly	100											
* FDHG	M	Tris-Gly	100	70										
* FH	M	CAnE6.8	100	(84)	(75)									
bGALA	L	CAM6.1	100											
	ML	Tris-Gly	100											
	L	TC-4	100	80										
	L	RW	100											
	L	CAME6.8	100											
* GAPDH-1	M	CAME6.8N	100											
GAPDH-2	H	CAME6.8N	100											
* GAPDH-3	HM	CAME6.8N	100	33	120									
GAPDH-4	E	CAME6.8	100											
GAPDH-5	E	CAME6.8	100											
bGLUA	L	CAt46.1	100	-39	-11	93								
	L	TC-4	100	-39	-11	93								
	L	RW	100	77	85	93								
	L	CAME6.8	100	2	10	93								
* GPI-Bl	M	RW	100	142	[130]	15	[25]							
*	M	Tris-Gly	100	148		15								
* GPI-B2	M	RW	100	60	150									
*	M	Tris-Gly	100	60	150									
* GPI-A	M				89	[107]								
	M	RWis-Gly	100	105	93									
GR	H	CAME6.8	100	(115)										
	E	CAM6.8	100											
*	MH	EBT	100											
* G3PDH-1	M	CAME6.8	-100	80										
	M	CAM6.1	-100	-7										
*	M	RW	100	120										
* G3PDH-2	M	CAME6.8	-100	150										
	M	CAM6.1	-100											
? G3PDH-3	H	CAME6.8N	100	64										
? G3PDH-4	H	CAME6.8N	100	124										
	M	CAME6.8	100	124										
IDDH-1	L	RW	100	200	15	400								
IDDH-2	L	RW	100	143	5									
* mIDHP-1	MH	CAME6.8	100											
* mIDHP-2	MH	CAME6.8	100	144	162	67								
* sIDHP-1	MH	CAME6.8	100		122	71				116				
sIDHP-1,2	L	CAM6.1	100	4	129	50	[?]	118		121				
	L	CAMB6.8	100	42	121	72		123	40	116	58	74	27	80
	E	CAM6.8	100	42	121	72		123	40	116	58	74	27	80
* LDH-Al	M	RW	100	420										
*	M	Tria-Gly	100											
	M	CAM6.1	-100											

Table 2. (cont.)

LOCUS	T	Buffer	Rainbow trout relative allele mobilities A 1	B 2	C 3	D 4	E 5	F 6	G 7	H 8	I 9
* LDH-A2	M	RW	100								
*	M	Trie-Gly	100								
	M	CAM6.1	-100								
LDH-Bl	E	CAM6.8	100								
*	M	RW	100								
*	EM	Trie-Gly	100								
* LDH-B2	EM	Trie-Gly	100	76	113	[97]					
*	LM	RW	100	76	113						
LDH-C	E	Trie-Gly	100	95							
	E	CAM6.8	100	97							
aMAN	L	Tris-Gly	100	115	83						
	L	TC-4	100								
* sMDH-A1,2	LHM	CAMB6.8	100	155	37	120	49				
	LM	cAM6.1	100	210	-15						
* sMDH-B1,2	HM	CAMB6.8	100	78	116	83	92	120	104	125	
	M	CAM6.1	100	75	115	81		119			
	M	Trie-Gly	100	64	130	(#2)		(#3)			
* mMDH-1	HM	CAME6.8	-100								
* mMDH-2	HM	CAME6.8	100								
	LM	CAM6.1	100								
* mMDH-3	HM	CAME6.8	100	185	50						
	M	CAME6.8	100								
	LM	CAM6.1	100								
*ME	HM	CAME6.8N	100	110							
	M	CAME6.8	100	110							
* mMEP-1	M	CAME6.8	100	90	36	115					
mMEP-1,2	H	CAiiB6.8	100	90	36	115					
* sMEP-1	MH	CAMB6.8	100	83	98	102					
sMEP-2	L	CAME6.8	100	83			115				
	L	TC-4	100	83							
MPI	H	EBT	100	95	104	90					
*	ELM	Tris-Gly	100	95	104						
	E	CAM6.8	100	96	104						
* NTP	M	RW	100	135	161	76					
* PEPA	M	CAME6.8	100	122	79						
*	HM	EBT	100	111	93	%%	119				
	M	CAM6.1	100	138	75						
*	MLE	Trim-Gly	100	111	92						
	M	RW	100	111	92						
* PEPB-1H	MH	EBT	100	134							
*	M	Trie-Gly	100	131				110			
*	M	RW	100	118	(74)	69					
PEPB-1L	L	TC-4	-100	[#5]	(110)	%%	-50				
	L	CAM5.8	-100				-75				
PEPD-1	M	CAMB6.8	100	94	110						
?	HM	EBT	100	93	105						
	M	Tris-Gly	100	93	111						
PEP-LT	M	CAMB6.8	100	125							
?	M	EBT	100	125							
* PGDH	M	CAME6.8	100								
	E	CAM6.8	100								
* PGK-1	M	CAME6.8	-100								
PGK-2	H	CAM6.8	100	115	144	136	llO:B	90			
*	ME	CAME6.8	100	115	144	136	110:B	90			
* PGM-1	MB	CAMB6.8	-100	null	-85	-140					
*	M	Trim-Gly	100	null							
PGM-lr	L	CAME6.8	null	100							

Table 2. (cont.)

