TEN MILE RIVER WATERSHED 1997
INSTREAM MONITORING RESULTS

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CONTENTS

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Data Collection: Ethan Bell, Jennifer Feola, Jimi Gragg, and David Wright.

Data Analysis: Bob Taylor and Debbie White.

Software: Mark Hannon, Darrell Martin, and the Forest Science Project.

We thank you all for your contributions.

JA DH

KEY TO ABBREVIATIONS

C	Celsius
CDF&G	California Department of Fish and Game
CEMR	California Educational Manpower Resources
cc	cubic centimeters
CFT	Clark Fork Ten Mile
cm	centimeters
Cms	cubic meters per second
F/M2	fish per square meter
HCP	habitat conservation plan
km	kilometers
L	little
Lg.	large
m	meter
mm	millimeter
MWAT	maximum weekly average temperature that should not be exceeded
CRWQCB	California Regional Water Quality Control Board
NFT	North Fork Ten Mile
NMFS	National Marine Fisheries Service
7DMADA	seven day moving average of the daily average temperature
7DMADM	seven day moving average of the daily maximum temperature
Sm.	small
SFT	South Fork Ten Mile River
STE TEN	survival-to-emergence Ten Mile
TMR	Ten Mile River
TMRW	Ten Mile River Watershed
UILT	upper incipient lethal temperature
USA	Usal Creek
UUILT	ultimate upper incipient lethal temperature

Abstract

This document presents results from the fifth year of monitoring instream conditions for Georgia-Pacific's (d/b/a The Timber Company) landholdings in the Ten Mile River Watershed. Instream variables measured include water temperature, sediment, and aquatic vertebrate populations. Monitoring results are used to ; (a) assess baseline conditions, (b) mitigate management activities within the timber harvest plan process, and (c) direct Georgia-Pacific's stream enhancement efforts within the Ten Mile River Watershed. This monitoring plan is the realization of an agreement between Georgia-Pacific and the California Regional Water Quality Control Board - North Coast Region.

INTRODUCTION

Georgia-Pacific (d/b/a The Timber Company) has completed the fifth year of instream monitoring for the Ten Mile River Watershed (TMRW). This effort was initiated when the California Regional Water Quality Control Board - North Coast Region (CRWQCB) expressed concern over possible instream impacts associated with Georgia-Pacific's land management activities in the TMRW. To address these concerns, Georgia-Pacific and the CRWQCB agreed to an instream monitoring plan for the TMRW. From the inception of this monitoring plan in 1993, Georgia-Pacific has annually produced a document detailing instream monitoring results and enhancement activities within the TMRW.

Watershed monitoring along the Pacific Northwest has been catalyzed, in part, by concerns regarding the effects of land management activities on critical instream habitat factors potentially limiting salmonid abundance, occurrence and species distribution. These habitat factors, which influence viability and productivity of salmonid populations during their inland life stages, include the following items: stream temperature, instream gravel composition, large woody debris, nutrient input, aquatic macro-invertebrate distribution and water flow. By quantifying many of these critical habitat components, Georgia-Pacific has focused specific efforts toward enhancement of those most limiting for salmonids.

Unfortunately, this program has been curtailed since the listing of the coho salmon (Oncorhynchus kisutch) as a threatened species by the National Marine Fisheries Service (NMFS). Since listing, the NMFS has expressed doubts concerning the benefit of stream enhancement activities for restoring salmonid stocks. As a result of this apprehension, the process for obtaining, and conditions applied to, incidental take permits for these types of activities has become difficult. As a result, Georgia-Pacific refrained from stream enhancement activities in 1997. however the company does believe in the benefit of these projects and may continue in the future.

Although this document describes activities only within the TMRW, these methods are currently applied, in varying degrees, throughout other watersheds within Georgia-Pacific's ownership. The TMRW was chosen as the primary watershed to report instream conditions, in part, because it is largely owned by Georgia-Pacific (85%).

Although the standard monitoring parameters have not changed since 1993, metrics are continually reviewed. In this respect, Georgia-Pacific's monitoring will continue to be refined to ensure data collection is scientifically sound. Results of this monitoring are used to assess overall conditions for timber harvest activities and specify areas where instream and upslope enhancement will have the greatest benefit.

JA

STUDYAREA

Location & Geography

The Ten Mile River (TMR) is located in central coastal Mendocino County in northern California (Appendix A). The nearest city is Fort Bragg, 13 kilometers (km) to the south from the river's principle access point (Highway 1). The TMRW (Appendix B) drains an area of approximately 31,000 hectares. The TMRW consists of approximately 192 km (Appendix C) of Class 1 watercourses (within Georgia-Pacific ownership) with three main forks: North Fork (70.6 km of Class 1 streams), dark (Middle) Fork (57.2 km of Class 1 streams) and South Fork (65.0 km of Class 1 streams). Generally, the forks of all three mainstems flow from east to west.

The TMRW is highly convoluted and incised with many ridges and deep ravines. Slow downward soil movement and landslides are the natural erosional processes chiefly responsible for forming the topography in this area. Like most of the Coast Range, deep soils mantle nearly all of the TMRW covering bedrock and giving the hills their softly rounded shape (Alt and Hyndman 1982). Elevations range between 0 meters (m) and 977 m. The dark Fork extends the farthest inland (approximately 22 air-km from the coast), followed by the South and North Forks respectively.

Climate and Hydrologic Processes

The TMRW is influenced by the Maritime climate of the Pacific Northwest and the Mediterranean climate of central and southern California. Summers are characterized by cool breezes and fog, along the coast, and hot, dry conditions inland (temperatures up to 37 ° Celsius are not uncommon). Winters are characterized by abundant rainfall and cool temperatures. Precipitation consists primarily of rain, with some limited snowfall on the highest ridges during the colder months. Fog and fog-drip are an important climatological feature to the region during summer months, providing a cooling influence as well as significant precipitation at some locations near the coast and river canyons. This form of precipitation is generally not included in annual precipitation data. However, Azavedo and Morgan (1974) found precipitation from fog-drip ranging between 25.4 centimeters (cm) to 30.5 cm in the open and 18.4 cm to 21.6 cm under forested canopy within the western Eel River divide in southern Humboldt County.

Rain distribution varies both temporally and spatially. Approximately 90% of the annual precipitation occurs between October and April with most of this precipitation (approximately 75%) occurring between November and March. Annual average rainfall varies considerably depending on location, generally increasing with higher elevation. Western portions of the TMRW receive about 102 cm of precipitation per year, while the majority of the watershed receives approximately 152 cm to 178 cm per year. The eastern edge of the TMRW has a maximum annual precipitation average of 200 cm (Rantz 1969).

Watercourse characteristics are dictated by these temporal and spatial patterns of precipitation and the topographic characteristics of the area. Stream flows can dramatically respond to rainfall fluctuations. While interior, higher-elevation areas receive higher annual rainfall, most of this precipitation tends to occur from relatively few intense winter storm events. These intense storm events, associated with generally steep terrain, result in many watercourses of significant size. However, due to hot dry summer months typical of this climate, many first order watercourses are completely dry by mid to late-summer.

Vegetation

The TMRW is located in the North Coastal Forest Plant Community (Ornduff 1974) with a dominant overstory consisting of redwood (Sequoia sempervirens) and Douglas-fir (Pseudotsuga menziesii). Redwood is the dominant constituent of coastal forest stands, while Douglas-fir dominates the more inland sites. Other conifers in the area, of limited extent, include grand fir (Abies grandis). California nutmeg (Torreya californica) and Western hemlock (Tsuga heterophylla).

Common components of conifer stands on xeric sites are tanoak (Lithocarpus densiflorus) and Pacific madrone (Arbutus menziesii) with a smaller component of giant chinquapin (Castanopsis chrysophylla). which occur together on major ridgelines and mid-slopes. Generally, tanoak and Pacific madrone constitute a higher percentage of the stands in the inland portions of the TMRW. Interior live oak (Quercus wislizenii) is a minor component at the more xeric sites on inland ridges.

Further inland, near the headwaters of the North Fork and dark Fork, the conifer overstory turns to open grasslands. These grasslands also have valley and foothill woodlands with a dominant overstory of California black oak (Quercus kelloggii) and Oregon white oak (Quercus garrvana) punctuated with occasional Douglas-fir/redwood/tanoak stands of various sizes.

The canopy cover of the shrub layer throughout the TMRW is usually moderate to dense, consisting of California huckleberry (Vaccinium ovatum). ceanothus (Ceanothus sp.) salal (Gaultheria shallon), and rose bay (Rhododendron macrophyllum). Associated understory plants include deer fern (Blechnum spicant). bracken fern (Pteridium aquilinum). sword fern (Polystichum munitum). redwood violet (Viola sempervirens). and modesty (Whipplea modesta). Saprophytes, such as phantom orchid and striped candyflower, occur sporadically on the forest floor.

Watercourses throughout the drainage consist primarily of redwood and red alder (Alnus rubra) with a component of California bay-laurel (Umbellularia californica). bigleaf maple (Acer macrophyllum), and willow (Salix sp.). Within this zone, red alder typically occurs as a narrow band that is replaced by conifers further upslope.

Geology

The geology of the area is composed of Franciscan sedimentary rock uplifted from the ocean floor approximately 40 million years ago forming the California Coast Range. The Franciscan formation is a heterogeneous mixture of rocks with diverse origins. Graywacke sandstone conglomerate and associated shale are the dominant rock types in the Franciscan assemblage. Altered sea floor basalt, siliceous chert, and exotic high-pressure/low temperature metamorphic rocks also occur widely. Serpentine is associated with much of the Franciscan formation, especially along fault zones. The Franciscan formation in the TMRW is generally a dark mudstone, with smaller proportions of conglomerates and serpentines. Weathering of the formation has produced a weak mantle of regolith (i.e., unconsolidated soil and bedrock fragments) and saprolite (i.e., deep, weathered bedrock) (Jones & Stokes Associates, Inc. 1997). This complex is relatively young and highly erosive, and it has been suggested rivers and streams on the North Coast act as sediment 'conveyer belts' between the hills and the sea (Alt and Hyndman 1982).

About 15,000 years ago, the ocean level was approximately 90 m lower than its present level. While the sea level was lower, coastal rivers cut channels deeper into the terrain. As sea levels rose, coastal river valleys were flooded to create estuaries. Many of the rivers in Northern California, including the TMR, have these estuaries that are now bordered by alluvial floodplains as a result of sediments carried down-river over thousands of years. The several square kilometers of sand dunes south of the TMR estuary are upstream deposits that prevailing winds and tides have moved back on shore. Similar to many coastal streams and rivers, the mouth of the TMR is closed by a sandbar during the summer months and remains so (except for the occasional tidal breaching) until the first autumn rains.

Logging History

Georgia-Pacific owns approximately 85% of the TMRW which is comprised of second and third growth forests under timber management. The rotation age within the TMRW is approximately 60 years. Various silviculture prescriptions were and are applied within the watershed since the first harvest began over 100 years ago. Current timber harvest techniques are radically different from those of the past where sluice dams, steam yarders, bull teams, railroads, road building and heavy equipment were used adjacent to and sometimes within streams. Sluice dams are not known to have been used within the TMRW, rather it was primarily railroad logged until the late 1930's. Tractor logging replaced railroad logging and resulted in what is thought to be the greatest instream impacts. It is generally agreed that the most serious in-stream impacts occurred between the 1940's and late 1960's.

Harvest techniques were different within the three main forks of Ten Mile partially as a result of access, technology and economic considerations. The difference in harvest techniques in the three main forks also influenced the overall analysis presented within this monitoring plan. For these reasons I believed it best to consider each fork independently. Most of the following historical information was adapted from the September 1995 *Georgia-Pacific Corp. Sustained Yield Plan.*

North Fork Ten Mile River

In 1870 logging efforts began in the mainstem of Mill Creek and continued until the mid-1880's. Essentially, a clear-cut method was used, trees were felled and the bark was peeled. Fire was used to dispose of the bark and limbs, providing the loggers and animal teams access for logging activities. Cut logs were rolled by hand into gulches, and teams of oxen pulled them to a rail tram located along Mill Creek, where they were hauled to the Fort Bragg sawmill. Fire was used to clear slash following logging, and regeneration was by natural means.

Railroad access became available in the North Fork in the late 1920's. Logging advanced slowly within the North Fork since this area was not the primary location for log supply to the Fort Bragg mill (the South Fork of Ten Mile was the primary location). Slackline cable systems were used to remove logs in the area up to and including the Little North Fork. Timber was felled essentially as a clear-cut, and trees not cut were knocked down by cables. Slash fires were regularly used to remove peeled bark and cut limbs prior to yarding and, again, after yarding to clear the land. Regeneration was by natural means.

