TEN MILE RIVER WATERSHED 1996 INSTREAM MONITORING RESULTS

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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
HCP	habitat conservation plan
HWAT	highest weekly average temperature
km	kilometers
L	little
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
7DMM	average seven day moving maximum temperature
SFT	South Fork Ten Mile River
STE	survival-to-emergence
TMR	Ten Mile River
TMRW	Ten Mile River Watershed
UILT	upper incipient lethal temperature
UUILT	ultimate upper incipient lethal temperature

Abstract

This document describes results from the fourth year of monitoring instream conditions for Georgia-Pacific West, Inc's. landholdings in the Ten Mile River Watershed. Instream variables measured include water temperature, sediment, and aquatic vertebrate populations. These monitoring results are directing Georgia-Pacific's stream enhancement efforts through the assessment and prioritization of specific areas 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 West, Inc. (Georgia-Pacific) has completed the fourth 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 critical 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 those most limiting for salmonids. Georgia-Pacific will attempt to enhance many of these limiting features via restoration and/or active management.

Although the TMRW is the primary monitoring watershed, methods described in this document are currently applied in varying degrees throughout other watersheds within Georgia-Pacific's ownership. The TMRW was chosen as the primary watershed to study instream conditions because most of it is contained within Georgia-Pacific ownership (85%). This allows efficient evaluation and effective implementation of enhancement efforts throughout the watershed.

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 and pin-point areas where capital enhancements and improvements will have the greatest benefit.

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STUDY AREA

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 shaping the hills 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 Clark 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. 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 an annual precipitation average of 203 cm (Georgia Pacific SYP 1995).

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, lower inland fog-drip, 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) 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 Clark 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 garryana) punctuated with occasional Douglas-fir/redwood/tanoak stands of various sizes.

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 (Warrick and Wilcox 1981). Graywacke sandstone 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 (Bailey et al. 1964). The Franciscan formation in the TMRW is generally a dark mudstone, with smaller proportions of conglomerates and serpentines. 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 occasional tidal action 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 average rotation age within the TMRW is approximately 60 years. Various silviculture prescriptions were 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 1930's. Tractor logging replaced railroad logging and resulted in what is thought to be the greatest instream impacts. It is generally agreed that most in-stream impacts occurred between the 1940's and 1960's, before the passage of the Z-berg-Nejedly Forest Practice Act of 1973.

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 45 to 65 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 Clark 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 Clark 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 45 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 45 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, 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 as part of its commitment to the environment.

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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 last year and if we were to wait until the completion of habitat typing, no instream data would have been collected for the past 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 1996 sampling across the TMRW included: 25 aquatic vertebrate stations (approximately 1 per 7.68 km of Class 1 stream), 43 temperature monitoring stations (approximately 1 per 4.36 km of Class 1 stream), and 23 sediment sampling stations (approximately 1 per 8.34 km of Class 1 stream. Through this sample design we believe enough of the TMRW is being sampled to effectively gauge actual instream conditions.

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 1997 when Georgia-Pacific submits 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.

INSTREAM SUBSTRATE COMPOSITION

Introduction

The complex life history of anadromous salmonids has directed most research toward habitat variables readily quantified during their freshwater residency. The principle freshwater life cycles of anadromous salmonids 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 more important instream habitat variables include, but are not limited to, stream temperature, habitat complexity (for refugia) 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 that 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 include: (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 in 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. (1983) suggested that 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 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 clear and easily quantifiable parameters between the biology of a fishs' lifestage and instream conditions.

McNeil sediment samples were utilized to calculate particle size distribution of instream substrate and corresponding values of geometric mean diameter and fredle index. These three measurements have been used by others to calculate STE of salmonids, to (arguably) link stream conditions to land management activities, and to 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 follow 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 biases.

All samples were collected with a modified McNeil sampler[3] (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 2547.3 cubic centimeters

[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.

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

[3] The 1993, 1994, and 1995 TMRW monitoring reports indicated that future sampling efforts would include a shovel method since Grost et al. (1991) described the use of a shovel as a comparable technique to the McNeil sampler. The shovel technique was not implemented however, pending further literature review. Schuett-Hames et al. (1996) further investigated the feasibility of these two techniques and recommended sampling remain consistent for both baseline assessments and follow-up monitoring. Furthermore, they recommended use of the McNeil sampler in situations when a high degree of accuracy is important. Based upon this and other literature (Young et al. 1991), I decided to continue utilizing a McNeil sediment sampler as the primary instream substrate composition technique within the TMRW.

(cc) of material. All samples were processed in-situ and wet-sieved (volumetric method) rather than dry-sieved (gravimetric method).

Samples were taken from the pool/riffle juncture and not necessarily extracted from known salmonid redds. Data were recorded on standardized data sheets (Appendix C). Pool/riffle junctures, or riffle crests are often the first area in the stream selected by anadromous fishes for spawning (Tripp and Poulin 1986). The winnowing of fine sediments that occurs when salmonids are excavating redds results in a substantial decrease in this fine material.[5] This winnowing is very difficult to model and is not estimated in this study. Also, our sampling occurs during the late summer and early fall low flows; the time when fines are most concentrated in potential spawning substrates (Appendix D). 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 graphically.

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, and 1995 sample locations were revisited in 1996.[6] However, the same riffle crests were not necessarily sampled each year. High winter flows often moved these riffle crests or eliminated them completely; in such cases, the nearest suitable location was sampled.

[4] The volumetric method is advantageous because it is less time intensive and requires less equipment than the gravimetric method (expediency is critical to this monitoring program due to the short sampling period and the large number of samples taken in the TMRW and other watersheds within the Fort Bragg ownership). 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 1996 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.

[5]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.

[6] Two additional sampling locations were added in 1995 in the North Fork; NPT2 and NFT10.

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.[7] A single measure of substrate composition is probably inadequate; subsequently, results are presented in percent fines, geometric mean particle size and fredle index.

Fines within the TMRW monitoring plan were defined as material < 0.85 mm. A great deal of 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 (McNeil and 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, accordingly, the established threshold of concern for the TMRW monitoring plan.

A variety of variables affect changes in gravel composition from year to year. A variety of statistical tests were run on data collected over the past four years. A mixed-model repeated-measure multivariate analysis of variance (MANOVA) for the past four years' data was analyzed with both fixed and random effects using the program SYSTAT (Taylor 1997). The "fork" (e.g., NFT), "year" (e.g., 1993), and "stream type" (tributary or mainstem) were fixed effects. The "fork" effect was fixed because forks constitute different analysis areas. The "creek" (e.g., Campbell Creek), and "site" (sample station) effects were random. The "year" effect was a repeated-measures factor.

A number of partial analyses were conducted to reveal broad patterns in these data. This partial analysis was dictated by the addition of sampling sites in 1995 and the result of some missing data points from the 1993 and 1994 sampling effort. The first step in the analysis was the equalization of "creeks" in each "fork". The full data set

[7]Beschta (1982) stated a modified fredle index might be the best statistic for describing the composition of spawning gravels. Stowell et al. (1983), Bjornn (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.

has eight sample stations in NFT, six in CFT, and nine in SFT. However, in 1993 and 1994, CFT and NFT had six sample locations and SFT had nine. Sample size had to be equal in order to analyze differences between "forks". NFT2 and NFT10 were excluded from the North Fork because no samples were taken at these sites in 1993 and 1994. SFT4 was excluded because only four samples were taken in 1993 and 1994. SFT1 and SFT13 were removed to balance the number of samples overall between "creeks" and "mainstems".

To stabilize variances each percentage was transformed with the formula (Taylor 1997):

$$Y = 2 * ARCSIN(SQRT(X/100))$$

An analysis of variance was performed to determine if a significant change ($P < 0.05$) in percent fines occurred within the watershed. Percent fines among the three forks were calculated to determine if significant differences existed ($p < 0.05$) between 1995 and 1996 results for all sample sites (including NFT2 and NFT10).

Results

A total of 184 cores samples were extracted in the TMRW in 1996 from 23 locations in the watershed. Results are displayed graphically in Appendix E. Individual particle-size distribution, per core, with corresponding geometric mean, fredle index, and standard deviation are presented in Appendix F.