	Locus	T	Buffer	A 1	B 2	C 3	D 4	E 5	F 6	G 7	H 8	I 9
				Rainbow trout relative 811010 mobilities								
	PGM-2	M	CAM6.8	-100	-120	200	150					
*		ME	CAMB6.8	-100	-120	200	150					
		M	EBT	100	84							
		M	RW	100	85	120						
*		M	Tris-Gly	100	81	115	100					
	PNP	E	CAM6.8	100	107							
		E	Tris-Gly	100	102							
	PNPl-1		CAM6.8	100	82							
	PNPl-2	I	CAM6.8	100								
	sSOD-1	L	CAM6.1	100	226	16						
*		LM	RW	100	152	38						
		L	Tris-Gly	100	154	42						
*		HM	EBT	100	152	38						
		H	CAME6.8	100	226	16						
*	sSOD-2	HM	EBT	100								
		H	CAME6.8	100								
	mSOD	H	EBT	100	148							
*		HM	CAME6.8	100	124							
*	TPI-1	MH	EBT	-100	-153							
*		ME	Tris-Gly	-100	-153							
*	TPI-2	MH	EBT	-100	500							
*		ME	Tris-Gly	-100	500							
*	TPI-3	MH	EBT	100	94	102	97					
*		ME	Trie-Gly	100	96	102	98					
*	TPI-4	MH	EBT	100	(101)	90						
*		ME	Trie-Gly	100	(101)	90						

Table 3. Location and time of sampling information for all collections used in electrophoretic analyses.

Report Code	Collection notes
1. WILSON/NS91	Wilson and Naneum creeks steelhead smolts, spring 1991
2. LITNACHS91	Little Naches River steelhead smoits, spring 133 1
3. LOGYS91	Logy Creek (Satus Creek trib.) steelhead smolts, spring 1991
4. ROZAS91	Roza Dam steelhead smolts, spring 1991
6. WAPATOXS91	Wapatox Canal steelhead smolts, spring 1991
6. TEANSTS91	Teanaway River steelhead smolts, spring 133 1
7. TEANNFSTS91	North Fork Teanaway River steelhead smolts, spring 1991
8. TOPPENS91	Toppenish Creek steelhead smoits, spring 1991
3. BADGERF91	Badger Creek rainbow trout, fall 1991
10. BADGERS92	Badger Creek rainbow trout, spring 1991, 1392
11. BIG 90F	Big Creek rainbow trout, spring & fall 1930 and spring 1991
12. CABIN 90F	Cabin Creek rainbow trout, fall 1990
13: CHERRY 901 F	Cherry Creek rainbow trout, fail 1990 & 1931
14. CHERRY 91 S	Cherry Creek rainbow trout, spring 1989 and 1991
15. MANASH 901 F	Manastash Creek rainbow trout, fall 1990 & 1991
16. MANASH912S	Manastash Creek rainbow trout, spring 1990 - 1392
17: SWAUK 901 F	Swauk Creek rainbow trout, fall 1990 & 1991"'
18. SWAUKS92	Swauk Creek rainbow' trout, spring 1990 - 1992
19. TANEUM 901F	Taneum Creek rainbow trout,. fall 1990 & 1991
20. TANEUNS921	Taneum Creek rainbow trout, spring 1989 - 1932
21. TNAWMF 901 F	Middle Fork Teanaway River rainbow trout, fall 1990 & 1991
22. TEANMFS921	Middle Fork Teanaway River rainbow trout, spring 1991 & 1332
23. TNAWNF 901F	North Fork Teanaway River rainbow trout, fall 1990 & 1991
24. TEANNFS921	North Fork Teanaway River rainbow trout, spring 1990 - 1992
25. TNAWWF 901F	West Fork Teanaway River rainbow trout, fall 1990 & 1991
26. TEANWFS921	West Fork Teanaway River rainbow trout, spring 199 1 & 1992

27. UMTAN#1F	Umtanum Creek section 1, rainbow trout, fall 1990 & 1991
28. UMTANF#2	Umtanum Creek section 2, rainbow trout, fall 1990 & 1991
29. UNTANS#1	Umtanum Creek section 1, rainbow trout, spring 1989, 1991, 1992
30. UMTAN#2S	Umtanum Creek section 1, rainbow trout, spring 1383, 1991, 1332
31. WILSON 901F	Wilson Creek rainbow trout, fall 1990 & 199 1
32. WILSONS921	Wilson Creek rainbow trout, spring 1989, 1991, 1992
33. YAKIMA7 9091 F	Yakima River mainstem section 7 (Crystal) rainbow trout, fail 1990 & 1991
34. YAKIMA7S92	Yakima River mainstem section 7 (Crystal) rainbow trout, spring 1992
35. YAKIMA6F91	Yakima River mainstem section 6 (Nelson) rainbow trout, fall 1991
36. YAKIMA6S9192	Yakima River mainstem section 6 (Nelson) rainbow trout, spring 1991 & 1992
37. YAKIMA5F9091	Yakima River mainstem section 5 (Cle Elum) rainbow trout, fall 1990 & 1991
38. YAKIMA5S9192	Yakima River mainstem section 5 (Cle Elum) rainbow trout, spring 1992
33. YAKIMA4F9091	Yakima River mainstem section 4 (Thorp) rainbow trout, fall 1990 & 1991
40. YAKIMA4S9291	Yakima River mainstem section 4 (Thorp) rainbow trout, spring 1989, 1991, 1992
4 1. YAKIMA3F9091	Yakima River mainstem section 3 (Ellensburg) rainbow trout, fall 1990 & 1991
42. YAKIMA3S991	Yakima River mainstem section 3 (Ellensburg) rainbow trout, spring 1990, 1991, 1992
43. YAKIMA2F9091	Yakima River mainstem section 2 (U. Canyon) rainbow trout, fall 1990 & 1991
44. YAKIMA2S9291	Yakima River mainstem section 2 (U. Canyon) rainbow trout, spring 1989-1992
45. YAKIMA1F9091	Yakima River mainstem section 1 (L. Canyon) rainbow trout, fall 1990 & 133 1
46. YAKIMA1S9291	Yakima River mainstem section 1 (L. Canyon) rainbow trout, spring 1989-1992
47. GOLDENDALE 90	Washington Department of Wildlife rainbow trout hatchery, Goldendale strain
48. NACH HAT 90	Washington Department of Wildlife rainbow trout hatchery, Goldendale strain
49. SPOKANE HAT 90	Washington Department of Wildlife rainbow trout hatchery, Spokane strain
50. S TACOMA HAT 90	Washington Department of Wildlife rainbow trout hatchery, S. Tacoma strain
51. TOKUL HAT 90	Washington Department of Wildlife rainbow trout hatchery, Tokul River strain
52. UFISH 90	U-fish trout business