As logging progressed up the North Fork, east of the Little North Fork Ten Mile River, other methods were utilized. During the late 1930's and 1940's, equipment changed from the heavy slackline systems to tractors pulling wheeled arches for log yarding on most slopes, and, for the very steep slopes, to double-drum ground-lead cable systems with a short reach capability. This change in equipment started a move away from a total clear-cut method to an economic clear-cut. The more mobile equipment allowed "seed trees" to be left, typically those tress less than 91 cm diameter. In the North Fork, the area covered by these practices were deployed from the Little North Fork up to and including Bald Hill Creek. Beginning in the late 1960's and continuing to the mid-1980's, residual trees left from the first entry were removed. Regeneration was accomplished by aerial seeding which occurred from the mid-1960's to early 1970's. Since that time tree planting has been used.

Practices differed east of Bald Hill Creek. Logging in the late 1940's to 1960's was almost entirely by tractors. Cutting practices during this time period included the regulation of cutting to diameter limits (122 cm in Redwood and 91 cm in Douglas-fir), resulting in an increase of remaining "seed trees." Regeneration after these operations was by natural means. During the late 1960's, operations began to remove residual trees, and this continued to the mid-1980's. Regeneration was accomplished by aerial seeding in the early 1970's and tree planting in the mid-1970's. For operations on steep slopes at this time, running skyline systems were used.

Currently, thinning operations and some even-age regeneration harvest are being conducted in stands that range in age from 40 to 60 years. Tractors are now used on slopes generally below 50 percent with running skyline cable systems used on steeper slopes.

Clark Fork Ten Mile River

Early logging in the dark Fork area occurred on the north slopes of Sherwood Peak. Railroad access from the area northwest of Willits (what is now the Brooktrails community) allowed logging to occur along the range line between R 15 W and R 16 W, generally south of the river. Timber was clear-cut and peeled, followed by slash fires to provide room for additional logging. Cable systems were used to move logs to the railroad. These operations ran from the late 1890's to about 1920.

Young-growth stands that grew after the early logging in Clark Fork were entered in the early 1980's, and operations continue to the present. Even-age regeneration cuts have been used: clear-cut and cable yarding on steeper slopes and shelterwood and tractor yarding on gentle slopes. Large volumes of hardwoods have been removed. Hardwoods were dense in these stands as a result of the repeated fires occurring in the area during the period from the 1940's to the early 1960's. Tree planting has been used to regenerate harvested lands.

As in the North Fork of the TMR, railroads provided access for logging at the mouth of the dark Fork in the late 1920's. Generally, timber stands in the Clark Fork were of very high volume and quality compared to the North Fork, so harvest operations were concentrated in the Clark Fork from the 1930's to 1960's. In the 1930's and 1940's, the economic clear-cut concept was used, generally leaving trees less than 91 cm as "seed trees." Log yarding was by tractors pulling wheeled arches, except for the double-drum cable systems used on very steep slopes. By the 1950's, diameter limits were imposed, 122 cm for Redwoods and 91 cm for Douglas-fir, and regeneration was by natural means. From the mid-1960's to the late 1980's, residual trees were removed followed by tree planting and aerial seeding.

Currently, thinning operations and some even-age regeneration harvest are being conducted in stands that range in age from 40 to 65 years. Tractors are now used on slopes generally below 50 percent with running skyline cable systems used on steeper slopes.

South Fork Ten Mile River

In the mid 1910's, plans were prepared to build a railroad into the TMR area from the sawmill at Fort Bragg. Easily accessible timber stands of the Noyo River area had been depleted quite some distance from Fort Bragg and a new access route was needed. In 1917, a main logging camp was established along the South Fork of Ten Mile, near the mouth of Smith Creek. From the late 1910's to the 1940's, the South Fork was the major log supply source and transportation was by railroad. The typical logging operation was to fall and peel trees, burn the slash for access, chop the trees into logs, and then transport the logs to the railroad or to an incline connecting to the railroad at the river. This resulted in very large continuous clear-cuts that were repeatedly burned to clear the land for grazing.

Regeneration for the area was by natural means until the 1920's. A tree nursery was then established in Fort Bragg, and large areas were hand planted up to the early 1930's. From the 1930's to the 1970's regeneration was by natural means.

In 1945, a particularly destructive fire occurred in the South Fork. A lightning strike started a fire on the west slope of Sherwood Peak. For about two weeks, the fire burned slowly on the ground. A weather change resulted in dry, east winds and high temperatures. The fire "blew up" and burned to the south and to the west. It burned the area between Sherwood Ridge and Smith Ridge and westerly between Riley Ridge and Leidig Ridge roughly to the mouth of Churchman Creek. About 17,000 acres burned in three days. This ultimately resulted in a 10 to 20 year delay in reproduction for the area compared to other areas of the South Fork.

In 1948, the sawmill company at Fort Bragg was required to sell a large acreage of cutover timberlands to pay back a loan from the federal government. In the aftermath of World War II, a loan to stimulate business under the Reconstruction Finance Act had been granted to the local company. Courts later found the Reconstruction Finance Act unconstitutional. In the South Fork, lands were sold from near the mouth of Smith Creek to Churchman Creek; the entire Campbell Creek drainage was also sold. Owners of these cutover lands used repeated burning to convert and maintain the lands for grazing. On north-facing slopes, fires burned cooler and less successfully than on south-facing slopes. At the end of this slash burning period (early 1960's), the lands were purchased back for timber growing. The stands on northern slopes were generally older and better-stocked than stands on south slopes.

Beginning in the late 1970's and continuing to the present, thinning and even-age regeneration harvests have been used in stands from 40 to 70 years of age. Regeneration following these harvests has been by tree planting and natural regeneration. Log yarding has been by tractors on slopes under 50 percent and by running skyline systems on steeper slopes.

Instream History

Unlike land management history within the TMRW, information of in-stream conditions prior, or during logging activities prior to the 1930's is practically non-existent for coastal Mendocino County. However, effects of these past practices can be witnessed today in many watersheds. Increased sedimentation, canopy removal, instream blockages and other operations that occurred directly in the stream zone probably resulted in extreme environmental impacts.

California Department of Fish & Game (CDF&G) surveys, from the 1950's and 1960's provide the earliest information on biotic and abiotic instream conditions. This information is important but much of it is anecdotal and quantifiable conclusions are usually difficult to ascertain.

Today much more information on the TMRW's instream parameters exists, most collected by CDF&G, the Salmon Trollers Marketing Association and Georgia-Pacific. Georgia-Pacific has collected, the majority of this information and will continue to do so into the foreseeable future.

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MONITORING DESIGN

Although some instream information existed from surveys conducted by various agencies and local organizations, most of the information for TMRW was too scattered and anecdotal to have any influence on the initial project design. Progress (for most monitoring plans) has largely been by trial and error with no source of standard measures and procedures available for guidance (Platts et al. 1983a). The monitoring design for the TMRW began in a similar fashion. For example, many of the sites selected for sampling in 1993 were not based on representative reach locations within the watershed. Representative reaches were not previously delineated due to the lack of information concerning channel types. Habitat typing information for the TMRW was not completed until 1995 and if we were to wait until the completion of habitat typing, collect of instream data would have been delayed for three years. To compensate for the lack of stream reach information a large number of sample sites were distributed throughout the watershed to increase the magnitude of the sampling scheme and facilitate analysis of instream conditions. We believe this increased sampling effort has compensated for the lack of *a priori* information. As with any monitoring plan, there are a variety of inherent constraints involved with sampling the aquatic ecosystem, several of these include:

> lack of information concerning channel types
> the random nature of climatic events
> anthropogenic effects (e.g., fishing pressure)
> lag time between a management action and its effects on water quality
> difficulty distinguishing between effects of management activities and natural events
> larger watersheds have overlapping activity, making problem sources harder to pin-point

Sample site selection was based on horizontal and elevational distribution, adjacency to confluences, historic data, and logistic constraints. Many monitoring stations were placed adjacent to confluences which assist in isolating discrete inputs from upper reaches in an attempt to focus stream assessment efforts. For example, temperature monitors were placed above and below confluences in many areas to monitor thermal inputs from higher order streams into lower order streams.

Areas with historical information are also important, even if such sites are few and locations possibly biased. These areas provide comparisons with present data, which is beneficial for trend determination. Replication of previous efforts has resulted in a more comprehensive data set which is presented in this document.

Due to the extent of the monitoring program and size of the watershed, logistical constraints also dictated the sampling scheme. For example, company biologists often selected locations in consideration of weather conditions (e.g., wet roads, high stream flows), limitations and bulk of sampling equipment, transportation time and other priorities (other monitoring efforts). Since much of the TMRW is rather remote, and access to many areas limited, monitoring efforts often prove time-consuming and difficult. Additionally, aquatic vertebrate monitoring and sediment sampling stations must be sampled within one week of the previous years survey efforts to reduce statistical bias. Constraints such as these are part of any monitoring program and must be addressed in a manner that allows an accurate portrayal of instream conditions as well as annual comparability of data. In 1997 sampling across the TMRW included: 24 aquatic vertebrate stations (approximately 1 per 8.3 km of Class 1 stream), 33 temperature monitoring stations (approximately 1 per 5.8 km of Class 1 stream), and 23 sediment sampling stations (approximately 1 per 8.3 km of Class 1 stream. Through this sample design we believe enough of the TMRW is being sampled to effectively gauge abiotic instream conditions. Nonetheless, our results indicate we do not have a large enough sample size to effectively gauge juvenile coho salmon population. We are currently working with the National Marine Fisheries Service in testing a modified snorkel sampling protocol to assess with greater confidence actual coho salmon populations within the watershed.

With stream assessment methods the observed physical, biological, and chemical conditions and variations used to predict fishery condition and reactions have often been of low value for providing valid interpretations (Platts et al. 1983a). To compensate for these deficiencies during the refinement stages of a project, it is essential that protocols are well described to ensure consistency (Bryant 1995). Georgia-Pacific has continued to refine the TMRW monitoring plan, based on the best available information, in order to facilitate analysis and collection of scientifically sound data. To keep up with this myriad of evolving metrics, Georgia-Pacific has been an active participator in the Fish, Farms and Forestry Committee (FFFC) both at the policy and technical levels since 1993. The FFFC has been reviewing issues and monitoring techniques unique to the Northern California inland fishery resource. Georgia-Pacific will implement and adhere to methods that conform to the most widely accepted techniques recommended by the scientific community to allow broad comparisons. In gauging the integrity of the monitoring design, professionals were consulted and literature is constantly reviewed. For example, a qualitative ranking of monitoring parameters (especially for areas under timber management) provided by the Environmental Protection Agency (1991) was reviewed to assess the usefulness of our methods (see *Ten Mile River Watershed 1995 Instream Monitoring Results).* Numerous sources were consulted to ensure our methods and protocols remain consistent with the most widely recognized monitoring metrics and enhancement techniques.

Since its inception in 1993, the monitoring design has expanded and been refined to encompass a variety of metrics. This design has provided rigorous quantitative data allowing appropriate land management decisions to be implemented where feasible. Without well-described protocols and a method of evaluating current conditions (standard concern thresholds), interpretation of information is difficult, frequently leaving restoration unrealized or ineffective. Hence, Georgia-Pacific has set threshold limits for sediments and temperatures and is evaluating thresholds for other variables critical to salmonid life stages. These limits, if exceeded, have directed enhancement and restoration efforts to the area in question. It is Georgia-Pacific's goal to maintain a monitoring program that integrates enhancement activities to maximize benefits to salmonid habitat throughout the ownership. The underlying principles of this monitoring plan are to ensure that methods are consistent, repeatable and measurable. Assessment methods are not static, and we intend to refine monitoring methods and measurement of key variables when practicable.

The overall design of this monitoring effort may be altered in 1998 when Georgia-Pacific anticipates submittal of a multi-species habitat conservation plan. The riparian component of this plan will include a refined instream monitoring plan. Whether or not the variables analyzed here will continue in its present form is currently unknown.