Percent Fines

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

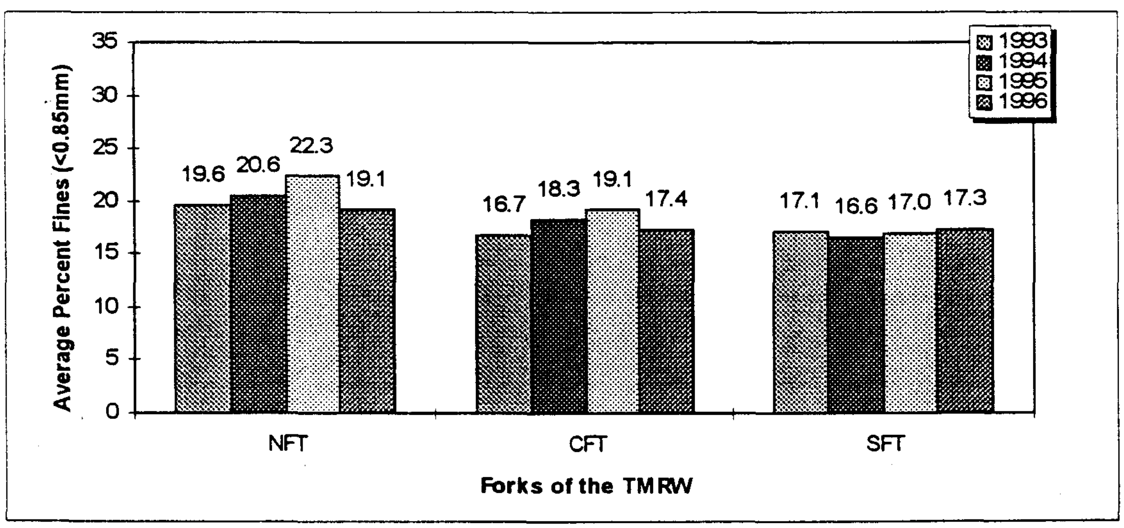

Figure 1. Summary of sediments <0.85mm, per fork, for the entire TMRW McNeil sediment sampling effort, 1996.

Substrate particles < 0.85 mm for the TMRW ranged (per station) from 12.4% (SFT below Churchman Creek (SFT13)) to 27.1% (Patsy Creek (NFT10)). Percent fines decreased in 1996 over the previous three years' samples. Increases were noted at seven locations, decreases were noted at 16 locations.

In NFT average fines decreased significantly (p = .007) from 22.3% in 1995 to 19.1% in 1996, between eight sample stations (Figure 2). Percent fines ranged between 27.1% (Patsy Creek (NFT10)) and 13.7% (Bald Hill Creek (NFT2)) in 1996.

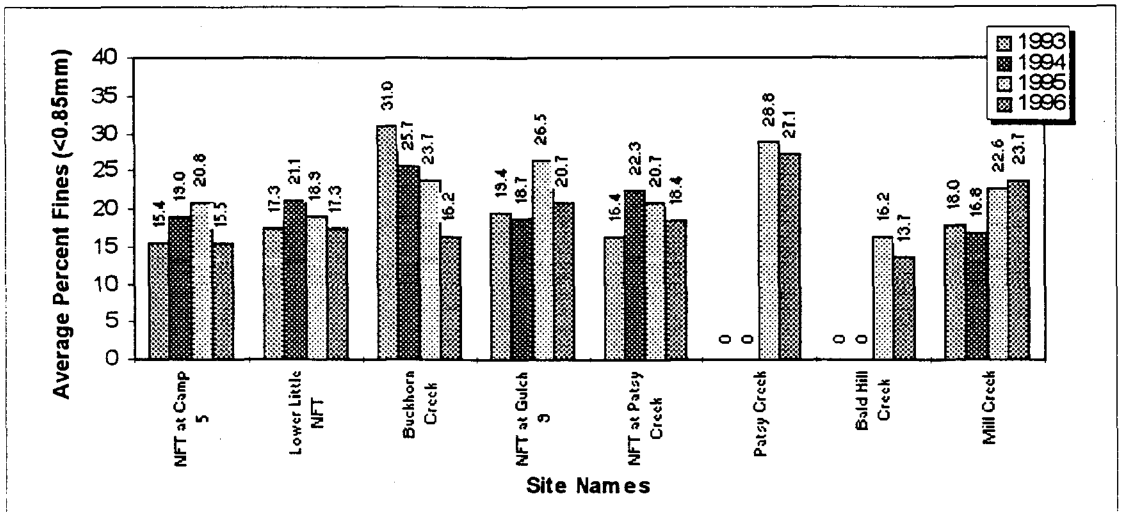

Figure 2. Summary of sediments < 0.85mm for NFT McNeil sediment sampling sites, 1993-1996.

In CFT fines decreased, from 19.1% in 1995 to 17.4% in 1996, between six sample locations (Figure 4). This decrease was not significant (p = .117). Percent fines ranged between 22.5% (Booth Gulch (CFT5)) and 12.9% (Lower Bear Haven Creek (CFT3)) in 1996.

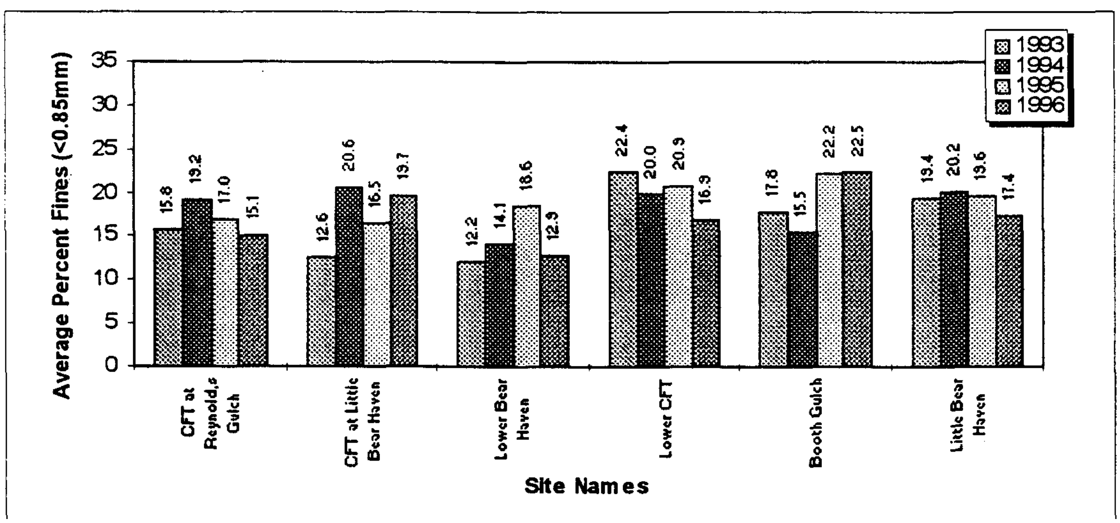

Figure 3. Summary of sediments < 0.85mm for CFT McNeil sediment sampling sites, 1993-1996.

In (SFT) fines increased, from 17.0% in 1995 to 17.3% in 1996, between nine sample locations (Figure 4). This difference was not significant (p = .381). Percent fines ranged between 22.8% (Lower Campbell Creek (SFT2)) and 12.4% (SFT below Churchman Creek (SFT13)) in 1996.