Table 4. Genetic variability at 43 loci in **all** populations **(standard errors** in **parentheses).**

POPULATION	MEAN SAMPLE SIZE PER LOCUS	MEAN YO. OF ALLELES PER LOCUS	PERCENTAGE OF LOCI POLYMORPHIC*	MEAN HETEROZYGOSITY DIRECT-COUNT	MEAN HETEROZYGOSITY HDYWBG EXPECTED**
1. WILSON/NS91	19.9	1.6	37.2	0.088	0.089
	(0.0)	(0.1)		(0.026)	(0.025)
2. LITNACHS91	43.8	1.6	37.2	0.069	0.071
	(1.0)	(0.2)		(0.024)	(0.024)
3. LOGYS91	107.7	1.7	44.2	0.076	0.078
	(0.2)	(0.2)		(0.023)	(0.024)
4. ROZAS91	81.6	1.8	55.8	0.085	0.089
	(0.2)	(0.1)		(0.024)	(0.024)
5. WAPATOXS91	103.3	1.9	58.1	0.074	0.076
	(1.61	(0.2)		(0.023)	(0.024)
6. TEANSTS91	24.6	1.6	39.5	0.079	0.082
	(0.7)	(0.1)		(0.024)	(0.025)
7. TEANNFSTS91	24.4	1.5	41.9	0.077	0.081
	(0.2)	(0.1)		(0.022)	(0.024)
8. TOPPENS91	61.2	1.5	37.2	0.067	0.070
	(0.2)	(0.1)		(0.021)	(0.021)
9. BADGERF91	32.5	1.4	37.2	0.096	0.096
	(0.3)	(0.1)		(0.025)	(0.025)
10. BADGERS92	59.1	1.6	41.9	0.094	0.091
	(0.5)	(0.1)		(0.026)	(0.025)
11. BIG 90F	50.1	1.8	51.2	0.091	0.099
	(1.2)	(0.2)		(0.022)	(0.024)
12. CABIN 90F	24.5	1.5	34.9	0.084	0.084
	(0.4)	(0.1)		(0.025)	(0.026)
13. CHERRY 901F	82.3	2.0	65.1	0.091	0.097
	(0.3)	(0.2)		(0.021)	(0.023)
14. CHERRY 91S	22.8	1.6	39.5	0.098	0.091
	(0.6)	(0.1)		(0.029)	(0.025)
15. MANASH 901F	79.3	1.8	58.1	0.086	0.089
	(1.1)	(0.2)		(0.023)	(0.023)
16. MANASH912S	67.3	1.8	55.8	0.085	0.090
	(0.4)	(0.2)		(0.024)	(0.024)
17. SWAUK 901F	80.7	2.1	67.4	0.086	0.088
	(0.7)	(0.2)		(0.024)	(0.023)
18. SWAUKS92	69.9	1.9	55.8	0.073	0.031
	(0.4)	(0.2)		(0.023)	(0.024)
19. TANEUM 901F	80.1	1.8	53.5	0.087	0.086
	(1.7)	(0.2)		(0.024)	(0.024)
20. TANEUMS921	77.5	1.8	53.5	0.080	0.080
	(0.4)	(0.2)		(0.023)	(0.023)
21. TNAW MF 901F	80.8	1.9	60.5	0.080	0.079
	(0.6)	(0.2)		(0.024)	(0.024)