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Table 1
Qualitative Ranking of the Usefulness of Monitoring Parameters, EPA (1991)
(Parameters shaded are those analyzed within current or past TMRW monitoring plans)

Parameters	**Forest Management Activities**	
	Harvest	**Road Building and Maintenance**
Water Column Temperature	1-3	3
PH	3	4
Conductivity	3	2-4
Dissolved oxygen	3	4
Intergravel DO	2	2
Nitrogen	3	3
Phosphorus	3	3
Herbicides	4	3-4
Pesticides	4	4
Flow Peak flows	4	3
Low flows	2	4
Water yield	3	4
Discharge	3	2
Sediment Suspended	2	2
Turbidity	2	2
Bedload	4	4
Channel Cross-sections	2	2
Channel Width/Depth	2	2
Pool parameters	2	2
Thalweg profile	2	2
Habitat units	3	3
Bed Particle Size	2	2
Embeddedness	3	2
Surface vs. subsurface	3	2
Large woody debis	2	3
Bank stability	2	2
Riparian Canopy opening	2	2
Vegetation	2	2
Aquatic Organisms Bacteria	4	4
Algae	3	4
Invertebrates	2	2
Fish	3	3

Legend
1 = Highly likely to be useful
2 = Moderately likely to be useful
3 = Unlikely to be useful (or little relationship)
4 = Not useful

INSTREAM SUBSTRATE COMPOSITION

Introduction

The complex life history of anadromous salmonids has directed most research toward habitat variables readily quantified during their freshwater residency. Anadromous salmonid life stages include upstream migration of adults, spawning, incubation, juvenile rearing, and seaward migration of smolts. Accordingly, the habitat needs of anadromous salmonids in streams vary with season of year and stage of their life cycle (Reiser and Bjornn 1979). Most research has focused on the identification and quantification of related attributes critical to juvenile salmonid survival, distribution, and abundance. Some of the instream habitat variables analyzed include, but are not limited to, stream temperature, habitat complexity, and fine inorganic sediment. Excess fine inorganic sediment can affect the success of salmonid spawning, egg incubation, and egg-to-fry emergence.

The non-random selection of spawning sites by salmonids is influenced by environmental variables such as water depth and velocity, substrate composition and proximity to cover (Platts et al. 1983b). The deposition of salmonid eggs in the instream substrate protects the eggs from predators and provides a flow of oxygen-rich water during the incubation period. Fine inorganic sediment in the salmonid nest, or redd, limits oxygen flow and results in decreased survival of eggs and alevins. Progressively higher percentages of sediments have been documented to result in progressively lower egg survival (Tappel and Bjornn 1983).

As a result, attention has focused on the impacts of sediments as a quantifiable limiting factor. Fine sediment in spawning gravels influences the survival-to-emergence ratio (STE) of salmonids through several possible mechanisms which including: (a) reduction in intragravel water flow with a subsequent buildup in metabolites and a corresponding reduction in dissolved oxygen, (b) smothering of embryos and sac fry from high concentrations of suspended sediment particles entering the redd, and (c) entrapment of fry attempting to emerge from the gravel to reach the water column.

Despite complexities determining effects in the amount and distribution of gravels (especially under natural conditions) pertaining to embryo survival, sediment is a clear and quantifiable parameter. Thus, the composition (or particle-size distribution) of instream substrate can be considered a limiting freshwater habitat factor for salmonids (if high in fines) and is often evaluated to estimate potential spawning success and egg-to-fry STE (Platts et al. 1983b).

Platts et al. (1983b) suggested the most widely accepted method for sampling and analyzing the particle size distribution of gravels used by spawning salmonids is one described by McNeil (1964) and McNeil and Ahnell (1964). McNeil samples, of all the current instream metrics (Q-STAR, V-STAR, RASI, D-50, etc.), exhibits the most direct link between stream condition and subsequent biological effects. Survival-to-emergence[1] depends on the amount and grain size of fine sediment deposited at

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[1] Under natural conditions STE is normally quite low (Johnson 1980). McNeil (1976) calculated an average STE of eight percent for three salmonid species in twelve streams in Alaska and British Columbia. Other estimates of STE under natural conditions have been documented at higher percentages, 27% and 30%, but even these are relatively low (Koski 1966, Tagart 1976, 1984). Under artificial conditions (e.g., hatcheries) STE can approach 90% or more.

different depths in spawning gravel, as well as on biologic and water-quality factors (Chapman 1988). Other techniques such as arithmetic mean particle size (Crisp and Carling 1989), median particle size (Witzel and MacCrimmon 1983b), sorting coefficient (Sowden 1983), and skewness (Crisp and Carling 1989) may adequately establish instream trends but they lack readily quantifiable parameters between the biology of a fishes lifestage and instream conditions.

The McNeil sediment samples were utilized in the TMRW to calculate particle size distribution of instream substrate and corresponding values of geometric mean diameter and fredle index. These three measurements were used by others to calculate STE of salmonids, to (arguably) link stream conditions to land management activities, and calculate percent fines in potential salmonid redds.

The McNeil sediment sampling technique (McNeil and Ahnell 1964) was used on Georgia-Pacific's ownership in the past by company personnel and others (Burns 1972, Valentine and Jameson 1994) to indicate particle size distribution and percentages of fine sediments in streams within the ownership. Collection methods followed standardized protocols for McNeil sampling.

Methods

Collection Methods

Methods for McNeil sampling follow those recommended by Valentine (1995, *in* Taylor, ed. 1996), and the Timber-Fish-Wildlife Ambient Monitoring Program Manual (Schuett-Hames *et al.* 1994). There were 23 instream substrate sampling stations (Appendix A) in the TMRW (Appendix B): eight in NFT, six in CFT, and nine in SFT. Sampling occurred during the low flow of late summer and early fall subsequent to fry emergence and prior to adult spawning[2]. All sites were visited within one week of the previous year's effort to reduce sampling bias.

All samples were collected with a modified McNeil sampler (modified with a Koski plunger to avoid loss of core material) with a core measuring 15.5 centimeters (cm) in diameter, 13.5 cm in length and capable of holding 2547 cubic centimeters (cc) of material. All samples were processed in-situ and wet-sieved (volumetric method) rather than dry-sieved (gravimetric method)[3].

Samples were taken from the pool/riffle juncture and not necessarily extracted from known salmonid redds. Pool/riffle junctures, or riffle crests are often the first area in the stream selected by anadromous fishes for spawning (Tripp and Poulin 1986). Winnowing of fine sediments when salmonids excavate redds results in a substantial

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[2] Adult salmonids have been observed spawning in coastal streams on the Port Bragg ownership between November and May during periods of adequate water flow.

[3] The volumetric method is advantageous because it is less time intensive and requires less equipment than the gravimetric method. Wet-sieving does produce error since water is increasingly retained with decreasing sieve size allowing greater volumetric displacement of smaller sediments. Correction factors (Shirazi and Seim 1979) will account for this type error but they frequently are not used nor were they suggested by Valentine (1995. *in* Taylor, ed. 1996). Correction factors were not calculated, for the 1993 through 1997 monitoring efforts. Furthermore, all known historical sediment sampling was done using the volumetric method without correction factors. These data further reinforced my decision to utilize the volumetric method.

decrease in this fine material[4]. Winnowing is difficult to model and not estimated in this study. Also, our sampling occurred during the late summer and early fall low flows; the time when fines are most concentrated in potential spawning substrates (Ambrose and Hines, 1997). For these reasons, we consider samples taken from the riffle crests indicate a worse case scenario of the true sediments found in the spawning substrate (Valentine 1995, *in* Taylor, ed. 1996).

Two riffles were sampled at each station, with four cores taken at each riffle, for a total of eight cores per station. Individual core samples were averaged and particle distributions are presented graphically, and in tabular form. Geometric mean and fredle index were calculated individually, averaged, and presented in Appendix C.

To classify the overall particle-size distribution of the sample, based on a geometric progression, the following 30.5 cm diameter sieves were used: 63.0 mm, 31.5 mm, 16.0 mm, 8.0 mm, 4.0 mm, 2.0 mm, 1.0 mm, and 0.85 mm as recommended by Shirazi et al. (1981). Instream characteristics noted during collection were stream gradient and stream flow.

As recommended by Valentine (1995, *in* Taylor, ed. 1996), measurements were taken along the second medial axis of the three largest rocks collected per individual core. If the largest particles are greater than 1\3 - 1\4 the diameter of the sampling core, a larger sampler is suggested (Valentine 1995, *in* Taylor, ed. 1996). These measurements were taken for all core samples at all locations.

All 1993, 1994, 1995, and 1996 sample locations were revisited in 1997[5]. However, the same riffle crests were not necessarily sampled each year. Winter flows often moved these riffle crests or eliminated them completely; in such cases, the nearest suitable location was sampled.

Analysis Methods

Two approaches are widely used to describe substrate composition (Young et al. 1991, Waters 1995): particle size distribution and the central tendency. In the first, the proportion of substrate particles less than a given size is quantified by weight or volume (generally percent fines). In the second approach, aspects of central tendency of the entire particle distribution are described (geometric mean, fredle index, and others). However, more recent literature estimated STE from either geometric mean (Platts et al. 1979) or fredle index (Lotspeich and Everest 1981) rather than percent fines. A single measure of substrate composition is probably inadequate;

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[4] Considerable flushing of the finer sediments occurs during redd construction (Kondolf et al. 1993, Everest et al. 1987) Although an extreme example, data for chinook salmon (Oncorhynchus tshawytscha) in Evans Creek, Oregon (Everest et al. 1987) indicated, fine sediment content lowered during spawning from 30% to 7.2%. Such extreme modification is unusual, but not unique. For all salmonids, the size of the redd is directly proportional to the size of the female, and is inversely related to the size of the gravel and degree to which it is compacted (Groot and Margolis 1991) Salmonids utilizing the TMRW are smaller than chinook salmon, subsequently expected decreases in finer material would not be as extreme. Conditions in the actual redds should be no worse than the samples, so actual survival would likely be better than indicated.

[5] Two additional sampling locations were added in 1995 in the North Pork; NFT2 and NFT10.

[6] Beschta (1982) stated a modified fredle index might be the best statistic for describing the composition of spawning gravels. Stowell et al. (1983), Bjomn (1969), Phillips et al. (1975) and others however attempted to estimate STE ratios from the percentage of fine sediment in a substrate. Young et al. (1991) found predicting STE from the percentage of substrate less than a given size unsatisfactory because survival was sensitive to the distribution of sediment with the target range. Their studies indicated geometric mean particle size was the best predictor of STE.

subsequently, results are presented as percent fines, geometric mean particle size and fredle index.

Fines within the TMRW monitoring plan were defined as material < 0.85 mm. Discrepancy exists in the literature concerning the definition of what constitutes percent fines. According to Waters (1995) the definition of fines as material less than 0.8 mm is well established and accepted by many researchers as the criterion above which significant mortality of embryos could be expected. Other research with definitions similar to Waters (1995) include, but are not limited to: 0.8 mm (NCASI 1984), 0.83 mm (McNeiland Ahnell 1964, Hall and Lantz 1969), 0.84 mm (Reiser and White 1988), and 0.85 mm (Tagart 1976, Koski 1966). Sources citing different criteria for fines include, but are not limited to: 1.0 mm (Hall and Campbell 1969), 2.0 mm (Hausle and Coble 1976), 3.3 mm (Phillips et al. 1975), 4.0 mm (MacCrimmon and Gots 1986), 6.3 mm (Burton et al. 1990) and 6.35 mm (Bjornn 1969).

The threshold of concern most frequently cited in the literature for salmonid eggs and larvae development usually falls around 20% (Koski 1966, Tagart 1976, Lisle and Eads 1991). Twenty percent fines (< 0.85 mm) is the threshold of concern for the TMRW.

Results

A total of 184 cores samples were extracted in the TMRW in 1997 from 23 locations in the watershed. Results are displayed graphically in Appendix D. Individual particle-size distribution, per core, with corresponding geometric mean, fredle index, and standard deviation are presented in Appendix C.

Percent Fines

Overall averages for percent fines from all three forks are displayed in Figure 1.

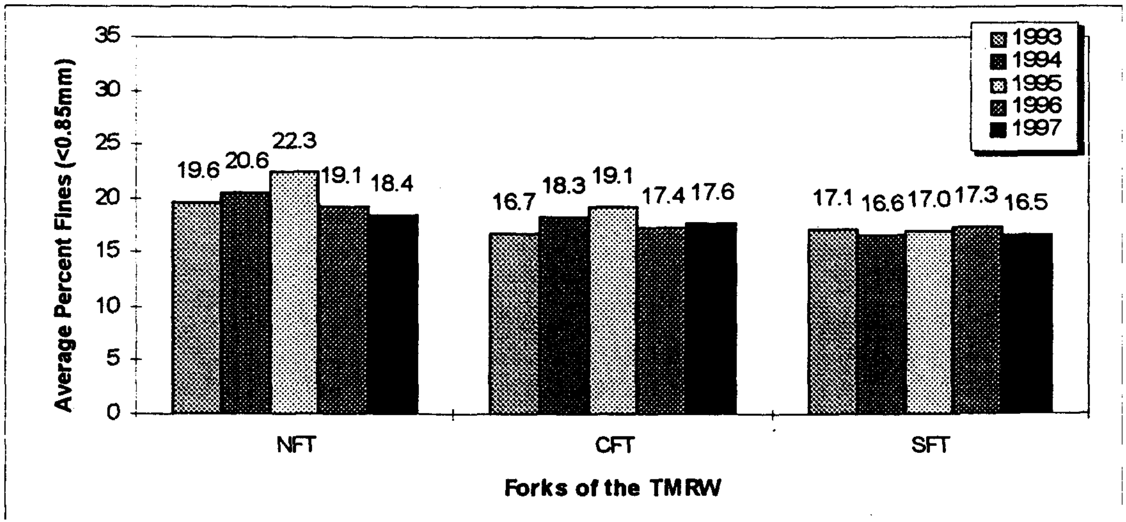

Figure 1. Summary of sediments < 0.85mm, per fork, for the 1997 TMRW instream substrate composition sampling effort on Georgia-Pacific Fort Bragg timberlands, Mendocino Co., CA .