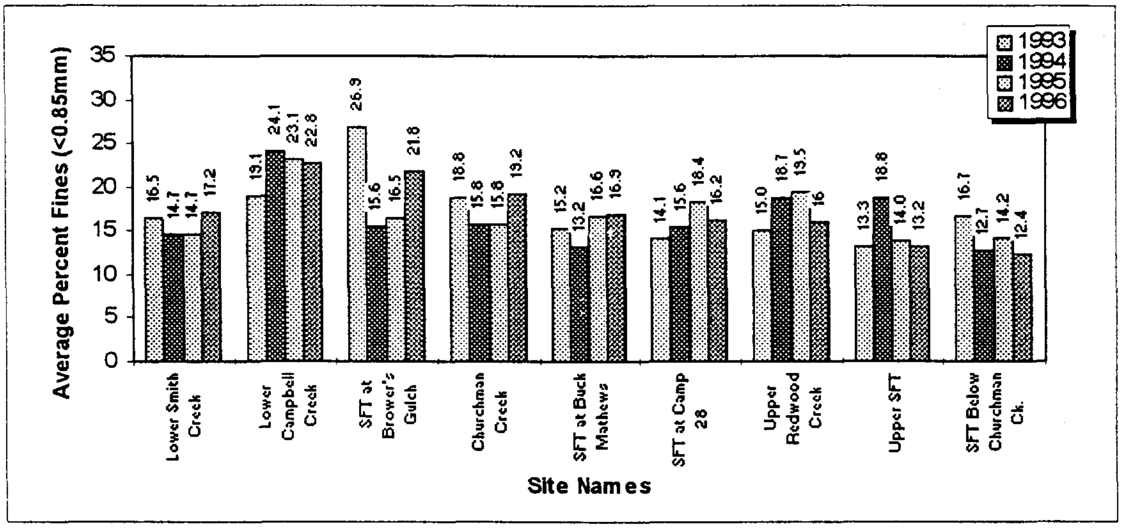

Figure 4. Summary of Sediments <0.85mm for SFT McNeil Sediment Sampling Sites, 1993-1996.

While fines increased slightly in SFT an overall analysis for the TMRW indicated percent fines did decrease significantly in 1996 ($p = .029$). The MANOVA also calculated that the overall decrease in percent fines in 1996 was determined to be significant. Variability within the four years' data did not allow for trend determination. Analysis of percent fines among the three forks indicated significant differences exist. Additionally, the differences among the three forks were significant between analysis years. In other words, the yearly patterns of changes in instream substrates were different in the different forks. This is evidenced by the changes in percent fines between the forks. For example, fines remained relatively stable in SFT while fluctuating significantly in NFT. This suggests the differences found in percent fines among NFT, CFT, and SFT may be the result of actual differences in particle size distributions of each fork's respective bedloads and not simply an artifact of random variation.

Geometric Mean Diameter

Geometric mean particle-size ranged from 4.6 mm to 17.2 mm for the TMRW with an overall average of 8.9 mm. Average geometric mean increased in 1996 over all previous sample years; 8.79 mm in 1993, 7.71 mm in 1994, and 7.10 mm in 1995. In NFT geometric mean particle size ranged from 9.2 mm (Mill Creek - TEN1) to 13.2 mm (Camp 5 - NFT5) with an overall average of 8.7 mm. In CFT geometric mean particle size ranged from 5.5 mm (Little Bear Haven Creek - CFT6) to 17.3 mm (CFT near Reynolds Gulch - CFT1) with an overall average of 10.2 mm. In SFT geometric mean particle-size ranged from 4.6 mm (Churchman Creek - SFT4) to 16.4 mm (Upper SFT - SFT9) with an overall average of 8.2 mm. Geometric mean increased at 18 of the 23 sites sampled in 1996 when compared to 1995.

Fredle Index

The fredle index ranged from 1 to 5.9 for the TMRW with an overall average of 2.62. The average fredle index increased in 1996 when compared to 1994 (2.40) and 1995 (2.02) but was still lower than the average for 1993 (2.91). In NFT the fredle index ranged from 1 (Patsy Creek - NFT10) to 5.3 (Bald Hill Creek - NFT2) with an overall average of 2.53. In CFT the fredle index ranged from 1.5 (Booth Gulch -CFT5) to 5.9 (CFT near Reynolds Gulch - CFT1) with an overall average of 3.18. In SFT the fredle index ranged from 1.4 (Campbell Creek - SFT2 and Churchman Creek SFT4) to 4.2 (Upper SFT - SFT9) with an overall average of 2.33. Percent STE, per site, is plotted against fredle index in Appendix G. The fredle index increased at 16 of the 23 sites sampled in 1996 when compared to 1995.

Second Medial Axis

A partial analysis (n = 13) comparing the second medial axis of the three largest rocks to the core diameter of the McNeil sampler indicated a larger sample core was needed. Eleven of the 13 samples had an average intermediate axis of the three largest rocks too large to allow for an accurate sample.[8]

Discussion

The MANOVA analysis indicated a significant overall decrease of percent fines in 1996. Variability within the four years' data did not allow for trend determination.

In 1996, 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 improved in 1996 over 1995 as indicated by an overall decrease in percent fines and an overall increase in fredle index and geometric mean. I hypothesize that the higher than normal rainfall during the winter of 1995/1996 was the primary variable dictating this effect. It is generally accepted that high flows have the potential to decrease percent finer material. However, due to the high variability inherent with sediment sampling studies Taylor (1997) and White (per. comm.) could statistically conclude that changes in percent fines were significant in only one of the three forks within the watershed. These results are expected when the inherent variability of particle sizes within pool\riffle junctures is considered. Valentine (1995, *in* Taylor ed. 1996) described a number of other possible influences that obscure determination of current conditions:

> *Current condition can be variable due to localized natural geologic events, historic land uses, current land uses, and short (1-5 year) to long-term (decade +) climate conditions. Relative to land-use decisions, interpretation of the significance of condition' is complicated by this inherent variability. Even short-term conditions may be critical when the population of a species (be it fish or of another taxa) which is sensitive to substrate character is extremely low. However, generally trend is of greater significance than a 'snap-shot' of current condition. Repeated application of these guidelines over time will enable trend to be assessed.*

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 Appendix F illustrate

[8]We are planning to build a new sampler with a core diameter of 68.6 mm for the 1997 monitoring effort. 25

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 the same sample locations appear to remain 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, but again this should be expected when gathering baseline data on any physical process. 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 are being utilized to direct restoration and enhancement programs throughout the watershed.

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 NFT 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.

The MANOVA demonstrated significant differences between watersheds for percent fines. The overall patterns of change in fines were significantly different as evidenced by the stability of fine sediments in SFT and, to a lesser degree, CFT. The changes between 1995 and 1996 were determined to be significant only for NFT. The reasons for this are currently unknown but will continue to be evaluated into the future.

Many studies have attempted 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. Future research in the TMRW may attempt to correlate rainfall patterns and roaded acres to the three main forks. 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.

JA

AQUATIC VERTEBRATES

Introduction

The purpose of the aquatic vertebrate study was to monitor the presence, distribution and abundance of fish and amphibian species throughout Georgia-Pacific'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 situation accents the importance of monitoring efforts on managed timberlands and provides the rational for our focus on salmonids in this report. Georgia-Pacific is currently developing a multi-species HCP which may affect the method and intensity of future aquatic vertebrate monitoring. Additional information presented here includes an analysis of habitat associations with salmonid abundance, description of our tailed frog survey and a review of other fisheries-related activities occurring in the TMRW.

Methods

We sampled aquatic vertebrates at 25 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, #2221, #801035-08 and #801608-06.

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 Platts 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 four 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.

Habitat

Of the 20 habitat variables analyzed, we collected 15 during the aquatic vertebrate sampling effort. Water temperature and instream substrate composition data accounted for the remaining five metrics. These data are described in their respective sections of this report.

We correlated all metrics with estimated coho and steelhead fish densities. We used a significance level of $p < .05$, making r values of 0.34 or more and -0.34 or less significant (Deborah White pers. comm. 1997).

In an additional analysis of site conditions associated with coho salmon use, we made comparisons between "coho sites" and "non-coho sites." We designated coho sites as those both used by this species in 1996 and with evidence of use for more than one year prior to 1996.[1] Criteria for this designation included detection by electrofishing or spawning observations. We consulted the following records: 1993-1996 Georgia-Pacific electrofishing records; CDF&G, Region 1 electrofishing records collected by Wendle Jones for the years 1983, 1989 and 1991; 1990-91 through 1995-96 spawning survey results (Maahs 1996a). We lumped site-specific results for the 20 different metrics into two categories (coho and non-coho). We averaged the values of each category and compared them using a significance level of $p< 0.05$ to determine differences. This comparison encompassed all monitoring sites electrofished in 1996.

In the final portion of the habitat analysis, we compared steelhead trout densities to the same 20 habitat metrics. However, since steelhead occupied all sites, we divided the sites into two discrete groups: "high density sites" and "low density sites." We listed all sites in descending order of steelhead density, the top third were designated high density sites and the bottom third were designated low density sites.

Tailed Frog Survey

Each year since 1994, we conducted an area search for Tailed Frogs in the same location on Fox Gulch, a tributary of the dark fork TMR, to monitor this population. Any other Tailed Frog sightings have been the result of opportunistic observations or as part of the aquatic vertebrate survey.