22. TEANMFS921	65.6 (0.3)	1.8 (0.2)	51.2	0.084 (0.026)	0.080 (0.024)
23. TNAW NF 901F	77.3 (1.2)	1.7 (0.1)	53.5	0.081 (0.024)	0.084 (0.024)
24. TEANNFS921	66.9 (0.6)	1.8 (0.1)	55.8	0.086 (0.025)	0.086 (0.024)
25. TNAW WF 901F	82.7 (0.4)	1.7 (0.1)	51.2	0.080 (0.025)	0.078 (0.023)
26. TEANWFS921	65.4 (0.3)	2.0 (0.1)	65.1	0.081 (0.023)	0.083 (0.024)
27. UMTAN#1F	43.4 (0.1)	1.8 (0.2)	51.2	0.108 (0.0281	0.113 (0.027)
28. UMTANF#2	39.6 (0.1)	1.6 (0.2)	34.9	0.105 (0.029)	0.101 (0.027)
29. UNTANS#1	53.3 (0.6)	1.9 (0.2)	60.5	0.114 (0.029)	0.112 (0.027)
30. UMTAN#2S	45.2 (0.4)	1.7 (0.1)	46.5	0.107 (0.028)	0.111 (0.028)
31. WILSON 901F	48.7 (0.1)	1.8 (0.2)	51.2	0.097 (0.025)	0.102 (0.025)
32. WILSONS921	70.1 (0.7)	1.9 (0.2)	62.8	0.090 (0.022)	0.095 (0.023)
33. YAKIMA 1 9091F	35.3 (0.6)	1.6 (0.1)	41.9	0.076 (0.021)	0.086 (0.024)
34. YAKIMA1S92	24.7 (0.3)	1.4 (0.1)	30.2	0.074 (0.026)	0.073 (0.024)
35. YAKIMA2F91	19.8 (0.1)	1.6 (0.1)	44.2	0.102 (0.026)	0.101 (0.024)
36. YAKIMA2S9192	34.2 (0.4)	1.7 (0.2)	44.2	0.088 (0.023)	0.096 (0.026)
37. YAKIMA 3F9091	32.6 (0.2)	1.9 (0.2)	60.5	0.108 (0.026)	0.110 (0.026)
38. YAKIMA3S9192	41.7 (0.1)	1.8 (0.2)	58.1	0.098 (0.026)	0.100 (0.025)
39. YAKIMA 4F9091	32.4 (0.4)	1.7 (0.2)	51.2	0.089 (0.023)	0.095 (0.025)
40. YAKIMA4S9291	35.5 (0.3)	1.7 (0.2)	51.2	0.103 (0.026)	0.104 (0.026)
41. YAKIMA 5F9091	33.3 (0.4)	1.9 (0.1)	58.1	0.106 (0.024)	0.113 (0.024)
42. YAKIMA5S991	40.8 (0.2)	1.9 (0.2)	51.2	0.096 (0.026)	0.094 (0.024)
43. YAKIMA 6F9091	34.9 (0.1)	1.8 (0.2)	53.5	0.112 (0.028)	0.105 (0.025)
44. YAKIMA6S9291	53.7 (0.2)	1.9 (0.2)	53.5	0.094 (0.022)	0.102 (0.023)
45. YAKIMA 7F9091	25.7 (0.1)	1.7 (0.1)	55.8	0.086 (0.021)	0.097 (0.021)

46. YAKIMA7S9291	65.6 (0.2)	2.0 (0.2)	62.8	0.104 (0.023)	0.105 (0.023)
47. GOLDENDALE 90	99.1 (0.7)	1.4 (0.1)	32.6	0.085 (0.025)	0.089 (0.026)
48. NACH HAT 90	49.8 (1.1)	1.4 (0.1)	27.9	0.077 (0.026)	0.080 (0.025)
49. SPOKANE HAT 90	98.3 (1.6)	1.5 (0.1)	37.2	0.091 (0.027)	0.084 (0.024)
50. S TACOMA HAT 90	97.0 (1.6)	1.3 (0.1)	30.2	0.088 (0.026)	0.088 (0.025)
51. TOKUL HAT 90	99.1 (0.5)	1.3 (0.1)	23.3	0.075 (0.025)	0.075 (0.025)
52. UFISH 90	37.4 (0.5)	1.5 (0.1)	34.9	0.081 (0.025)	0.087 (0.027)

* A locus is considered polymorphic if more than one allele was detected
** Unbiased estimate (see Nei, 1978)

Table 5. Heterogeneity chi-square between fall and spring **collections** within a sampling location

	Chi-sauare	d f	Probability	
Badger Creek	51.099	27	0.00339	*
Cherry Creek	30.424	42	0.90784	
Manastash Creek	64.531	42	0.01427	*
Swauk Creek	54.270	50	0.31503	
Taneum Creek	66.461	43	0.01235	*
Umtanum Creek #1	57.283	42	0.05814	
Umtanum Creek #2	63.501	36	0.00313	*
Wilson Creek	55.811	42	0.07513	
MF Teanaway River	40.907	43	0.55969	
NF Teanaway River	61.634	40	0.01557	*
WF Teanaway River	74.481	45	0.00372	*
Yakima River #7	27.053	26	0.40654	
Yakima River #6	46.821	33	0.05608	
Yakima River #5	40.059	44	0.64121	
Yakima River #4	30.924	36	0.70857	
Yakima River #3	56.421	46	0.13959	
Yakima River #2	68.530	45	0.00344	*
Yakima River #1	59.300	49	0.14877	

*** P<0.05**

Table 6. Allele frequencies at selected loci used to estimate the percentage of hatchery origin genes in Yakima River rainbow trout collections.