Substrate particles < 0.85 mm for the TMRW ranged (per station) from 12.4% (Churchman Creek - SFT8) to 26.7%, (Booth Gulch - CFT5).

In NFT fines decreased from 19.1% in 1996 to 18.4% in 1997, between eight sample stations (Figure 2). Percent fines ranged between 23.9% (NFT at Gulch 9 NFT9) and 14.2% (Bald Hill Creek - NFT2).

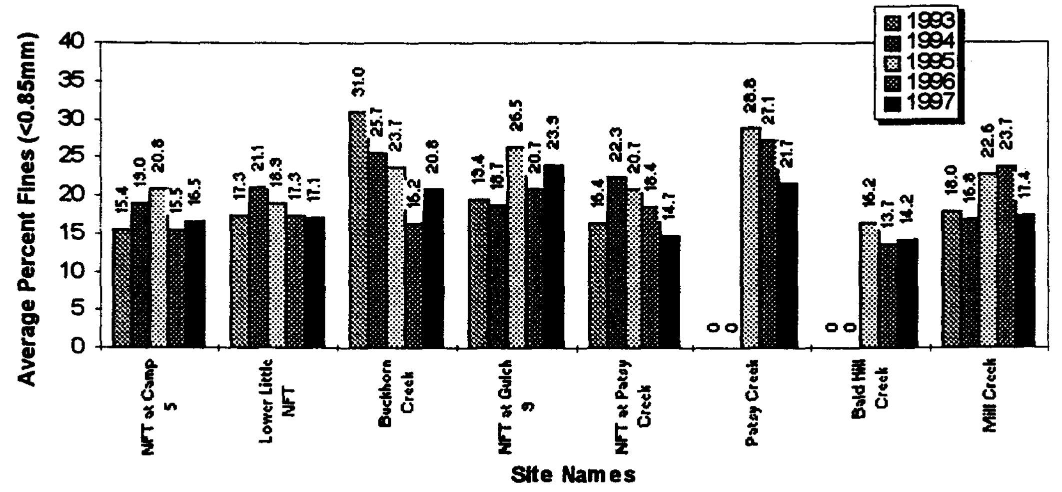

Figure 2. Summary of sediments < 0.85mm for 1993-1997 NFT instream substrate composition sampling sites, Georgia-Pacific Fort Bragg timberlands, Mendocino Co., CA.

In CFT fines increased, from 17.4% in 1996 to 17.6% in 1997, between six sample locations (Figure 4). Percent fines ranged between 26.7% (Booth Gulch - CFT5) and 11.4% (Lower Bear Haven Creek - CFT3).

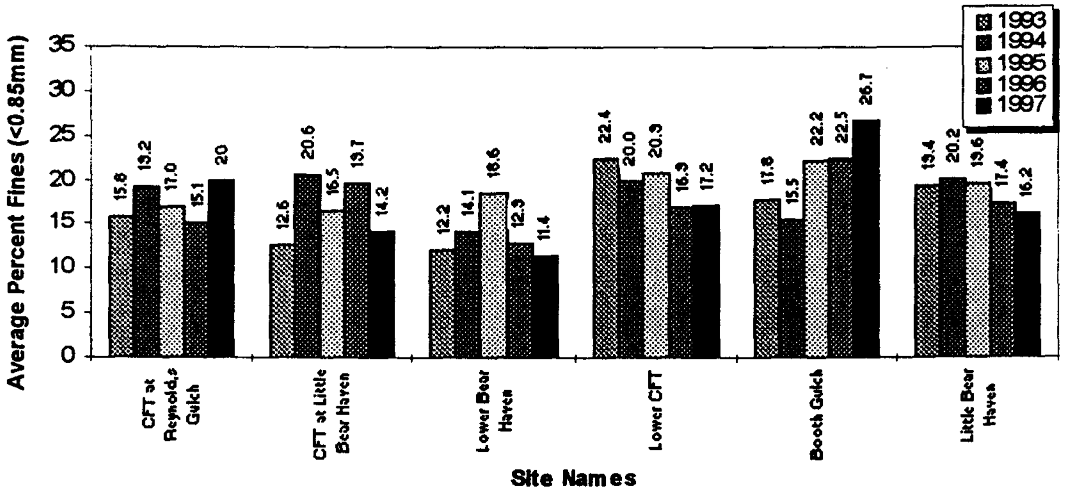

Figure 3. Summary of sediments < 0.85mm for 1993-1997 CFT instream substrate composition sampling sites, Georgia-Pacific Fort Bragg timberlands, Mendocino Co., CA.

In SFT fines decreased, from 17.3% in 1996 to 16.5% in 1997, between nine sample locations (Figure 4). Percent fines ranged between 22.7% (Upper Redwood Creek - SFT8) and 12.4 % (SFT at Churchman Creek - SFT4) in 1996.

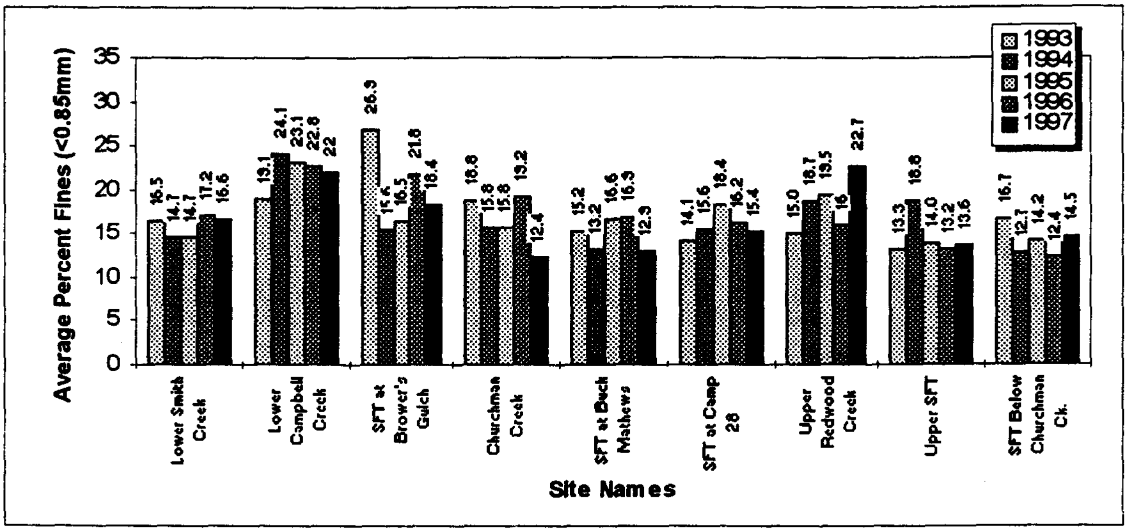

Figure 4. Summary of sediments <0.85mm for 1993-1997 SFT instream substrate composition sampling sites. Georgia-Pacific Fort Bragg timberlands, Mendocino Co., CA.

Overall, percent fines < 0.85 mm within all three watersheds remained relatively consistent with previous years monitoring efforts.

Geometric Mean Diameter

Geometric mean particle-size ranged from 5.3 mm to 14.9 mm for the TMRW with an overall average of 8.8 mm. Average geometric mean in previous years was calculated at 8.9 mm for 1996, 7.10 mm for 1995, 7.71 mm for 1994, and 8.79 mm in 1993. In NFT geometric mean particle size ranged from 6.3 mm (Patsy Creek - NFT 10) to 11.5 mm (NFT at Patsy - NFT1) with an overall average of 8.5 mm. In CFT geometric mean particle size ranged from 7.3 mm (Lower CFT - CFT4) to 14.9 mm (Lower Bear Haven Creek - CFT3) with an overall average of 8.8 mm. In SFT geometric mean particle-size ranged from 5.3 mm (Churchman Creek - SFT4) to 12.3 mm (SFT at Buck Mathews - SFT5) with an overall average of 8.0 mm.

Fredle Index

The fredle index ranged from 1.2 to 4.8 for the TMRW with an overall average of 2.6. Average fredle index for previous years was calculated at 2.62 for 1996, 2.20 for 1995, 2,40 for 1994, and 2.91 for 1993. In NFT the fredle index ranged from 1.2 (Patsy Creek - NFT10) to 3.4 (NFT at Patsy Creek - NFT1) with an overall average of 2.2. In CFT the fredle index ranged from 2.0 (Lower CFT - CFT4) to 4.8 (CFT at Little Bear Haven - CFT2) with an overall average of 3.2. In SFT the fredle index ranged from 1.4 (Campbell Creek - SFT2) to 4.4 (SFT at Buck Mathews - SFT9) with an overall average of 2.1. Percent STE, per site, is plotted against fredle index in Appendix E.

Discussion

In 1997, for the overall per fork average (Figure 4), the threshold of concern for the TMRW monitoring plan (fines <0.85 mm at 20%) was not exceeded in any of the three principal analysis areas (forks) within the watershed. Potential spawning conditions remained relatively consistent with 1996' as indicated by percent fines, fredle index, and geometric mean.

A great deal of variability in substrate composition within a riffle crest exists in the natural environment. Hence, the variability within and between sample sites from the past four years was expected. Results from individual samples in Tables 1-4 illustrate this point. The high degree of variability has made it difficult to determine the effects on any significant basis so far. Despite this variability, overall percentages from most sample locations appear relatively stable (within a few percentage points for the smallest fractions). It will probably take many years to describe the trend of these data with any statistical reliability, this is expected when gathering baseline data on physical processes. According to EPA Monitoring Guidelines (1991) the definition of baseline monitoring is to:

> *...characterize existing water quality conditions, and to establish a data base for planning future comparisons. The intent of baseline monitoring is to capture much of the temporal variability of the constituents of interest..*

Baseline monitoring within the TMRW has begun to capture the temporal variability within the watershed. Although generalized trends cannot be determined, these results have been used to direct restoration in the watershed[7].

Some studies attempt to relate land management activities with instream sediments (Cederholm et al. 1981) while others have shown more effects from natural geology (Duncan and Wood 1985). Due to a variety of natural and anthropogenic forces interacting, McNeil samples must be viewed with some caution. Factors such as lack of unmanaged local watersheds (which could determine historic conditions), and site geology must temper any broad based conclusions when comparing site-specific conditions to other areas.

Georgia-Pacific is planning to continue monitoring the TMRW instream bedload composition. However, modifications to the monitoring within the TMRW may occur pending approval of a multi-species HCP currently under development for the Fort Bragg ownership.

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[7] In NFT, fines increased past the 20% threshold in 1994 and 1995, reaching a high of 22.27%. Subsequently Georgia-Pacific concentrated enhancement efforts in this part of the watershed in 1995 and 1996 (Also see section on Stream Enhancement). The 1996 monitoring results indicate a significant decrease in the percentage of fines for NFT. However, while the decrease was significant, it cannot be extrapolated as a trend. I suspect past fines were elevated within NPT due in large part to effects of past practices. Tractor logging, especially in the upper end of NFT, was utilized on virtually every slope in the watershed prior to 1974. The landscape often takes decades to recover from such techniques.

STREAM TEMPERATURE

Introduction

Overview

Stream temperature monitoring was initiated in the spring of 1993 in an attempt to evaluate instream temperatures within the TMRW over time. Results presented within this portion of the report reflect instream conditions for 1997 and their potential impact on anadromous salmonids. Future monitoring may attempt to correlate ambient air temperatures to instream thermal regimes.

A number of variables influence the presence and distribution of salmonids in Northern California's coastal streams. These variables include, but are not limited to: freshwater habitat, oceanic conditions, and anthropogenic factors. Stream temperature, in freshwater habitats, is one of the most important of these variables (Fry 1967, 1971, Hutchinson 1976, *in* Armour 1991). Stream temperature regimes influence salmonid migration, spawning, egg maturation, incubation success, inter- and intraspecific competitive ability, resistance to parasites, diseases, and pollutants (Armour 1991). In fish, metabolic activity is directly related to temperature and affects process such as enzymatic activity and whole organismic activity such as growth (ODEQ 1994). The optimal temperature range for most juvenile salmonid species has been approximated between 12° - 14° C (Brett 1952), but the impacts to salmonids at temperatures above optimal are not well documented.