The area search was conducted by constraining 50 meters of stream with seine nets and, visually searching the substrate from the bottom of the stream segment to the top. Four workers searched the stream channel three times, removing all tadpoles and adults each time. All specimens were measured by length and biomass and released.

Results

This year's aquatic vertebrate sampling began on 5 August 1996 and was completed on 22 October 1996 (Table 1). This schedule was intended to coincide with the late summer period when juvenile salmonid populations are typically most stable (Meehan and Bjornn 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.

[1]This criteria resulted in seven sites (CFT7, NFT2, NFT4, SFT3, SFT4, SFT5, SFT16) being designated as non-coho sites despite coho being found there in 1996. I made this decision because there was no evidence of prior coho use and/or densities were so small that I did not feel justified in declaring them significant occupations of habitat. It was my judgement that either these areas supported transient coho use or did not represent rearing habitat. Results of habitat analysis differed considerably when sites were grouped strictly by presence and absence as determined by the 1996 electrofishing results alone.

Table 1. Aquatic Vertebrate Sampling Sites within the TMRW.

DATE	CODE	SITE NAME	LEGAL LOCATION
960806	CFT1	CFT AT REYNOLD'S GULCH	T19N R17W SEC.06
960805	CFT3	LOWER BEAR HAVEN CREEK	T20N R16W SEC.31
960909	CFT5	BOOTH GULCH	T19N R16W SEC.01
961002	CFT6	LITTLE BEAR HAVEN CREEK	T20N R16W SEC.33
960924	CFT7	UPPER BEAR HAVEN CREEK	T20N R16W SEC.19
960807	CFT8	CFT AT FORD GULCH	T20N R15W SEC.33
960923	NFT1	NFT AT PATSY CREEK	T20N R15W SEC.18
960916	NFT2	BALD HILL CREEK	T20N R16W SEC.09
960927	NFT4	NFT AT CAMP 3	T20N R17W SEC.24
960911	NFT5	NFT AT CAMP 5	T20N R17W SEC.24
960906	NFT6	LOWER LITTLE NFT	T20N R17W SEC.11
960905	NFT7	BUCKHORN CREEK	T20N R17W SEC.14
960910	NFT8	UPPER LITTLE NFT	T20N R17W SEC.11
960912	NFT9	NFT AT GULCH NINE	T20N R16W SEC.15
960821	SFT1	LOWER SMITH CREEK	T19N R17W SEC.02
960819	SFT2	LOWER CAMPBELL CREEK	T19N R17W SEC.13
960816	SFT3	SFT AT BROWER'S GULCH	T19N R17W SEC.24
960827	SFT4	CHURCHMAN CREEK	T19N R16W SEC.29
960814	SFT5	SFT AT BUCK MATHEWS	T19N R16W SEC.21
960903	SFT6	SFT AT CAMP 28	T19N R16W SEC.23
960813	SFT7	LOWER REDWOOD CREEK	T19N R16W SEC.14
960823	SFT8	UPPER REDWOOD CREEK	T19N R16W SEC.13
961022	SFT9	UPPER SFT	T19N R15W SEC.18
960812	SFT16	SFT AT BIG CAT CROSSING	T19N R16W SEC.21
960930	TEN1	MILL CREEK	T19N R17W SEC.01

The number of species detected per sample site ranged from nine to two. Figure 3 shows species richness for each site, grouped by drainage. We identified a total of eleven 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 eleven species detected by this survey method are not the total number of aquatic vertebrate species known to occur in the watershed.

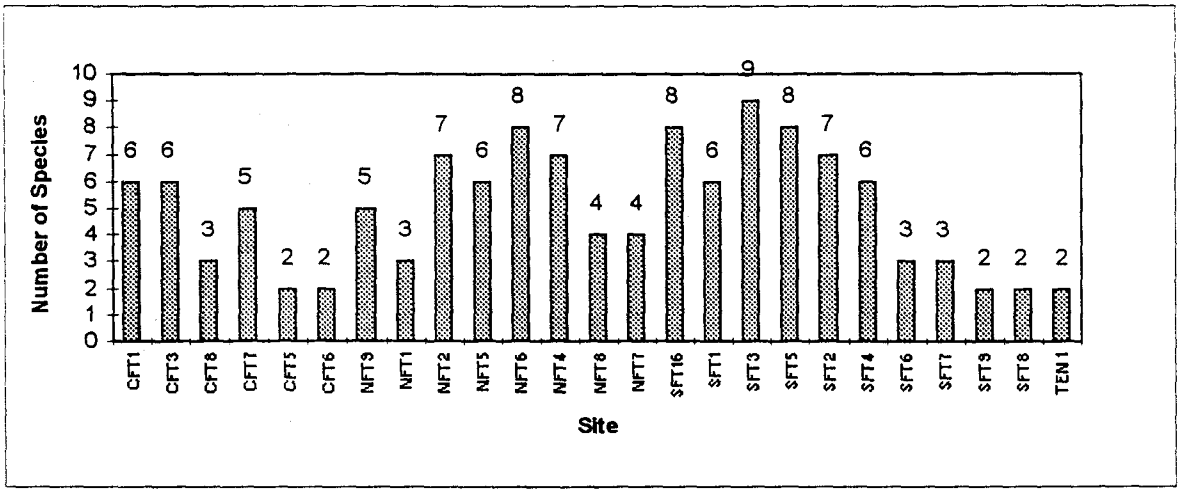

Figure 3. Number of Aquatic Vertebrate Species per Site Based on 1996 Aquatic Vertebrate Survey in the TMRW. (Refer to Table 1 for locations associated with site codes.)

Table 2. List of Species from the TMRW aquatic vertebrate survey.

Common Name:	Scientific Name:	# of Sites:
Coho Salmon	*Oncorhynchus kisutch*	14
Steelhead Trout	*Oncorhynchus mykiss*	25
Three-Spined Stickleback	*Gasterosteus aculeatus*	12
Coastrange Sculpin	*Cottus aleuticus*	11
Prickly Sculpin	*Cottus asper*	15
Lamprey	*Lampetra spp.*	9
Pacific Giant Salamander	*Dicamptodon ensatus*	24
Rough-Skinned Newt	*Taricha granulosa*	4
Red-Bellied Newt	*Taricha rivularis*	1
Yellow-Legged Frog	*Rana boylii*	7
Tailed Frog	*Ascaphus truei*	1

Coho Salmon were found in 14 of the 25 sample sites, five of which were in the North fork (NFT2, NFT4, NFT6, NFT7, NFT8), three in the dark fork (CFT1, CFT3, CFT7) and six in the South fork (SFT1, SFT2, SFT3, SFT4, SFT5, SFT16). This was, by far, the greatest frequency of Coho detections in the four years of monitoring the TMRW. The average density of Coho was 0.04 fish per square meter (f/M2). This value ranged from a low of 0.004 f/M2 at SFT3 (SFT at Brewer's Gulch) to a high of 0.35 f/M2 at SFT2 (Campbell Creek).

Steelhead Trout were found in all 25 sample sites. The average density was 0.48 f/M2. The location with the lowest density was SFT9 (Upper SFT) with 0.07 f/M2. This was the only site where no young of the year Steelhead were found. The highest density site was SFT6 (SFT at Camp 28), which had 1.33 f/M2.

There was a combined average mortality of 5.5% for salmonids. Mortalities were not discriminated to the species level. Twenty three of 25 sample sites had some degree of observed mortality with the highest being 15.6% at SFT5 (SFT at Buck Mathews).

The performance curve analysis was the primary tool we used to asses our sampling design. The results are shown in Figures four and five.