	Allele Frequency	
Locus/Allele	Hatchery	Wild
ADA-l*85	0.800	0.000
CK-Al*67	0.060	0.000
IDDH-2*143	0.240	0.000
mIDHP-2*144	0.370	0.000
sIDHP-1,2*42	0.130	0.220
sIDHP-1,2*72	0.025	0.100
LDHB-2*76	0.000	0.400
LDH-C*95	0.100	0.000
sMDHB-1,2*83	0.280	0.000
MPI*95	0.000	0.050
PGM-2*85	0.040	0.000
sSOD-1*152	0.360	0.050

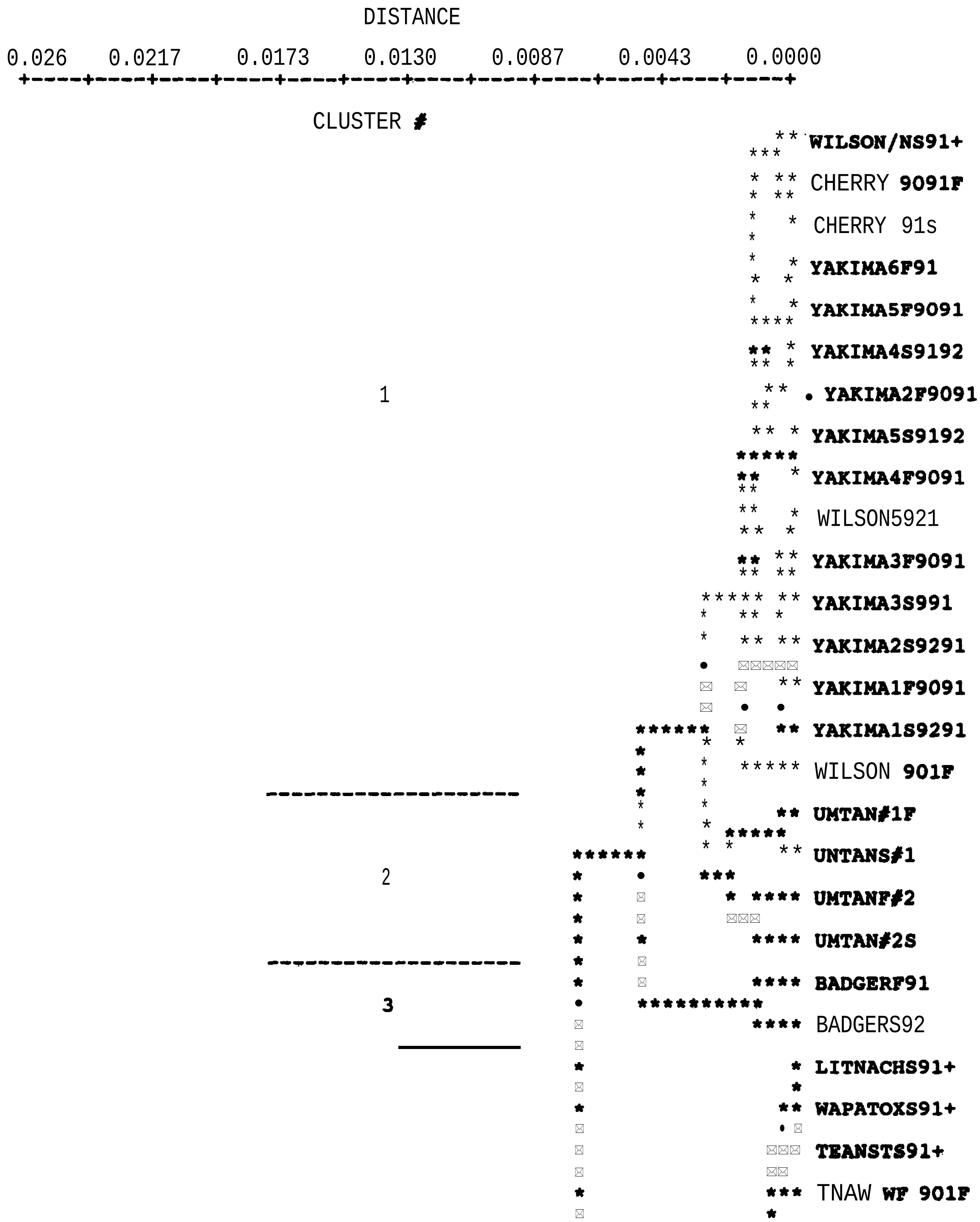
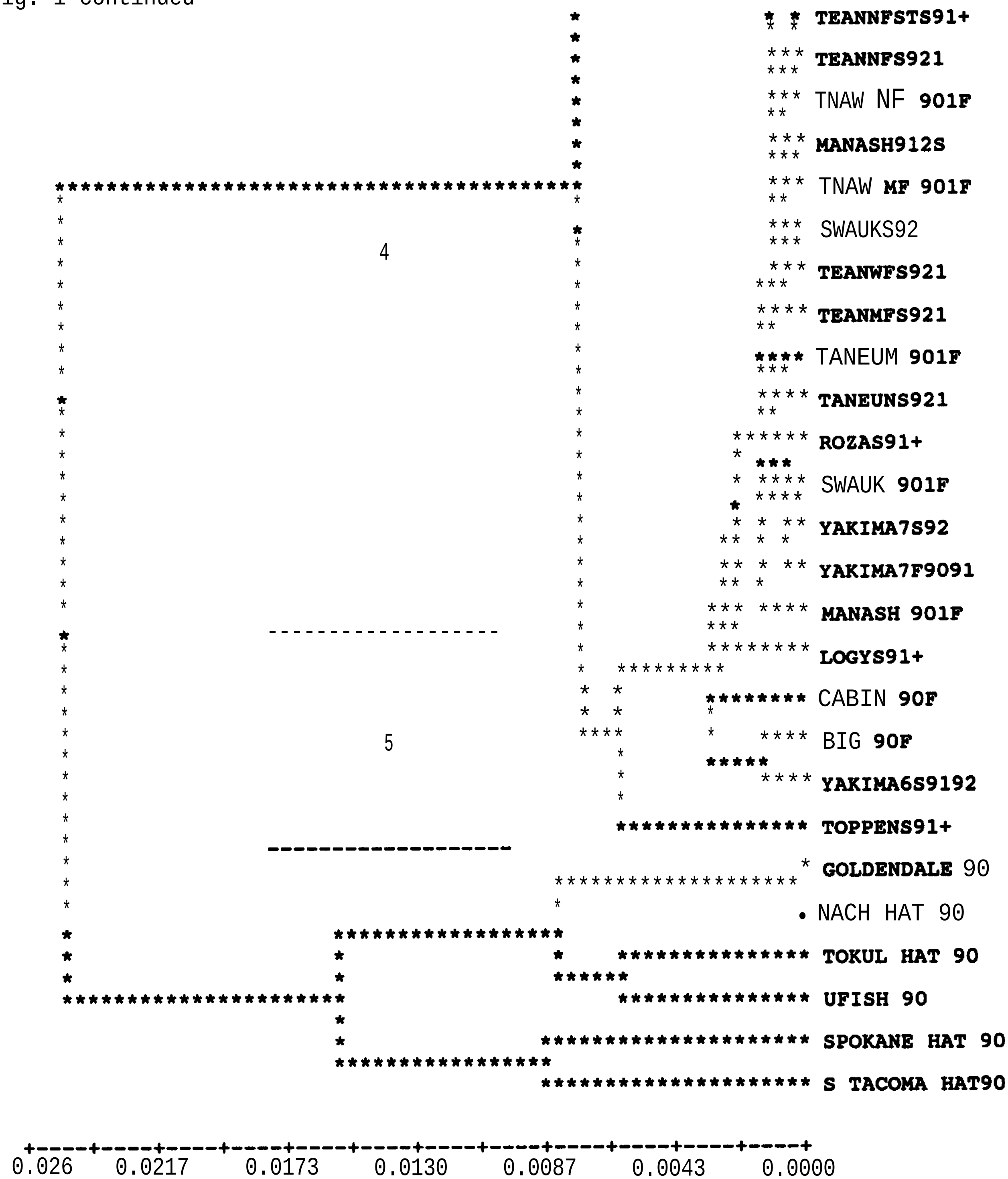