Poikilothermic fish do not regulate their temperature physiologically, but do compensate for thermal conditions behaviorally by adjusting activity rates and metabolic demand in adverse thermal conditions (Coutant 1985, Priede 1985, *in* Nielsen et al. 1994). Temperatures which increase to levels beyond the thermal tolerance limits for long periods of time can cause stress, reduced immunological resistance to pathogens and reduced growth in fish (Sniezko 1974, Avtalion 1981, Wishkovsky and Avtalion 1982). It is difficult to describe how fish respond physiologically to temperature stress because temperature modifies the clinical signs of stress (Strange et al. 1977, Barton and Schreck 1987). Elevated temperatures can eventually lead to death by direct and indirect modes. Lethal levels for adult salmonids will vary but are generally are in the range of 23° - 29° C (Bjornn and Reiser 1991). According to Bjornn and Reiser (1991):

> *Sub-lethal and lethal effects vary according to factors such as acclimation temperature, duration of temperature increase, daily fluctuations and ecological adaptations. Studies have shown that many populations of native salmonids respond to natural temperature patterns in streams by moving upstream or downstream - when water temperatures become unsuitable. In small streams where daily maximum temperatures approach lethal values, salmonids can thrive if the temperature is high only a short time and then declines into the optimum range.*

Anthropogenic activities can affect instream thermal conditions. If several activities occur along a stream, their effects on temperature can be additive for some distance downstream (ODEQ 1994) unless diluted by other cool water sources or climatic conditions (fog influence, topography, etc.). If temperatures exceed thermal tolerances of a given species they can reduce habitat availability for rearing juvenile fish.

The possible effects of natural and anthropogenic influences are not analyzed in this study due to the difficulty in isolating the influences of these forces. Rather, the instream monitoring goal was to isolate stream reaches that may limit the availability of summer rearing habitat for fishes in the TMRW. These data can direct implementation of site-specific land management decisions, where appropriate, by resource professionals.

Study Area

Streams in Mendocino County reach their warmest temperatures from mid to late-summer, the time of greatest solar incidence, lowest water flows, and highest ambient air temperatures. Subsequently, summer instream temperatures were identified as a local limiting freshwater habitat factor for juvenile salmonids. In limiting environments, pools often provide cool water refugia for fish (Neilsen et al. 1994). Freshwater fish are known to be able to detect small differences in water temperature (Bardach and Bjorkland 1957, *in* Eaton et al. 1995) and to seek cooler water if it is available under conditions of heat stress (Kaya et al. 1977, Headrick and Carline 1993, *both in* Baton et al. 1995).

To evaluate stream temperature as a possible limiting factor for salmonids in the TMRW, an instream temperature monitoring program was initiated in 1993. Temperature data loggers have been distributed each year throughout the TMRW during the summer low flow period (when thermal regimes attain their maximums). Stream temperature monitoring within the TMRW is expected to characterize baseline conditions to aid evaluation of conditions over time.

Coho salmon and steelhead trout are the cold water fish species[1] of primary emphasis in this monitoring effort due to their societal and economic value and current status under the Federal Endangered Species Act[2]. Of these two species, coho salmon have a narrower range of thermal tolerances and are more sensitive to elevated water temperatures than steelhead trout. The evaluation of temperature thresholds in this monitoring plan are based on the thermal tolerances of coho salmon.

To address potentially limiting temperatures for coho salmon, a maximum weekly average temperature (MWAT) threshold was established for the TMRW. This threshold is used by Georgia-Pacific biologists as a guideline to analyze temperature suitability for juvenile coho salmon in particular stream reaches. This guideline has been applied to allow a consistent analytical approach for the watershed, even though it may not be appropriate in all instances. For example, I applied the MWAT threshold

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[1] A loose but generally accepted grouping based on laboratory mortality data from Hokanson (1977, in Baton et al. 1995).

[2] Coho salmon are listed as a threatened species and steelhead trout are a candidate for listing under the act.

to mainstems as well as tributaries. This may be inappropriate because coho salmon, particularly in the southern part of their range, occur more frequently in tributaries than mainstems (Chamberlin et al. 1991, *in* Meehan, ed. 1991).

Methods

Collection Methods

Summer temperatures were measured continuously with 33 temperature data loggers (Onset Computer Corp. model — Hobo®-Temp temperature logger) in Class 1 (fish bearing) streams throughout the TMRW (Appendix A and B). These temperature loggers were placed near the bottoms of pools, usually towards the deepest portion . They were anchored in place with 95 mm diameter steel rebar and secured by 2 mm steel wire.

Hobo®-Temps record temperatures[4] at different time intervals resulting in a corresponding variety of memory longevity intervals. In 1993, all Hobo®-Temps were set at a time interval of 1.2 hours between sample periods. Analysis of these data revealed two to four redundant data points at high and low temperature peaks. The interval setting of 1.2 hours resulted in a memory life of three months for each logger. This was changed to 2.4 hours, to allow complete capture of daily thermal peaks and extending memory life to six months. A six month interval allowed complete bracketing of summer low flow temperatures by capturing initial summer temperature increases and subsequent autumn decreases.

All 33 loggers were installed in the TMRW between 28 May 1997 and 11 June 1997 and removed four to five months later. Installation dates for each logger occurred one day before the first day presented on individual temperature graphs. This allowed data loggers to reach equilibrium with instream temperatures and capture complete daily cycles.

Many juvenile salmonids congregate in pools over the summer months; hence, pools were chosen (over riffles and runs) as the primary data collection location. Nielsen et al. (1994) found when thermal stratification occurred in pools in northern California streams, significant numbers of steelhead trout utilized the cooler portions (bottom) of the pool. Cool water refugia, or pools, are believed to provide critical habitat in streams with elevated daily and/or weekly average temperatures and comprise the best available habitat in thermally stressed environments[5].

[3] Stream flows were not measured at temperature monitoring stations. Although flows account for a large source of temperature variation they were not measured due to the unavailability of an affordable and reliable continuous flow meter.

[4] All data loggers were calibrated according to methods described by Taylor (1996). All data loggers deployed in the TMRW were within the acceptable range as described by their manufacturer. We have found the removal of these data logger by unauthorized individuals occurs with less frequency in pool monitoring locations.

[5] No minimum or maximum pool depths were established *a-priori*. Locations were initially chosen by Georgia-Pacific biologists based on what was subjectively determined as a representative pool type within a sample reach. These same locations were monitored over the following years.

Analysis Methods

Temperature results are displayed as seven day moving averages of the daily maximums (7DMADM). This analysis allows comparisons to temperature standards for cold water fishes according to Armour (1991) and EPA (1976). Seasonal cumulative temperatures were not calculated but could provide a basis for future monitoring efforts.

In 1997 we compared nine predetermined MWATs to coho salmon presence/absence from data collected between 1993 and 1997 on the Fort Bragg ownership within the CCC ESU (see section on temperature thresholds in this report). From this analysis we found a range of significant values between 15° C and 18.3° C. From these data we established a maximum MWAT of 18.3° C and a lower limit of 16.8° C. This MWAT is a threshold temperature above which the instream environment may be limiting to coho salmon in the TMRW. These thresholds, particularly 16.8° C, involves both a spatial and *temporal* scale. A location can exceed the 16.8° C threshold and still not exceed the predetermined threshold if the exceedance occurred for less than six days. MWAT was derived from EPA (1976) water quality criteria for fish growth (18.0° C) and from Armour (1991) using the following:

$$\mathrm{MWAT} = \mathrm{OT} + (\mathrm{UUILT} - \mathrm{OT})/3$$

where

OT = a reported optimal temperature for the particular life stage or function, of a particular species.

and

UUILT[6] = the ultimate upper incipient lethal temperature (Fry et al. 1946).

The coho MWAT was applied to the 7DMADM temperature analysis to identify stream reaches possibly limiting to coho salmon in the TMRW. This analysis provided insight into average temperature conditions likely to affect coho salmon (by affecting spatial and physiological responses), rather than the short (2-3 hour) peaks above optimal.

Results

Of 34 data loggers deployed in the TMRW, 33 were successfully recovered and downloaded in 1997. The data logger at SFT 11 was not recovered in 1997. Individual results from each sampling location are displayed in Appendix C.

Fifteen monitoring stations did not exceed the 7DMADM for either coho salmon MWAT in 1997. Six stations ranged between the minimum and maximum MWAT and 12 stations exceeded the upper MWAT threshold. Stations exceeding the 18.3° C threshold were located at the following locations: SFT3, SFT5, SFT6, CFT1, CFT2, CFT4, NFT1, NFT3, NFT4, NFT5, NFT11, and NFT15.

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[6] The upper lethal temperature at which tolerance does not increase with increasing acclimation temperatures. The UUILT is also a time-of-exposure dependent 50% mortality value.

Temperatures exceeding the 18.3° C coho MWAT were all located in mainstems, none of the upper exceedances occurred in tributaries. However, four tributaries did have temperatures that ranged between the upper and lower threshold (SFT2, SFT7, SFT8, NFT2). Per fork, highest peak temperatures were recorded at SFT6 (20.7° C on 7 August), CFT2 (20.4° C on 25 July and 7 August), and NFT1 (21.4° C on 7 August).

Discussion

Results from the 1997 temperature monitoring program indicated temperatures in the TMRW were below the coho MWAT for most tributaries and some mainstem locations. Upper (18.3° C) MWAT exceedances were recorded for twelve locations. These stations were located in mainstem locations at all locations[7]. Depending on the fork, MWATs' were exceeded in the middle or lower portion of the respective mainstem. MWAT analysis focused on standard pool monitoring locations.

A number of variables influence stream temperature in the TMRW, including shade canopy, climatic conditions, streamflow, local air temperature, channel morphology, topography, stream substrates, channel width, pool frequency and coastal maritime influence. Additionally, a stream's volume, depth, and turbulence affect the actual temperature at any point in the water column due to the high heat capacity of water.

A important variable affecting stream temperatures in Mendocino County is the area of water exposed to solar input. One of the more crucial factors mitigating this, in smaller streams and rivers, is shade canopy. Brown (1971) found stream temperature is a function of many factors driven by the principle that the main source of heat for small mountain streams is the solar radiation that directly strikes the stream's surface. Solar energy is the largest component of energy available to warm stream water during the summer period (Chamberlin et al. 1991, *in* Meehan, ed. 1991). Shade canopy cover facilitates the reduction of solar energy from reaching the creek and also influences relative humidity and local air temperatures. When streamside vegetation is removed, summer water temperatures usually increase in direct proportion to the increase in sunlight that reaches the water surface (Chamberlin et al. 1991, *in* Meehan, ed. 1991).

Typically shade canopy was higher on tributaries within the TMRW than mainstems. This is a function of shade canopy and its effects decreasing with increasing stream widths. As stream widths increase, shade canopy interacts other abiotic environmental variables. For example, the color, composition and shape of stream cobbles and gravels cause a stream to reflect or absorb solar radiation. Dark gravels or cobbles on wide streams absorb solar radiation and subsequently result in warmer temperatures.

However, a wide channel with dark gravels doesn't necessarily result in increased water temperatures. If a wide channel is shaded by topography it can often maintain cooler temperatures than those that are not. This phenomenon appears to influence the thermal regimes in the TMR's mainstems.

A wide channel subject to coastal maritime influences can dissipate heat as it approaches the coast. This influence was most pronounced in SFT where river temperature dropped noticeably from the middle reaches to the lower reaches.

Regional mean air temperatures (n = 21) were approximately 1° C warmer in 1997 than the long term average regional air temperatures for the Northcoast (Joe Krieter, pers, comm.). Over a 120 year period mean regional air temperatures, between May and October, were 16.6° C. The mean air temperature for the Northcoast region in 1997 was 17.5° C.

Mean water temperatures (n = 66) for the Northcoast region had a corresponding increase in temperature in 1997. Over a period of two years (1995 and 1996) mean regional water temperatures, between May and October, were 14.5° C. The mean water temperature for the Northcoast region in 1997 was 15.4° C. This regional increase in temperatures last year is likely the most significant reason for a general increase in water temperatures within the TMRW in 1997.

The following is a discussion, by fork, of the 1997 thermal regimes and some of the variables influencing them, within the TMRW.

South Fork Ten Mile

Eleven stations were monitored for temperature in 1997. Five sites remained below both coho MWATs (SFT1, SFT4, SFT9, SFT12, SFT19), three ranged between 16.8° C and 18.3° C (SFT2, SFT7, SFT8), and three exceed 18.3°C (SFT3, SFT5, SFT6). All 7DMADM coho MWAT exceedances (of 18.3° C) occurred in the middle reaches of the mainstem. Temperatures exhibited a general warming trend as they moved from the headwaters (SFT7 and SFT12) through the middle reaches of the watershed. From SFT5 temperatures cooled downstream to the lower sampling locations (SFT3 and SFT16). Temperatures reached the maximum 7DMADM at SFT6.

Factors influencing temperatures in these areas include, but are not limited to: (1) canopy cover relative to channel width[8], (2) stream bed substrate and channel form, (3) tributary influence (flow), and (4) topographic orientation.