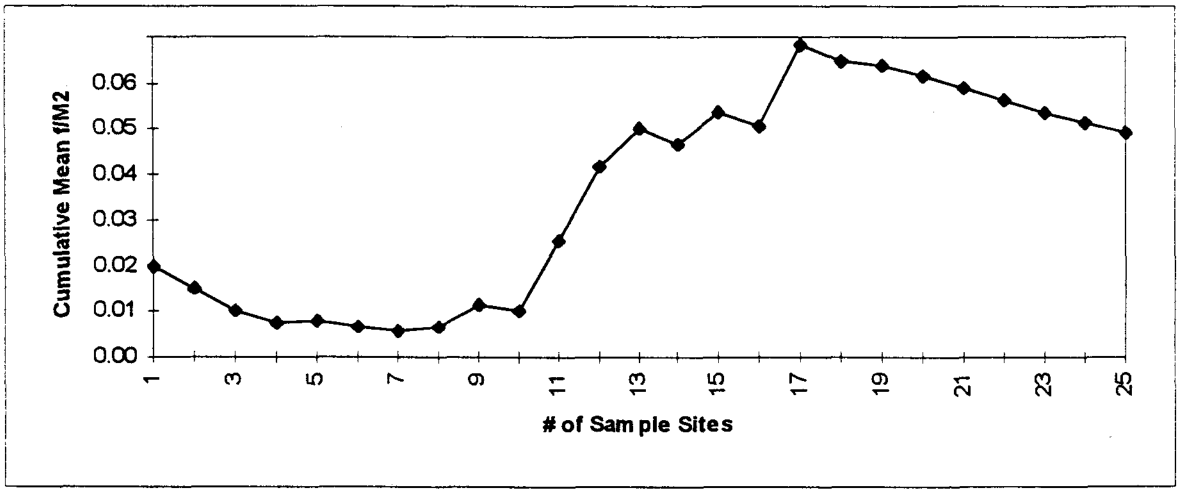

Figure 4. Coho Salmon Performance Curve.

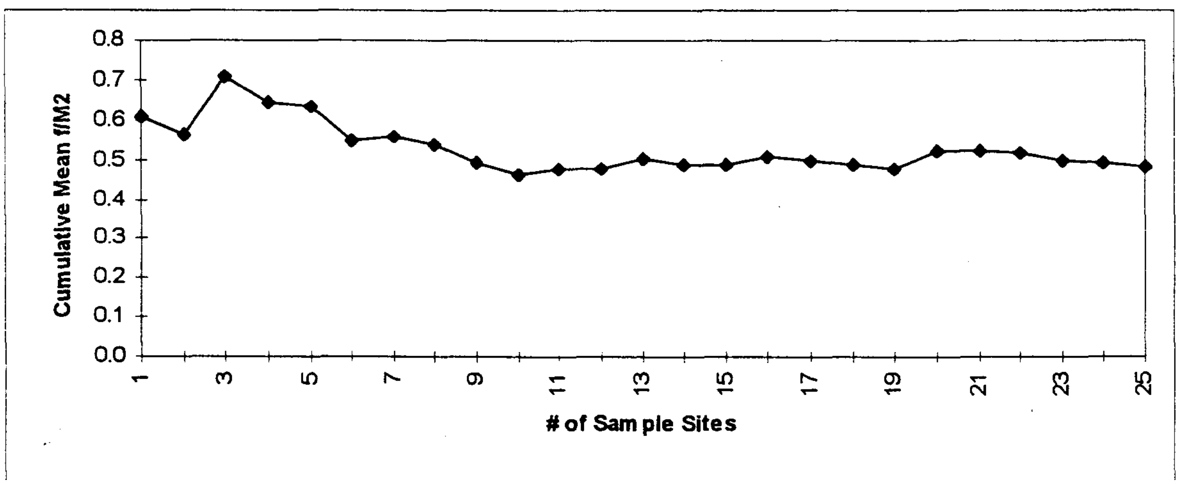

Figure 5. Steelhead Trout Performance Curve.

Table three 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 Species.

Year	1993		1994		1995		1996	
Species	Steelhead	Coho	Steelhead	Coho	Steelhead	Coho	Steelhead	Coho
# *of* Fish:	10063	781810	5149	1192519	1165	907195	56356	816672
f/M2:	0.006	0.439	0.003	0.670	0.001	0.510	0.032	0.459

We discovered several significant associations as a result of our habitat analysis (Appendix D). Specifically, the correlation between coho density and the percent pool values (r=0.44) and the figures for the boulder as cover and boulder as substrate values (r=-0.36 and 0.35 respectively) indicated an inverse association between coho and steelhead relative to boulder ratings. Additionally, the average number of days > 18.3°C shows a significant difference between coho and non coho sites with non-coho sites being subject to longer periods of elevated temperatures.

A single tailed frog larva was found at CFT8 (CFT at Ford Gulch) during the aquatic vertebrate survey. During the area search in 1994, 18 tadpoles were found. In 1995, 23 tadpoles and one adult were found. In 1996, 12 tadpoles and one adult were found. Georgia-Pacific will continue this survey effort.

The tailed frog is a California Species of Special Concern and is the only North American representative of the Family Leiopelmatidae. 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).
The foothill yellow-legged frog was found at seven 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);* the River Lamprey *(Lampetra ayresi);* 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 five 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.

As an additional measure in response to the mortality issue, Georgia-Pacific 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, Georgia-Pacific 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. Georgia-Pacific aquatic vertebrate monitoring results will be compared with the NMFS results as part of the project. Until the snorkel technique is fully developed, we feel it is best to continue electrofishing. Based on this intention, we have submitted a Section 10(a)(l)(A) direct take permit application with NMFS for our 1997 electrofishing efforts.

Population Trends

Figure 6 indicates coho density was far greater in 1996 than in previous years. This conclusion is consistent with other observations throughout the North Coast region (Pete Adams pers. comm. 1997). However, no firm conclusions can be made from this. 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. Abundances in one year are not directly related to the next, but to every third year. Uncertainty in our estimates combined with natural variations and the varied 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.

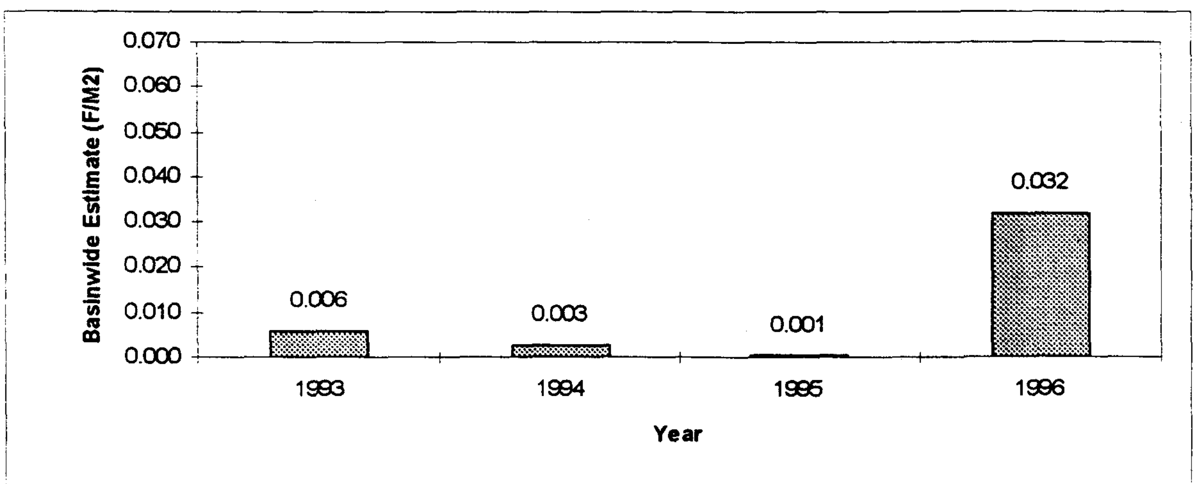

Figure 6. Annual Basinwide Estimate for Coho Salmon.

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 almost 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.