Figure 1. Cluster analysis of rainbow trout and steelhead alleles using unweighted pair group method and Nei (1978) unbiased genetic distance. Each collection is coded by place and time of capture. Steelhead samples end with a "+".

Fig. 1 continued



Appendix B

MAINSTEM YAKIMA RIVER RAINBOW TROUT LENGTH-AT-AGE COMPARISONS

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INTRODUCTION

The length-at-age of fish reflects the biotic and **abiotic** factors which are molding the population's demographics, productivity and population dynamics. An individual fish's growth is constrained by factors such as habitat availability and quality, genetics, fishing pressure and regulations, intra- and inter-species interactions, prey availability and natural mortality rates. Significant differences between two populations in mean length-at-age is a strong indicator that there are significantly different selection pressures being imposed on the two populations (Hilborn and Walters 1992).

METHODS

In order to estimate the length-at-age of Yakima River rainbow trout I analyzed scales collected by personnel from both the Washington departments of Wildlife (WDW) and Fisheries (WDF). Sampling of fish was done selectively in order to fill a series of incrementally larger length cells. Thus, within a given length range the intent was to have a representative sample. However, since fish were selectively sampled the data can not be used to estimate the age composition of the general population. Fish were collected from seven sites within tine **mainstem** Yakima River in the fall of 1991.

Scales were mounted on gummed cards in the field or in the lab and acetate impressions subsequently made (Koo 1962). Impressions were viewed with a micro-fiche reader using 24X and 48X lenses. Ages were then assigned based on the number of complete **annuli** observed. An **annulus** was defined as a group of closely spaced relatively narrow circuli which form during the period of slowest growth (Koo 1962). The convention that a fish's growth year begins on January 1 and ends on December 31 was followed. Many of the Yakima River fish had an incomplete **annulus** at the outer margin of the scale at the time of collection (Figure 1). Since this **annulus** was often not completely formed and occurred at the scale's outer edge it was interpreted as representing the end of the current year's growth which would not be completed until December 31. Therefore such **annuli** were not counted as representing a full year's growth. Had the scales from age 1 fish shown in Figure 1 been collected on January 1 they would have been aged as 2 year-olds because the second **annulus** would have demarcated the end of the previous (second) year's growth. In a few cases fish could not be aged because scales were mounted upside down, were missing or the scales were regenerated.