(1) Canopy cover: According to 1994 instream habitat typing information, the overall shade canopy in SFT was approximately 81 %. Overall tributary canopy cover was estimated at 85 % and mainstem canopy cover was estimated at 81 %. Canopy cover averages were calculated for the following stream reaches exceeding the 7DMADM coho MWAT:

~ Overstory shade canopy cover from SFT5 upstream to both SFT6 and SFT7 averaged 76% (total distance = 8835 m).
~ Overstory shade canopy cover from SFT6 upstream to SFT12 averaged 79% (total distance = 2217 m).

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[8] Information concerning canopy cover and channel width are contained in the *Ten Mile River Watershed 1995 Monitoring Results* (Ambrose et al. 1996)

~ Overstory shade canopy cover from SFT7 upstream to SFT8 (including the North Fork of Redwood Creek) averaged 87% (total distance = 3486 m).
~ Overstory shade canopy cover from SFT3 upstream to SFT5 (excluding Churchman Creek) averaged 76% (total distance = 9426 m).

(2) Stream bed substrates and channel form: According to the past three years' data sets, SFT6 exceeded the coho MWAT for all years. This is probably a function of its incised bedrock channel location. Beschta et al. (1987) found bedrock channels more efficient than gravel-bed channels at conducting heat. Interestingly, SFT6, according to the past five years aquatic vertebrate sampling data, has consistently maintained some of the largest steelhead trout populations within the TMRW[9].

(3) Tributary influence (flow): Tributary influence may have contributed to SFT exceeding the 7DMADM coho MWAT in the middle reaches due, in part, to the paucity of Class 1 tributaries in this area. Tributaries typically provide a cooling influence to mainstem streams. Redwood Creek and upper SFT above Camp 28 (SFT6) are both relatively long tributaries with approximately equal flows[10]. From these two location's temperatures increased to the SFTs' maximum at SFT5. Below the SFT/Redwood Creek confluence there are no significant tributaries providing cool water input until Churchman Creek.

Within the SFT analysis area, for every one kilometer of mainstem there exist 0.9 km of tributaries. However, the largest tributaries are close to the coast (Smith (7.2 km) and Campbell (4 km) Creeks). The only significant mid-river tributary is Churchman Creek (4 km). This creek, despite its relatively low flow (0.0102 cms)[11], coupled with topography and the coastal maritime influence, may combine to result in increasingly lower 7DMADMs as the river flows between SFT3 and SFT16.

(4) Topographic position: SFT flows essentially east/west until the SFT/Churchman Creek confluence where it begins flowing southeast/northwest. Topographic shading and coastal maritime influence may influence the cooling of temperatures from SFT6 through SFT16 below the coho MWAT.

Clark Fork Ten Mile

Ten stations were monitored for temperature 1997. Six sites remained below both coho MWATs (CFT3, CFT5, CFT6, CFT7, CFT8, CFT 19), one ranged between 16.8°C and 18.3° (CFT11), and three exceeded 18.3°C (CFT1, CFT2, CFT4). No coho MWATs were exceeded in any tributary sampling locations (n = 6) while four were exceed at mainstem locations. Temperatures exhibited a general warming trend as they moved from the headwaters (CFT8) through the middle and lower reaches of the watershed. Mainstem temperatures decreased downstream of CFT2 but did not drop

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[9] These populations were estimated, by year at the following levels: 0.85 f/M2 (1993), 2.32 f/M2 (1994), 1.74 f/M2 (1995), 1.33 f/M2 (1996), and 1.35 f/M2 (1997). For comparison, average steelhead trout density for all 1997 sites (n = 24) in the TMRW was estimated at 0.465 f/M2.

[10] Flows were measured during the aquatic vertebrate sampling effort.

[11] Measured on 20 September 1997.

below the coho MWAT threshold. Temperatures reached their greatest durations and highest 7DMADM coho MWAT at CFT2.

Factors possibly influencing this exceedance include, but are not limited to: (1) canopy cover, (2) tributary input (flow), (3) topography, and (4) coastal maritime influence.

(1) Canopy cover: Overstory shade canopy measured during the 1994/1995 instream habitat typing effort indicated tributaries within CFT maintained an average shade canopy cover of 90%. Mainstem CFT maintained an average shade canopy cover of 76% due, in part, to increasing widths in the lower reaches. Canopy cover averages were calculated for those temperature stations exceeding the 7DMADM coho MWAT:

~ Shade canopy from CFT2 upstream to CFT1 averaged 81% (total distance = 7910 m).
~ Overstory shade canopy from CFT 4 upstream to CFT 11 averaged 79% (total distance = 6647 m).
~ Overstory shade canopy from CFT 11 upstream to CFT2 averaged 80% (total distance = 5315 m).

(2) Tributary input (flow): The drop below coho MWAT from the mid-reaches to the lower reaches was not as dramatic as in SFT. This was due, perhaps in part, to less tributary input[12] (0.7:1 per km ratio) than the other two forks.

(3) Topography: CFTs instream thermal regimes may also be influenced by the fact it flows east/west for essentially its entire length. This greatly increases the duration of solar exposure on the mainstem.

(4) Coastal maritime influence: The differences between the decreases below the coho MWAT between SFT and CFT may be influenced by distance to the coast. CFT4 (the lowest station on CFT) was located further from the coast than those in SFT. Consequently .the stations in SFT were probably subject to a greater coastal maritime influence and the resulting cooling effect than which occurs in CFT.

North Fork Ten Mile

Twelve stations were monitored in 1997. Four sites remained below both coho MWATs (NFT6, NFT7, NFT8, TEN1), two ranged between 16.8° C and 18.3°C (NFT2, NFT9), and six exceeded 18.3°C (NFT1, NFT3, NFT4, NFT5, NFT11, NFT15). 7DMADM coho MWAT exceedances of (18.3°C) occurred in all mainstem locations but one (NFT9). Unlike the other two forks, the greatest exceedances and longest duration of the 7DMADM exceeding the coho MWAT occurred in the headwaters (NFT11) of NFT. Other than the universal exceedances of the coho MWAT, I observed no other clear patterns for the temperatures in the mainstem.

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[12] Based on stream lengths, not flow.

Four of the five tributaries did not exceed the coho MWAT. Baldhill Creek (NFT2) exceeded the lower threshold but did not exceed the upper limit. No coho MWATs were exceeded in any NFT tributary. NFT11 was located on the upper Georgia-Pacific property line and recorded higher temperatures than other headwater monitoring stations in the TMRW (SFT8, and CFT8).

Factors influencing these exceedances include, but are not limited to: (1) canopy cover, (2) stream bed substrates and channel form (3) tributary input (flow), and (4) topography.

(1) Canopy cover: Instream habitat typing information indicated NFT had an overall shade canopy of 86%. Shade canopy along the mainstem averaged 70% and 91 % in the tributaries. NFT had the highest overall shade canopy of the three forks but the lowest overall mainstem average. This is likely a function of increasing stream widths in the lower reaches of NFT. Canopy cover averages were calculated for those mainstem temperature stations exceeding the 7DMADM coho MWAT. Tributary canopy covers were not included.

~ Overstory canopy cover from NFT15 to both NFT4 and CFT4 averaged 41% (total combined distance = 2357 m).
~ Overstory canopy cover from NFT5 to NFT3 averaged 68% (total distance == 4670 m).
~ Overstory canopy cover from NFT4 to NFT5 averaged 81% (total distance = 3831 m).
~ Overstory canopy cover from NFT3 to NFT9 averaged 86% (total distance = 6471 m).
~ Overstory canopy cover from NFT9 to NFT1 averaged 70% (total distance = 6160 m).
~ Overstory canopy cover from NFT1 to NFT 11 averaged 85% (total distance = 2605 m).
~ Overstory canopy cover from NFT11 to the end of the survey reach averaged 80% (total distance = 1029 m).

(2) Stream bed substrates and channel form: NFT11 is located below areas of open grasslands with relatively poor canopy cover. The channel above this station was designated a bedrock reach by Georgia-Pacific's habitat typing crew in 1995. Beschta et al. (1987) found bedrock channels more efficient than gravel-bed channels at conducting heat. NFT11 had warmer temperatures than other headwater tributaries (SFT8, CFT8). This may be due (in part) to the greater degree of bedrock channel types in these upper reaches. Since stream temperatures are additive, these initial warmer temperatures may have a proportionately greater impact on the thermal regimes in this fork than in the other two.

(3) Tributary input (flow): NFT has many km of perennial tributary water flow entering it. The mainstem above NFT4 is approximately 24.5 km long and has approximately 40.8 km of Class 1 tributary flow (a 1:1.6 per km ratio). This ratio is

much greater than in the other two forks. While I did not analyze flow regimes in NFT the mitigating influence of tributary cool water input was an important variable within this watershed.

(4) Topography: Temperatures exceeded the 7DMADM coho MWAT throughout the mainstem in 1997. Like the other two forks, NFT generally flows east/west until reaching the Little NFT/NFT confluence. Summer solar angle contributes more thermal energy in east/west flowing streams and should be considered when assessing thermal regimes within this fork.

Temperatures did exceed the coho MWAT within the mainstem in 1997. While the precise reasons and their relative contributions are currently unknown it is reasonable to assume a variety of factors have contributed synergistically to 1997s instream temperatures. One of the most important of these variables was climatic conditions. For 1997 air temperatures were not measured and subsequently it was difficult to determine the influence of this variable. In 1998 we intend to measure air ambient air temperatures throughout the TMRW.

Discussion - cont.

Most tributaries of the TMRW generally exhibited instream thermal consistency and suitable temperatures for coho salmon. These temperatures were promoted by a myriad of environmental variables such as topography (channels are smaller and typically confined by slope), solar influence (many drain from north to south) and a higher percentage of canopy providing solar deflection. According to Sullivan et al. (1987) the most important factor in maintaining temperature in small streams is canopy relative to surface area and discharge. Greater canopy reduces solar influence and results in corresponding decrease in temperature and daily fluctuations (Brown 1971).

Temperatures in the mainstems were higher in daily peaks, daily fluctuations, and 7DMADMs than the tributaries. This was expected since the channel widths and water surface is greater, thus, naturally reducing the ability of the canopy to provide adequate protection from solar input. According to Hynes (1972, *in* Armour 1991) within streams, a natural gradient of increasing temperatures occurs from the headwaters to lower reaches. This was true for mainstem NFT but not for CFT and SFT where the warmest 7DMADMs were obtained in the mid-reaches. These reaches cooled as the river progressed down stream which is likely the result of tributary and coastal influences.

Cool water refugia is crucial to growth and survival of salmonids. According to Chamberlain et al. (1991, *in* Meehan ed. 1991) coho salmon spend most of their juvenile rearing stage in tributaries. Because mainstems are not typically utilized by juvenile salmonids during the critical summer period, due to a variety of abiotic and biotic factors, coho salmon presence and abundance may not be limited by lack of available cool water habitat.

These data are used by Georgia-Pacific biologists and foresters as a tool to evaluate potential limiting factors for salmonids within the TMRW. Coho MWAT exceedances usually promulgate further investigation if land management activities are proposed adjacent to these stream reaches. These data will aid the development of site specific prescriptions, where applicable, within these reaches to protect beneficial uses. According to Armour (1991), these site specific investigations are important because:

> *If impact predictions are made using equations given here (e.g., MWAT), remember that calculated results are not absolutes. For example, the calculated conservative MWAT for rearing spring juvenile chinook salmon is 15.6 C. Some hatcheries and streams exceed this temperature to a moderate degree;*
> *however fish populations are successful. This emphasises relying on temperature information applicable to heal conditions, and accounting for factors including natural variation, compensation, and other site-specific phenomena.*

Georgia-Pacific plans to continue monitoring instream thermal regimes within the TMRW. Modifications to the monitoring within the TMRW may occur pending approval of a multi-species HCP currently under development for the Fort Bragg ownership.

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AQUATIC VERTEBRATES

Introduction

The purpose of the aquatic vertebrate study was to monitor the presence, distribution and abundance of fish and amphibian species throughout TTC's Fort Bragg ownership and in the TMRW specifically. The listing of the coho salmon and the proposed listing of steelhead trout as threatened under the Endangered Species Act has necessitated increased monitoring efforts throughout their ranges. This listing highlights the importance of monitoring efforts on managed timberlands and provides the rationale for our focus on salmonids in this report. TTC is currently developing a multi-species HCP which may affect the method and intensity of future aquatic vertebrate monitoring. Additional information presented here includes a review of other fisheries-related activities occurring in the TMRW.

Methods

We sampled aquatic vertebrates at 24 locations throughout all three forks of TMRW (Appendix A). We selected sample sites in this study with the intent of providing uniform coverage of the watershed and an equal distribution of sample locations on the mainstem and tributaries. When established in 1993, habitat information was not available. As a result we were unable to select truly representative locations. This made it difficult to estimate basinwide populations accurately (Dolloff 1993). For the time being, we have chosen to favor consistency and remain with our existing sample locations.