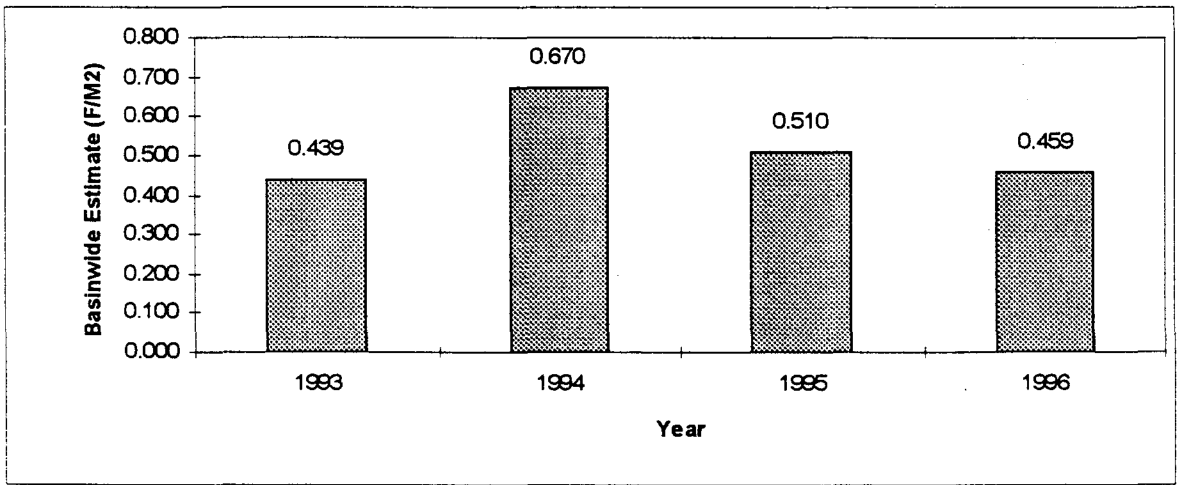

Figure 7. Annual Basinwide Estimate for Steelhead Trout.

Habitat

The purpose of the following analysis was to identify limiting factors affecting salmonid abundance. This will hopefully provide some focus to the watershed issues surrounding salmonid recovery.

The correlation analysis revealed a significant positive correlation (r=0.44) between coho density and percent pool habitat. This suggests the more surface area occupied by pool habitat, the greater likelihood of coho being present. This supports the widely held observation that pools are an important habitat component for coho (Bisson et al. 1988, Nickelson et al. 1991). The average value of percent pool in coho sites was 49%, which corresponds to the desired 50% recommended by Flosi and Reynolds (1994).

The number of days in which water temperatures exceeded the 18.3°C threshold also had a significant effect on coho distribution. In this case, there was a significant difference (p=.05) between coho sites (Figure 8), which averaged only 0.8 days of elevated temperatures, and non-coho sites which averaged 10.5 days of elevated temperatures. Our results indicated the influence of temperatures on coho is more a function of the duration of elevated temperatures rather than the degree to which the temperature is elevated, at least within the limits of the coastal stream environment.

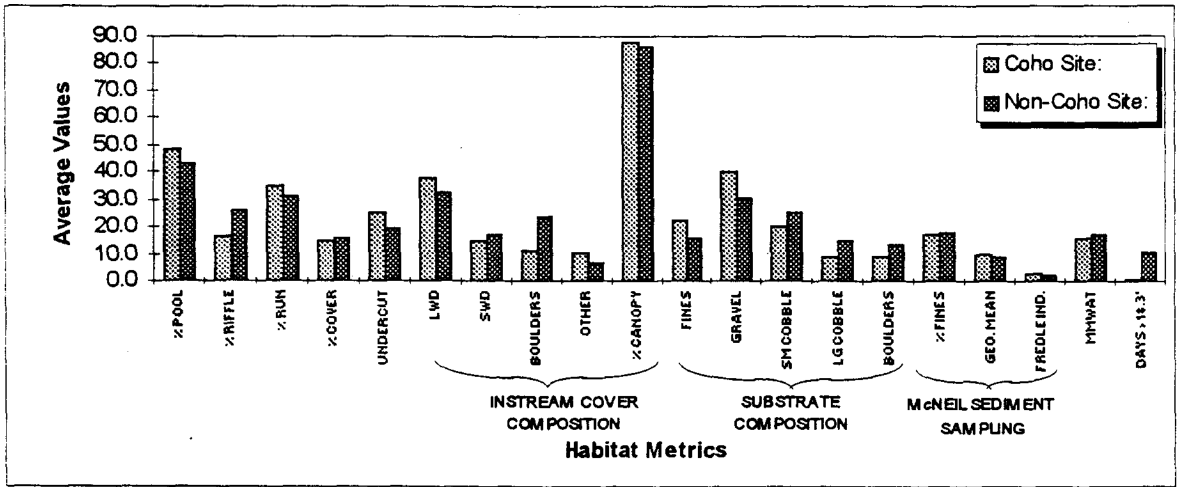

Figure 8. Habitat Metrics Associated with Coho Presence and Absence.

The other notable association was occurrence of boulders in the sample stream segments. We included two variables relating to boulders in this analysis. One was the percent of cover in the stream contributed by boulders (Appendix D, Figures 8 and 9). The other metric was the amount of stream substrate consisting of boulder material, regardless of cover value. The substrate metric showed a positive correlation with steelhead densities (r=0.35) and a significantly greater occurrence in sites with high steelhead densities. Additionally, the cover metric showed a similar difference with regard to steelhead densities. This would suggest that sites with a lot of boulders sustain more steelhead. However, both metrics show a negative correlation with coho densities (the correlation with the substrate metric at r=-0.31 did not exceed the significance threshold of r<-0.34) which would suggest that coho are limited in areas with increased boulder content. Our hypothesis is that boulders are associated with higher gradient stream segments which deters occupation by coho but not steelhead. In support of this is the observation that coho typically do not occupy streams with gradients >3% (Reeves et al. 1989) The associations implicating this relationship in the TMRW are tenuous, but it suggests the possibility of stream gradient as yet another variable to consider when analyzing limiting factors for coho.

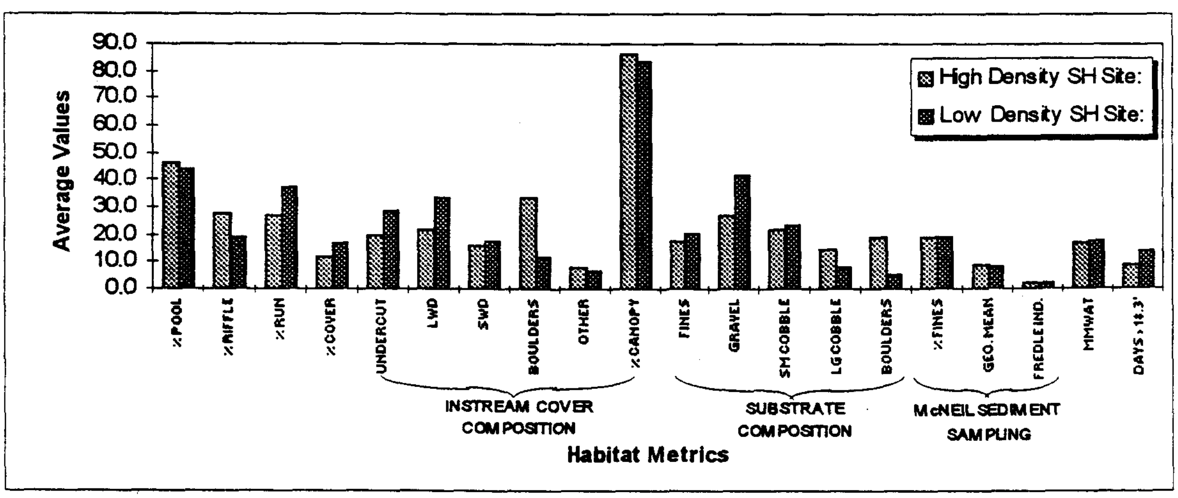

Figure 9. Habitat Metrics Associated with Steelhead Density.

Other Activities in the TMRW

Several other fisheries-related activities are occurring within the TMRW. Salmon Trollers Marketing Assoc. Inc. has conducted spawning surveys for the winters of 1990-91, 1991-92 and 1995-96. Contained in their reports were complete accounts of spawning records for those years. A 1996-97 survey was conducted, but no report was available at the time this report was submitted. 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 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). At the time this report was written no coho spawners had been collected and the hatchery had not applied for a permit to raise steelhead.

Georgia-Pacific issued permits to allow fishing in its streams from January through March of 1996. A total of 252 permits were issued and 55 percent of permit recipients returned the fishing report as requested of them when the permit was issued. Fifty-eight percent of those who returned the report caught no fish.

Summary

The data presented here, although useful, are limited in scope both temporally and spatially. For this reason, one should be tentative about any conclusions drawn from them. 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. Habitat analysis implicated temperatures and stream gradient as possible limiting factors for coho and suggested that pools are important habitat components.