RESULTS

A total of 207 rainbow trout collected in the fall of 1991 were assigned an age and ages -ranged from 0- to 4-years. For example, an age 0 fish is in its first year of growth (young-of-the-year) and an age 4 fish has completed 4 years (4 complete annuli formed) and is into its 5th year of growth. Once the samples were aged, the mean length-at-age for each mainstem sampling site was calculated (Table 1). Also included in Table 1 is the sample size, standard deviation, and range; It is clear from Table 1 that there were differences in length-at-age'between sampling sites with size generally decreasing with increasing site number. In order to statistically test this hypothesis a 2-way ANOVA testing for Site, Age and Site/Age interaction effects was performed (Zar 1984). There were not sufficient numbers of samples in each age/site cell to analyze all age classes so the analysis was confined to age 1 and 2 fish only which were compared across the 7 sampling sites. However, due to low sample size, it was necessary to pool site 6 and 7 samples. T-tests comparing length-at-age by age class between sites 6 and 7 showed the two samples were not significantly different ($P>0.05$). The results of the 2-way ANOVA are given in Table 2. The assumption of homogeneity of variances was not rejected ($P\geq0.17$, Table 3) for either of the two mainstem sections or interact&on effects using a Levene's test (Levene 1960). There were significant differences ($P<0.001$) in length-at-age due to age effects, as would be expected. That is, age 2 fish were in fact significantly larger than age 1 fish. There was no significant Age/Site interaction effeot ($P>0.05$). There was, however, a significant Site effect ($P<0.001$) with mean length-at-age increasing as the sampling-site moved down river.

A Student-Newman-Keuls (SNK) multiple range test was used to determine which groups were significantly different (Table 4). Age 1 fish-from sites 4 to 7 were the smallest and grouped together while sites 1 through 3 made up a second group of larger age 1 fish. For age 2 fish the-pooled Site 6+7 sample was significantly smaller than sites 1 to 5 which were not significant&y different from each other. Despite being a year older the pooled Site 6+7 age 2 group was smaller than the Site 1 age 1 group, although not significantly smaller.

DISCUSSION

Results from the **2-way ANOVA** show that fish from lower river sites are larger within the l- and l-year old age classes. This could be due to lower river fish growing faster than upper river fish or to different mortality/selection pressures imposed on the upper and lower populations. Selection factors could differ between populations and either be selectively removing larger fish from the upper areas or smaller fish from the lower areas thus shifting the length distributions. However, based on a subjective visual analysis of the scales (see Figure 1 which is generally representative of scales from upper and lower river sites) it would appear that the difference in length-at-age is due to factors controlling growth rates. In general, the spacing and thickness of circuli are greater in lower river fish than upper river fish, **annuli** are more widely spaced in lower river fish, and more circuli are involved within **annuli** in upper river scales. Wide circulus thickness and spacing is indicative of faster growing fish and wide multi-circulus **annuli** tend to *form* on slower growing fish. These qualitative impressions should be confirmed and tested by making inter-circulus and/or **inter-annulus** measurements on age 2 fish from each site and comparing the populations via a multi-variate technique such as linear discriminant analysis.

The results in Table 1 indicate that if an age/length key were to be constructed for aging purposes it should be to some degree site specific. I would recommend that the SNK results in Table 4 be used as an initial first cut at a definition of site grouping. Thus, one age/length key should be constructed for sites 4 to 7 combined while a second key is constructed for sites 1 to 3 combined. Ultimately, as more samples are analyzed, additional age classes are more fully represented and **the** precision of aging needs defined, there may be more than **two keys** necessary for the most accurate site specific age determination.

To date no known age samples have been used to verify the periodicity of **annulus** formation and confirm the interpretation of **annuli. Annulus** formation on fish scales is well documented, although in very cold environs trout have been known to **not** form yearly **annuli** (Lentsch and Griffith 1987). When possible it is prudent to confirm aging results with known age **samples.** In the future, scale samples from the WDW Species Interactions Studies will be available from tagged fish which were sampled at the time of capture and subsequently recaptured. The number of **annuli** which formed during the period between release and recapture can be compared to the actual number of years in order to verify **annulus** formation and confirm scale interpretation.