We established stream segments of 30 to 50 meters for each sample site, with the limits defined by change in habitat type (i.e. pool, riffle or run). We placed seine nets of 4.5 mm mesh across the stream at the boundaries of the sampling unit to prevent emigration and immigration of vertebrates.

We used a Smith-Root Model 12 Backpack electrofisher to stun all specimens. Field technicians began shocking at the downstream end of the unit and worked their way to the top. Moving from bottom to top helped maintain visibility in the water and aided detection and removal of stunned organisms. The completion of one shocking attempt from the bottom seine to the top constituted a single pass (Reynolds 1983).

Two additional technicians collected all stunned vertebrates with dip nets and placed them in buckets containing stream water. We kept these temporary holding tanks cool by placing them in shade until the catch was processed and released into an adjacent stream reach. We collected all specimens under California Department of Fish and Game (CDF&G) scientific collection permits, #801008-06, #801056-02, and #801087-03.

After each pass, we identified species and recorded the number of individuals (Appendix B). Fork length of all salmonids, snout to vent length of all amphibians, total length of lampreys and total biomass of each species were also recorded.

We measured the following habitat variables:

1. Stream dimensions. Stream widths at three meter intervals and stream depths at the center of the stream channel, left of center and right of center at the same three meter intervals as stream width.
2. Stream Flow. Using a Marsh-McBirney Flo-Mate Model 2000 flow meter.

3. Temperatures. Ambient air and water temperatures using hand-held Celsius thermometers.
4. Habitat type. Percents of pool, riffle and run based on visual assessments.
5. Instream cover. Instream cover as a percentage of surface area and each contributing type of cover as relative percentages. Cover types included, undercut bank, large woody debris, small woody debris, boulders and other.
6. Streambed composition. Visual estimates of substrate composition as percent boulder (defined as rock >250 mm in diameter), large cobble (130-250 mm), small cobble (65-130 mm), gravel (2-65 mm) and fines (<2 mm).
7. Percent canopy cover. Spherical densiometer readings taken in the four cardinal directions every ten meters of sample reach.
8. Salmonid mortalities: Water conductivity, voltage, hertz output and salmonid mortalities were all measured in an attempt to monitor and reduce the mortality typically associated with this sampling method.

We employed a removal depletion strategy to estimate populations within the sample unit. A minimum of three passes at each site was necessary to establish an adequate regression (Brower et al. 1990). We calculated salmonid populations using the MicroFish 3.0 Population Estimator (Van Deventer and Plans 1989). Regressions in removal sampling depletions are required when using the population estimator. To achieve regressions on all species would require an inordinate increase in sampling effort. For this reason, we decided not to use the population estimator on non salmonid species. Instead, we simply used the actual catch as the estimated population.

Sample Design

To evaluate the adequacy of our sampling design, we considered the location and frequency of sample sites. How many samples are adequate in order to estimate salmonid populations in the TMRW? To answer this question, we plotted performance curves for coho salmon (Figure 4) and steelhead trout (Figure 5). In both cases we plotted the cumulative mean of the estimated fish densities against the number of samples. The number of samples were considered sufficiently large when the cumulative mean became insensitive to fluctuations in the data. This was observed in the flattening of the performance curve (Brower et al. 1990).

Population Trends

We estimated basinwide fish densities to provide an index of population trends over the last five years. To derive these figures, we divided the TMRW streams into segments and calculated their surface area. We then applied fish densities to those stream segments surrounding or adjacent to each sampling location. We derived mainstem and tributary segments separately to avoid applying estimates to widely differing stream types. We then combined all segments to establish the basinwide estimate.

Results

This year's aquatic vertebrate sampling began on 2 September 1997 and was completed on 10 October 1997 (Table 1). This schedule was intended to coincide with the late summer period when juvenile salmonid populations are typically most stable (Meehan and Bjomn 1991). Sample dates were consistent with last year's when logistically possible. Consistency in sample dates helped eliminate bias due to seasonal changes in salmonid populations.

Table 1 Aquatic Vertebrate Sampling Sites within the TMRW.

DATE	CODE	SITE NAME	LEGAL LOCATION
970903	cm	CFT At Reynold's Gulch	T19N R17W SEC.06
970903	CFT3	Lower Bear Haven Creek	T20N R16W SEC.31
970921	CFT5	Booth Gulch	T19N R16W SEC.01
970921	CFT6	Little Bear Haven Creek	T20N R16W SEC.33
970926	CFT7	Upper Bear Haven Creek	T20N R16W SEC.19
970902	CFT8	CFT At Ford Gulch	T20N R15W SEC.33
970925	NFT1	NFT At Patsv Creek	T20N R15W SEC.18
970919	NFT2	Bald Hill Creek	T20N R16W SEC.09
970925	NFT4	NFT At Camp 3	T20N R17W SEC.24
970918	NFT5	NFT At Camp 5	T20N R17W SEC.24
970911	NFT6	Lower Little NFT	T20N R17W SEC. 11
970911	NFT7	Buckhom Creek	T20N R17W SEC. 14
970918	NFT8	Upper Little NFT	T20N R17W SEC. 11
970919	NFT9	NFT At Gulch Nine	T20N R16W SEC. 15
970908	SFT1	Lower Smith Creek	T19N R17W SEC. 02
970908	SFT2	Lower Campbell Creek	T19N R17W SEC. 13
970906	SFT3	SFT At Brewer's Gulch	T19N R17W SEC. 24
970910	SFT4	Churchman Creek	T19N R16W SEC. 29
970906	SFT5	SFT At Buck Mathews	T19N R16W SEC. 21
970910	SFT6	SFT At Camp 28	T19N R16W SEC. 23
970904	SFT7	Lower Redwood Creek	T19N R16W SEC. 14
970904	SFT8	Upper Redwood Creek	T19N R16W SEC. 13
971001	SFT9	Upper SFT	T19N R15W SEC. 18
971010	TEN1	Mill Creek	T19N R17W SEC.01

The number of species detected per sample site ranged from seven to two. Figure 3 shows species richness for each site, grouped by drainage. We identified a total of nine species during our sampling effort. Table 2 shows a list of those species and the number of sample sites where they were found. Appendix C shows species and densities presented in a site by site format. It is important to note that the nine species detected by this survey method are not the total number of aquatic vertebrate species known to occur in the watershed.

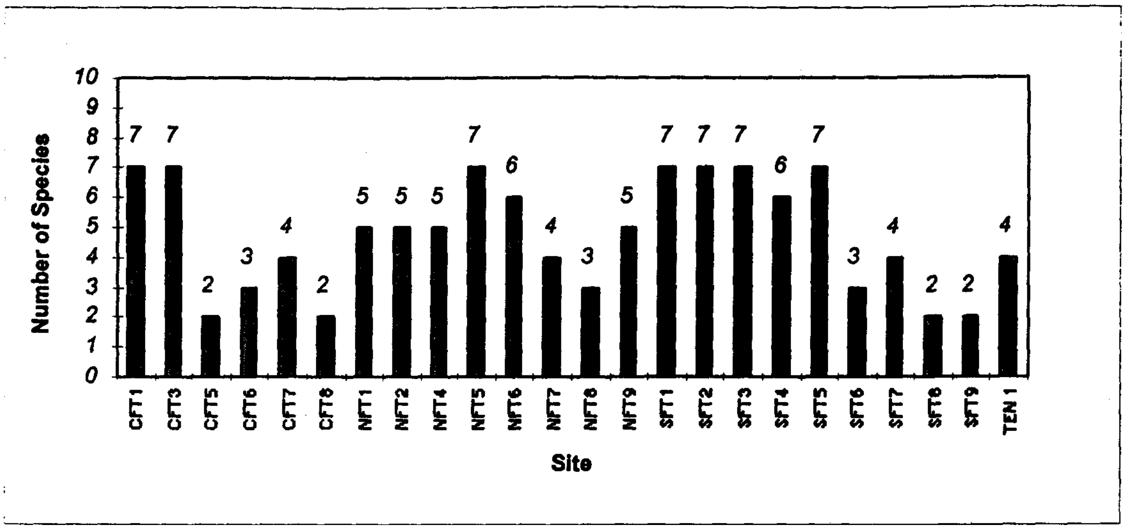

Figure 3. Number of Aquatic Vertebrate Species per Site Based on 1997 Aquatic Vertebrate Survey in the TMRW. (Refer to Table 1 for locations associated with site codes.)

Table 9. List of Species from the TMRW aquatic vertebrate survey.

Common Name:	Scientific Name:	# of Sites:
Coho Salmon	Oncorhynchus kisutch	7
Steelhead Trout	Oncorhynchus mykiss	24
Three-Spined Stickleback	Gasterosteus aculeatus	12
Coastrange Sculpin	Cottus aleuticus	12
Prickly Sculpin	Cottus asper	14
Lamprey	Lampetra spp.	7
Pacific Giant Salamander	Dicamptodon ensatus	23
Rough-Skinned Newt	Taricha granulosa	4
Yellow-Legged Frog	Rana boylii	11

Coho Salmon were found in 7 of the 24 sample sites, two of which were in the North fork (NFT6, NFT8), two in the dark fork (CFT3, CFT7) and three in the South fork (SFT1, SFT2, SFT4,). The average density' of Coho was 0.05 fish per square meter (f/M2). This value ranged from a low of 0.01 f/M2 at NFT6, NFT8, and SFT2 to a high of 0.10 f/M2 at SFT4.

Steelhead Trout were found in all 24 sample sites. The average density was 0.47 f/M2. The location with the lowest density was SFT9 (Upper SFT) with 0.03 f/M2. No young of the year Steelhead were found at this site. The highest density site was SFT6 (SFT at Camp 28), which had 1.35 f/M2.

There was a combined average observed mortality of 5.6% for salmonids (Appendix D). Coho salmon mortality averaged 2.3% and steelhead trout mortality

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[1] Average density means the average value of all coho densities other than those densities equaling zero. The actual density across all sites for coho salmon is 0.014 f/M2.

[2] The mortality analysis was not restricted to the TMRW, so the results reflect mortalities across the ownership.

averaged 6.5%. Twenty seven percent of sample sites, where coho salmon were present, had some degree of observed mortality with the highest being 18.2% at BIG4 (Lower Two Log Creek). Eighty one percent of sample sites, where steelhead trout were present, had some degree of observed mortality with the highest being 33.3% at NFT4 (NFT at Camp 3). The performance curve analysis was one way we assessed our sampling design. The results are shown in Figures four and five.

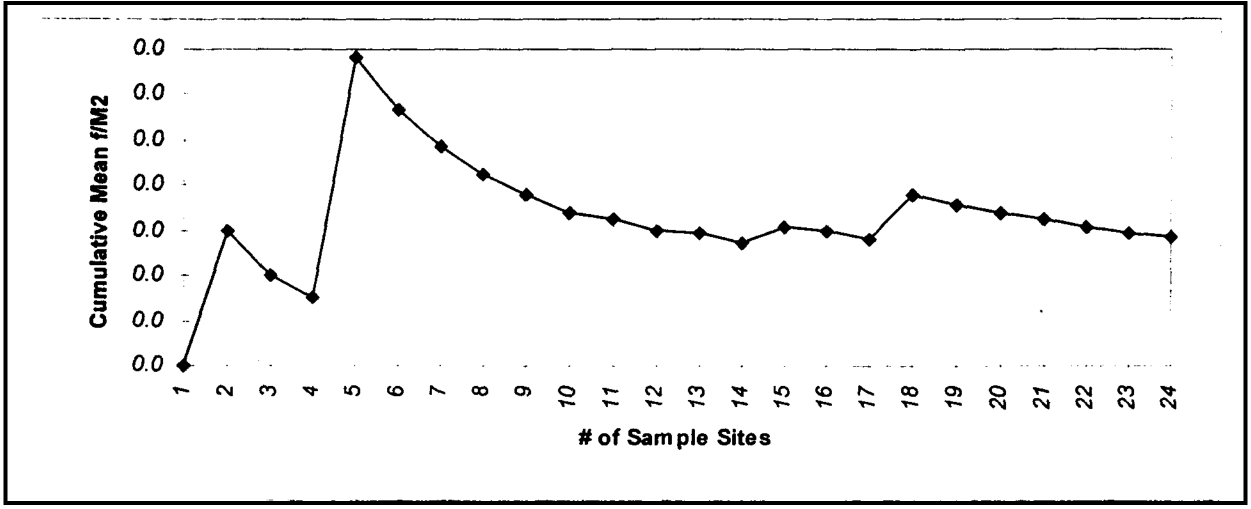

Figure 4. Coho Salmon Performance Curve.