DH

STREAM TEMPERATURE

Introduction

Overview

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, *both 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 of 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

(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 is 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 are 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* Eaton etal. 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 evaluate average conditions over time.

Coho salmon and steelhead trout are the cold water fish species[1] of primary concern in our 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 warmer 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 have applied the MWAT threshold to mainstems as well as tributaries. This is probably 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).

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

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

Methods

Collection Methods

Summer temperatures were measured continuously with 43 temperature data loggers (Onset Computer Corp. model — Hobo®-Temp temperature logger) in Class 1 (fish bearing) streams throughout the TMRW (Appendix A). These temperature loggers were placed near the bottoms of pools, usually towards the deepest portion.[3] 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 43 loggers were installed in the TMRW between 23 May 1996 and 3 July 1996 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 one day lag allowed the 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.

Data loggers have been placed in pools as the primary data collection location since 1993.[5] Due to concerns regarding possible biases associated with pool placement (e.g., sampling the coolest portions of the stream may not give an accurate representation of the complete thermal regimes within the watershed), four riffle temperatures were monitored in 1995. In 1996 seven temperature stations were located in mainstem

[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 desribed 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.

riffles and two in tributary riffles. These loggers were installed immediately adjacent to pool locations[6] to determine if riffle/pool temperatures differed within the TMRW.

Analysis Methods

The 1996 temperature results are displayed in two formats: continuous temperature monitoring[7] and seven day moving maximums (7DMM). 7DMMs were added to the 1996 analysis to provide a more comprehensive assessment of the instream thermal environment than presented in past TMRW reports. Additionally, 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.

A weekly maximum average temperature (MWAT) that should not be exceeded of 18.0° C to 18.3° C was established for coho salmon. The MWAT is a threshold temperature above which the instream environment may be limiting to coho salmon in the TMRW. MWAT was derived from EPA (1976) water quality criteria for fish growth (18.0° C) and from Armour (1991) using the following:

$$MWAT = OT + (UUILT - OT)/3$$

where

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

and

UUILT[8] = the ultimate upper incipient lethal temperature (Fry et al. 1946).

MWAT was then calculated using the following temperature standards:

OT[9] = 15° C (USDI 1970)

UUILT =25°C(Brett 1952)

The coho MWAT was applied to the 7DMM temperature analysis to identify stream reaches possibly limiting to coho salmon in the TMRW. This analysis provides insight into average temperature conditions likely to affect coho salmon (by affecting spatial

[6] Two in tributaries and seven in mainstems.
[7] Continuous temperature graphs display daily average and daily minimum and maximum temperatures.
[8] 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.
[9] An OT of 15° C was chosen over an OT of 12° -14° C (Brett 1952) because I wanted to establish the maximum temperature that should not be exceeded based on the maximum growth temperature at the juvenile lifestage. This is appropriate because fish species' thermal tolerances increase corresponding with the species' southern-range limits (Baton et al. 1995). Eaton et al. (1995) established a 95th percentile maximum weekly mean temperature value based on matching, spatially and temporally, stream temperature data sets to presence of 30 common freshwater fishes in the United States. While OT thresholds were not the basis of this analysis, it is logical to conclude as species MWAT thermal tolerance increases, the OT correspondingly increases. From these data Eaton et al. (1995) noted tolerance estimates for cold water fish were not consistently higher for either northern or southern (based on the 40th parallel) as they were for warm water fishes. This, however, may have been a function of a limited data set for the southern distribution of cold water fishes and requires further investigation.

and physiological responses), rather than the short (2-3 hour) peaks above optimal. A comparison of past[10] 7DMMs was conducted for those locations exceeding the coho MWAT in 1996.

Results

Of the 43 data loggers deployed in the TMRW (Appendix A), 37 were successfully downloaded in 1996. Individual results from each sampling location are displayed in Appendix B. Seven data loggers failed to download when retrieved at the end of the sampling period resulting in data loss. These sites were located in upper SFT (SFT9), CFT below Little Bear Haven (CFT2), Lower LNF (NFT6), Bald Hill Creek (NFT12), NFT at Gulch 9 (NFT9), and NFT below Patsy Creek (NFT1).

A total of 22 pool monitoring stations did not exceed the 7DMM coho MWAT in 1996. Instream temperatures exceeded the coho MWAT at seven pool monitoring stations.[11] Three of these stations were located in SFT: SFT at Buck Mathews (SFT5), SFT near Camp 28 (SFT6), and Lower Redwood Cr. (SFT7), two in NFT: NFT below the CFT confluence (NFT15) and NFT at Camp 5 (NFT5) and two in CFT: CFT near Reynold's Gulch (CFT1) and CFT near Gulch 18 (CFT12).

Of the eight successful stations placed in riffles (one failed to download), the coho MWAT was exceeded at six of these. Two of these stations were located in SFT: SFT at Buck Mathews (SFT18) and SFT near Camp 28 (SFT15), two in the CFT: Lower CFT (CFT9 and CFT near Gulch 18 (CFT13), and two in NFT: NFT at Camp 5 (NFT14) and NFT near Patsy Cr. (NFT13).

Pool temperatures exceeded the coho MWAT in mainstem locations (SFT5, SFT6, CFT11, CFT12, NFT5, NFT15) more frequently than tributaries (SFT7).[12] Riffle temperature stations were located in 3rd Order or greater streams in both mainstems and tributaries. SFT6 recorded a highest pool peak temperature in the TMRW of 20.3° C on 30 July. NFT13 recorded the highest peak riffle temperature in the TMRW of 21.1° C, also on 30 July. Per fork, the highest pool peak temperatures were recorded at SFT6 (20.3° C on 30 July), CFT12 (20.2° C on 30 July), and NFT15 (19.6° C on 30 July). Per fork, the highest pool peak MWATs' were recorded at SFT5 (19.6° C on 28 July). CFT12 (19.2° C on 27 July), and NFT15 (19.2° C on 28 July).

[10] 1994 and 1995 data were analyzed. 1993 monitoring data proved difficult to retrieve because it was not compatible with the current software and was consequently not include in the analysis.

[11] The 7DMM coho MWAT appears valid according to results of coho salmon presence/absence presented in the aquatic vertebrate monitoring results section of this report. These data suggest tributaries within the TMRW provide habitat conducive to juvenile rearing life requisites.

[12] The singular exception was lower Redwood Creek (SFT7) which is a 4th Order stream. The distinction of Redwood Creek as a tributary and SFT (above Camp 28 - a 3rd Order stream) as a mainstem is arbitrary, apparently based on differences in length. Mainstem Redwood Creek is 6.6 km in length while mainstem upper SFT is 10.0 km in length. According to stream flows taken during aquatic vertebrate sampling upper SFT has slightly higher flows (during the low flow period) than Redwood Creek. The distinction of Redwood Creek as a tributary and upper SFT as a mainstem will remain to allow for standardized analysis.

Discussion

Results from the 1996 temperature monitoring program suggest temperatures in the TMRW were below the coho MWAT for most standard sample sites. Standard pool monitoring locations recorded MWAT exceedances in seven locations. These stations were located in mainstem locations at all but one site (SFT7).[13] 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, background variability, 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.

One of the most important variables 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 usually shade canopy. Brown (1971) stated 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 the mainstems. This is a direct function of shade canopy's effects declining with increasing stream widths. As stream widths increase, shade canopy's effects interact with a variety of 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 TMRs' 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 the rivers temperature dropped noticeably from the middle reaches to the lower reaches.
The following is a discussion, by fork, of the 1996 thermal regimes and some of the variables influencing them, within the TMRW.

[13] SFT7 is located near the Redwood Cr./SFT confluence.

South Fork Ten Mile

A total of 14 temperature stations were successfully monitored in SFT for 1996. No coho MWATs' were exceeded in tributary pool sampling locations (other than SFT7) in 1996. All 7DMM coho MWAT exceedances occurred in the middle reaches of this fork (SFT5, SFT6, and SFT7). Temperatures exhibited a general warming trend as they moved from the headwaters (SFT8 and SFT12) through the middle reaches of the watershed (SFT5, SFT6, SFT7). From SFT5 temperatures exhibited a general cooling trend downstream from the mainstem to the lower sampling locations (SFT3 and SFT16). Temperatures reached the maximum durations and highest coho MWAT at SFT5.