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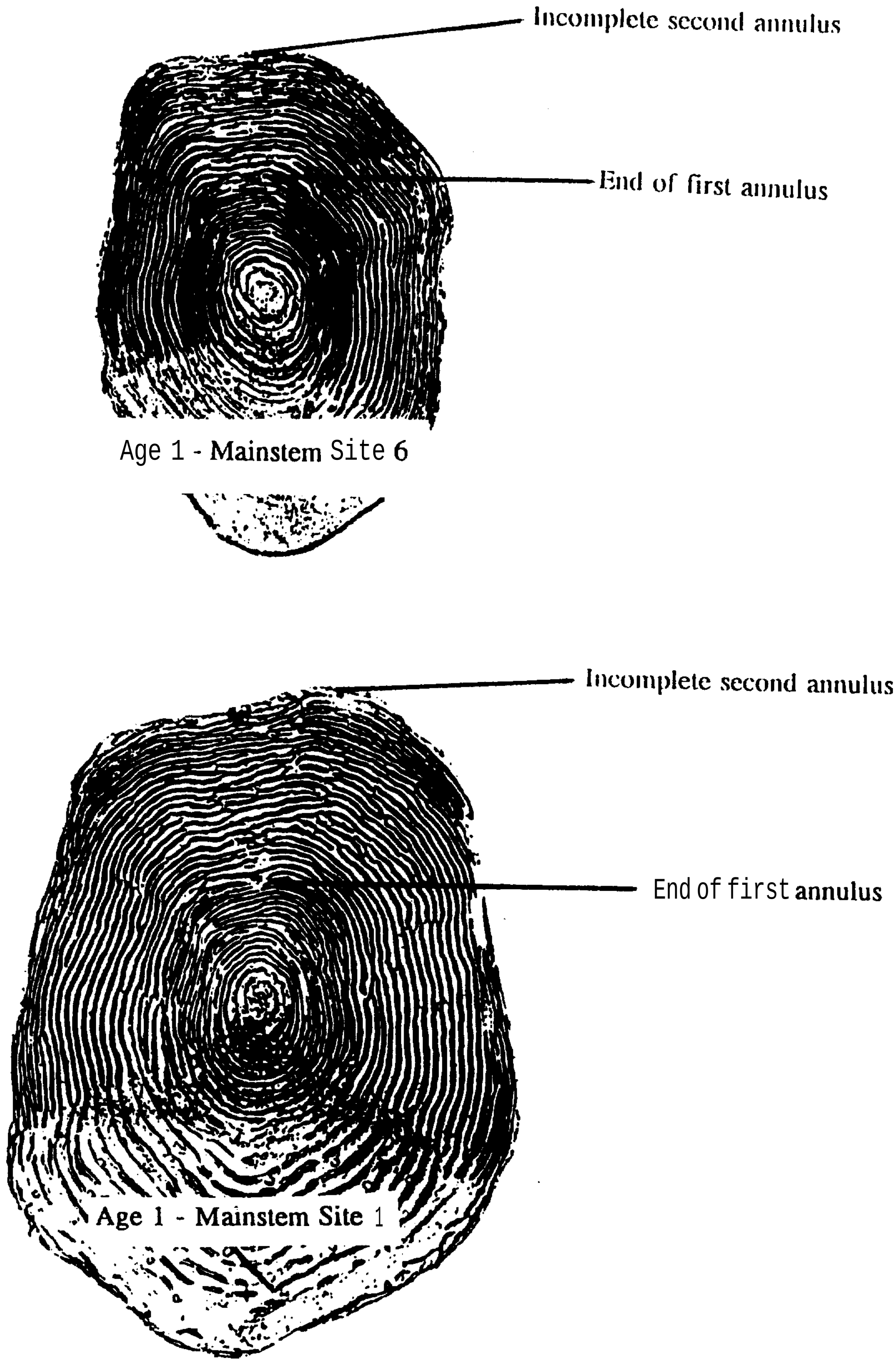

Figure 1. Scale micrographs illustrating age 1 fish sampled **in** the fall from **mainstem** sites 1 and 6. Note the completely formed first **annulus** and'incomplete second **annulus** on both fish. Also, note the difference in scale size reflecting the quantitative difference in lenath-at-aae between the two **mainstem** sites.

Table 1. Mean, standard deviation (sd) and range of length-at-age (mm) for fall 1991 mainstem Yakima River rainbow trout samples.

Age		Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
0	n	0	1	0	1	0	3	0
	mean		160		92		104	
	sd		0.0		0.0		2.3	
	range						100-108	
1	n	10	20	18	21	19	22	8
	mean	229	217	205	184	186	171	160
	sd	24.6	24.7	23.9	23.5	20.3	29.2	15.5
	range	182-254	181-271	172-264	143-227	157-231	124-252	127-178
2	n	9	10	11	14	8	4	3
	mean	274	290	291	271	269	230	211
	sd	27.0	32.4	22.4	38.4	10.5	53.8	7.8
	range	239-312	236-342	260-331	203-341	254-288	172-302	202-216
3	n	10	3	2	0	4	0	1
	mean	350	282	318		331		275
	sd	33.6	28.0	31.8		52.4		
	range	296-396	261-314	295-340		288-405		
4	n	3	0	2	0	0	0	0
	mean	343		365				
	sd	30.2		35.4				
	range	323-378		340-390				

Table 2. Two-way **ANOVA** results- from fall analysis of 1991 Yakima River **mainstem** rainbow trout length-at-age data testing for Site and Age main effects and Site/Age interactions.

Effects source	Sum of **squares**	DF	Mean **Square**	F Value	Tail Probability
Site	56829.9175	5	11365.9835	16.29	0.0000
Age	192357.6212	1	192357.6212	275.64	0.0000
Interact.	7414.5890	5	1482.9178	2.12	0.0649
Error	115147.5177	165	697.8637		

Table 3. The results of **Levene's** testing for homogeneity of variances in length-at-age data used in the 2-way **ANOVA.**

Source	DF	F Value	Probability
Site	5, 165	1.57	0.1710
Age	1, 165	0.78	0.3789
Interaction	5. 165	1.09	0.3701

Table 4. Results from the Student-Newman-Keuls multiple range test comparing length-at-age data from the **2-way ANOVA** in Table 2. Groups which are spanned by a vertical line on the right hand side are not significantly different from each other.

SITE/AGE	MEAN	SAMPLE SIZE
POOLED6+7 AGE1	167.80	30
MAIN4 AGE1	184.43	21
MAIN5 AGE1	185.89	19
MAIN3 AGE1	205.11	18
MAIN2 AGE1	216.50	20
POOLED6+7 AGE2	221.57	7
MAIN1 AGE1	222.90	10
MAIN5 AGE2	268.63	8
MAIN4 AGE2	271.14	**14**
MAIN1 AGE2	274.44	**9**
MAIN2 AGE2	290.40	**10**
MAIN3 AGE2	290.73	**11**