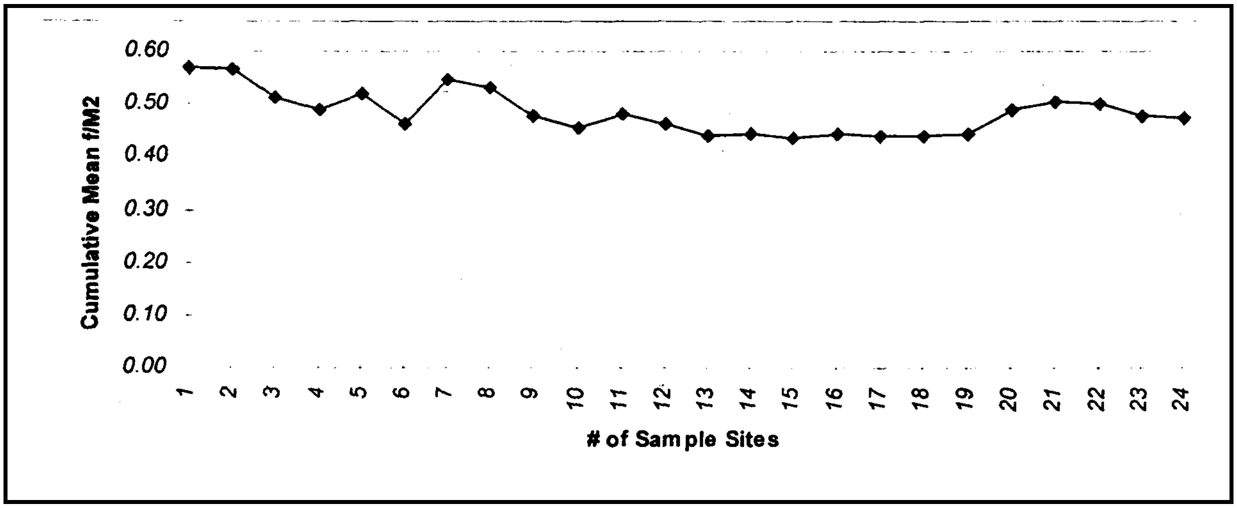

Figure 5. Steelhead Trout Performance Curve.

Table 3 shows basinwide estimates for coho and steelhead for the last four years. The highest density for coho was .032 f/M2 in 1996 and the highest density for steelhead was .670 f/M2 in 1994. Figures six and seven provide a comparison of these data.

Table 3. Annual Basinwide Estimates of Salmonid Soecies.

Year	Species	*# of fish*	Fish/Meter Squared
1993	Coho	10063	0.006
	Steelhead	781810	0.439
1994	Coho	5149	0.003
	Steelhead	1192519	0.670
1995	Coho	1165	0.001
	Steelhead	907195	0.510
1996	Coho	56356	0.032
	Steelhead	816672	0.459
1997	Coho	12853	0.007
	Steelhead	827647	0.465

Results of other species detections varied by species. The tailed frog, a California Species of Special Concern (and the only North American representative of the Family Leiopelmatidae) was not detected during this year's effort. This species is very philopatric, which makes it susceptible to population fragmentation (Daugherty 1982). It is associated with cold headwater streams with coarse substrates and low sedimentation (Welsh *et al.*, 1993). Tadpoles typically reside in shallow riffles where they cling to rocks with suckerlike mouths. Adults may be found in or adjacent to the wetted channel (Stebbins 1985). Efforts to find this species were largely opportunistic and therefore, do not necessarily indicate a negative trend for the population.

The foothill yellow-legged frog, a USF&WS Species of Concern, was found at eleven sites and primarily in mainstem locations with typically less canopy cover and more extensive gravel beds. Opportunistic sightings of this species were quite numerous throughout the watershed in addition to the 11 survey detections.

Lamprey of two morphological stages were encountered, ammocoetes and those in the macropthelmia stage. The latter was a transitional condition between the ammocoete and adult morphologies in which the eyes were proportionately larger, the structure of the gill openings and mouth were different and the overall body color changed from brown to gray. These two morphologies did not represent distinct species. Species differentiation of ammocoetes is based primarily on myomere counts and other more qualitative factors (Hopkirk Pers. comm. 1995). Three species are known to occur in this area: the pacific lamprey (Lampetra tridentata. USF&WS Species of Concern); the River Lamprey (Lampetra ayresi, USF&WS Species of Concern); and the western brook lamprey (Lampetra richardsoni). Lamprey were not identified to species in this study.

Discussion

Sample Design

The results of the performance curve analysis were mixed. The curve stabilized after ten to twelve sites for steelhead data. However, for coho data, no stabilization occurred. We concluded twenty four sites were adequate for estimating steelhead populations within the basin but were not enough to sample the highly variable coho population. The reason for the increased variation in coho data was due to the number of samples with negative results. This in turn was a reflection of the sparseness of coho in the watershed. However, the coho densities were plotted sequentially by site location. A truly random sequence may have changed the shape of the curve and therefore influenced our conclusions.

Electrofishing

One of the primary concerns with electrofishing as a sampling method has been the salmonid mortality associated with it. To address this issue, we compared voltage settings and mortalities with shock duration, water conductivity and temperature. This information will enhance our knowledge of the issue and help us to minimize this problem.

The high percent mortality at some sites seems to be associated with warm water temperatures. For example, the highest percent coho salmon mortality was in Lower Two Log Creek has had the warmest stream temperatures, on average, than any other site where coho salmon are regularly found (Hines and Ambrose 1998). However, the highest percentages of observed mortalities also tend to be at sites where the total catch is low. This suggests the high mortality may be a statistical artifact resulting from a small sample size.

As an additional measure in response to the mortality issue, TTC has been actively evaluating alternatives to electrofishing. Our participation in the Fish, Farm and Forest Communities Forum is one example. This group has been supporting the development of a salmonid survey technique that utilizes instream visual counts using mask and snorkel (Overton and Hankin in progress. 1997). Additionally, TTC has a cooperative arrangement with researchers from the National Marine Fisheries Service Tiburon Laboratory who are conducting snorkel counts on the South Fork TMR. The purpose of this research has been to evaluate the effectiveness of the Overton and Hankin survey technique as a means of estimating basinwide populations of coho salmon. TTC aquatic vertebrate monitoring results will be compared with the NMFS results as part of the project. As a condition of our direct take permit with NMFS, we have committed to overlaying next year's electrofishing efforts with snorkel counts. This will allow us to develop a comparative index between the two methods that will ultimately lead to the abandonment of electrofishing in favor of snorkel counts. This goal is contingent upon a favorable evaluation of the latter method by NMFS researchers and TTC management.

Population Trends

Figure 6 indicates coho density was far greater in 1996 than in any other year. This conclusion is consistent with other observations throughout the North Coast region (Pete Adams pers. comm. 1997). However, no firm conclusions can be made regarding yearly trends. Many variables influence coho population densities. Some variables are: ocean conditions, climatic regimes and stream conditions (Brown et al. 1994, Weitkamp et al. 1995). Additionally, the coho life cycle results in distinct year classes. Abundance in one year does not directly relate to the next, but to every third year. Uncertainty in our estimates combined with natural variations and the varied

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[3] Lower Two Log Creek (BIG4) is not in the TMRW, but is mentioned here because the mortality analysis encompasses all streams sampled on TTC ownership.

influences of many factors all act to obscure cause and effect relative to coho declines. It would be inappropriate to suggest any trends based on these data at this time. Nonetheless, this information serves well to inform us of the overall paucity of coho in the watershed.

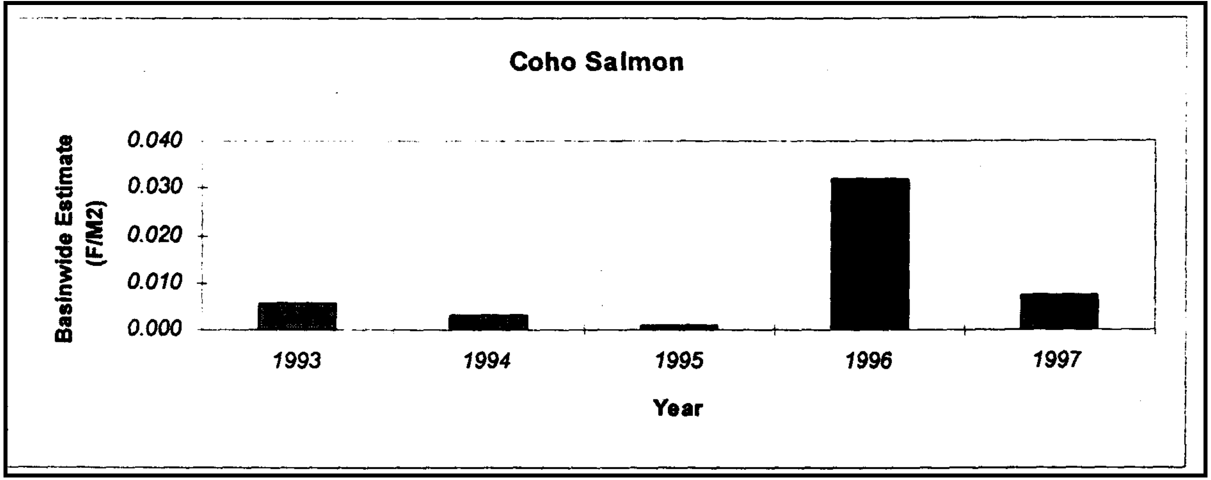

Figure 6. Annual Basinwide Estimate for Coho Salmon.

The annual basinwide estimates for steelhead (Figure 7) show a less erratic pattern suggesting greater stability and a lack of synchrony with coho populations. Note also the average density is approximately ten times greater than that of coho. This supports our general impression steelhead are ubiquitous and appear far more stable than coho in the TMRW.

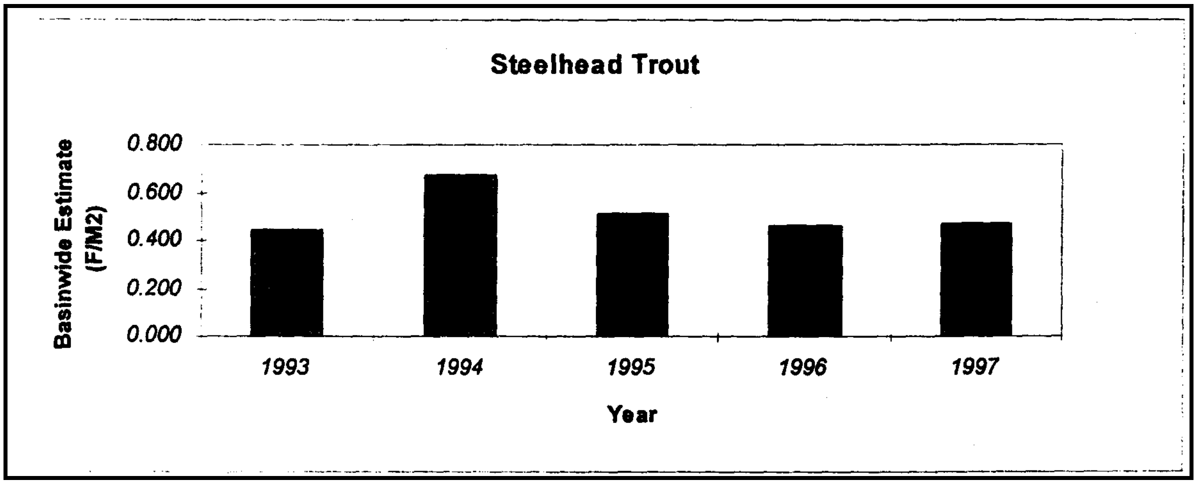

Figure 7. Annual Basinwide Estimate for Steelhead Trout.

Other Activities in the TMRW

Several other fisheries-related activities have occurred within the TMRW. Salmon Trollers Marketing Assoc. Inc. has conducted spawning surveys for the winters of 1990-91, 1991-92, 1995-96, and 1996-97. Contained in their reports are complete accounts of spawning records for those years. This same group has also completed an outmigrant study in 1995 and 1996 (Maahs 1996a and 1996b).

Another fisheries activity in the TMRW is the fish hatchery operated by the Salmon Restoration Association since 1989. Native steelhead trout have been raised and successfully released since 1990. Attempts to raise coho salmon have had mixed results. Small numbers were released from 1992 through 1994. In 1995 bacterial kidney disease (BKD) was detected and all salmon eggs/fry were subsequently destroyed. Trapping stations on SFT, CFT and Bear Haven Creek have been operating since 1993 and were the source for all coho salmon in the hatchery (Ed Moore Pers. Comm. 1996). The hatchery was not operational in 1997 due to a lack of permits from NMFS.

Summary

The performance curve analysis indicated the sample size was adequate for estimating steelhead populations, but not adequate for the less abundant coho due to increased variation. Trend analysis indicated steelhead dominated the salmonid community and appeared more stable than coho which have been sparse and erratic in distribution. We will continue using the electrofishing method for the 1998 season. In subsequent years, we anticipate using the visual count method.

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Final not supplied

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