Factors that may influence these areas include, but are not limited to: (1) canopy cover relative to channel width[14], (2) stream bed substrate and channel form, (3) tributary influence (flow), and (4) topographic orientation.

(1) Canopy cover: According to instream habitat typing information the overall shade canopy in SFT was approximately 81 %.[15] 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 7DMM coho MWAT:

* Shade canopy cover from SFT5 upstream to both SFT6 and SFT7 averaged 76% (total distance = 8835 m).

* Shade canopy cover from SFT6 upstream to SFT12 averaged 79% (total distance = 2217 m).

* Shade canopy cover from SFT7 upstream to SFT8 (including the North Fork of Redwood Creek) averaged 87% (total distance = 3486 m).

(2) Stream bed substrates and channel form: According to the past three years' data sets, SFT6 has 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 four years aquatic vertebrate sampling data, has consistently maintained some of the largest steelhead trout populations within the TMRW.[16]

(3) Tributary influence (flow): Tributary influence may have contributed to SFT exceeding the 7DMM 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

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

[15] Habitat typing was conducted in SPT in 1994.

[16] 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), and 1.33 f/M2 (1996). The average density for all 1996 sites in the TMRW was estimated at 0.48 f/M2.

mainstem streams. Redwood Creek and upper SFT above Camp 28 (SFT6) are both relatively long tributaries with approximately equal flows[17]. 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 (0.00445 cms), coupled with topography and the coastal maritime influence, may combine to result in a lower 7DMM at SFT3.

(4) Topographic position: SFT flows essentially east/west until the SFT/Churchman Creek confluence where it begins to flow southeast/northwest. Topographic shading and coastal maritime influence may be influencing the cooling of temperatures between SFT5 and SFT3 below the coho MWAT.

Clark Fork Ten Mile

A total of 12 temperature stations were monitored in 1996. No coho MWATs were exceeded in any tributary sampling locations while two were exceed at pool mainstem location (CFT1 and CFT12). A cooling influence, similar to SFT, was observed from the middle to lower reaches of CFT. However, the drop in the 7DMM below the coho MWAT was not as pronounced. Temperatures reached their maximum durations and highest 7DMM coho MWAT at CFT12. 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: 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. Tributaries in CFT had an average shade canopy of 90 %. Canopy cover averages were calculated for those temperature stations exceeding the 7DMM coho MWAT:

* Shade canopy from CFT12 upstream to CFT11 averaged 78% (total distance = 5267 m).
* Shade canopy from CFT11 upstream to CFT8 averaged 81 % (total distance = 7910 m).

[17] Rows were measured during the aquatic vertebrate sampling effort.
[18] Measured on 28 August 1996.

(2) Tributary input (flow): The drop below coho MWAT from the mid-reaches to the lower reaches was not as dramatic as that in SFT. This was due, perhaps in part, to less tributary input[19] (0.7:1 per km ratio) than the other two forks.

(3) Topography: CFT's 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 also 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

A total of ten temperature stations were successfully monitored in 1996 (Figure 1). No coho MWATs were exceeded in any NFT tributary while two mainstem pool stations exceed the 7DMM coho MWAT (NFT at Camp 5 (NFT5) and NFT below the NFT/CFT confluence). Unfortunately, most of the data logger failures occurred in NFT. A total of four data loggers failed, three of them (NFT6, NFT9, NFT1) from pool monitoring locations. In 1995, NFT1 recorded the warmest temperatures in NFT but this data logger unfortunately failed in 1996. Because of these failures thermal conditions are difficult to interpret for NFT, especially in the middle reaches.

NFT11 was located on the upper Georgia-Pacific property line and recorded higher temperatures than other headwater monitoring station in the TMRW (SFT8, and CFT8). Factors possibly 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 may be have been a function of increasing stream widths in the lower reaches of NFT. Canopy cover averages were calculated for those temperature stations exceeding the 7DMM coho MWAT:

* Shade canopy cover from NFT 15 to both NFT4 and CFT4 averaged 41 % (total combined distance = 2357 m).

* Shade canopy cover from NFT5 to NFT3 averaged 68% (total distance = 4670 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

[19] Based on stream lengths, not flow.

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 have been partially due 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): Despite an east/west orientation, 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. The importance of tributaries in this area may be reflected by a change in river orientation: NFT4 did not exceed the 7DMM coho MWAT while upstream the MWAT was exceeded at NFT5. Little NFT probably provided enough cool water influence to reduce the 7DMM by the time flows reached NFT4.

(4) Topography: Since two of three mid-reach mainstem temperatures are unknown it is difficult to describe thermal conditions within mainstem NFT for the summer of 1996.[20] Temperatures did exceed the 7DMM coho MWAT in the lower reaches of NFT in 1996. Like the other two forks, NFT generally flows east/west until reaching the Little NFT/NFT confluence. The 7DMM coho MWAT were exceeded at NFT5 and NFT15. NFT5 is located above the Little NFT/NFT confluence and NFT15 is located below the NFT/CFT confluence. From this confluence the river flows north/south until reaching the TMR lagoon. The summer solar angle contributes less thermal energy in north/south streams than those flowing east/west. Since two of three mid-reach mainstem temperatures are unknown it is difficult to describe thermal conditions within mainstem NFT for the summer of 1996.

Discussion - cont.

The tributaries of the TMRW generally exhibited instream thermal consistency and suitable temperatures for coho salmon. These constant temperatures are promoted by a myriad of environmental variables such as topography (channels are smaller), 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 7DMMs 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

[20] Results are available from only one mid-stream mainstem monitoring location (NFT3) as the data loggers at NFT9 and NFT1 failed.

lower reaches. This was true for mainstem NFT but not the case for CFT and SFT where the warmest 7DMMs 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.

Riffles, showed more daily fluctuations and higher 7DMMs than pool temperatures in both mainstems and tributaries. No apparent differences were detected between pool/riffle coho MWATs or pool/riffle highest weekly average temperatures in the 1995 TMRW monitoring results. However, the inability to detect differences may have been due more to differences in sample size and analysis methods[21] than actual instream conditions. Results indicate riffle temperatures exceeded the coho MWAT more frequently than standard pool monitoring stations in the TMRW in 1996. The surface to volume ratio is greater in riffles and subsequently riffles are influenced by incident solar radiation and ambient air temperature to a greater degree than pools. In areas where riffle MWATs are exceeded it appears pools may provide potential thermal refugia for fish.

Cool water refugia is very beneficial to growth and survival of salmonids. It is critical to note that all but one pool coho MWAT exceedance occurred in mainstem locations. 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 typical 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 availble cool water habitat.

These data will be used by Georgia-Pacific biologists and foresters as a tool to evaluate potential limiting factors for salmonids within the TMRW. Coho MWAT exceedances will 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 local conditions, and accounting for factors including natural variation, compensation, and other site-specific phenomena.*

Georgia-Pacific is planning to continue monitoring the 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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[21] Analysis differed in 1995 because highest weekly average temperatures (HWATs) were calculated. HWATs, as opposed to 7DMMs, are dependent on an arbitrary determination of beginning and ending of the sample period while 7DMMs were not calculated.

STREAM ENHANCEMENT

Much of the information contained in this monitoring plan is intended to help us identify factors limiting salmonid production. This information will, among other things, allow us to prioritize our stream enhancement and upslope efforts. Stream habitat typing and monitoring information, have indicated that embededness of spawning gravels, the occurrence of pools, the amount of large woody debris and water temperatures are all possible areas of improvement.

In 1996 we have addressed these enhancement concerns in a variety of ways. Our activities included capital improvement efforts and habitat enhancements. Capital improvements included road treatments, culvert upgrading and bridge replacements. Habitat enhancements included the creation of instream structures, riparian hardwood thinning, reduction of sediment input and riparian tree planting.

Capital Improvements

New Railcar bridges were constructed in 2 locations to replace old, failing bridges for an estimated cost of $180,884. One bridge spans the mainstem TMR below the NFT/CFT confluence and the other is located on the NFT haul road in the vicinity of Camp 6 1/2 Gulch. Approximately seven miles of road were rocked at a cost of $258,000. A number of culverts were upgraded costing an additional $50,000.

LWD Recruitment

Our habitat typing information indicated the lower reaches of SFT were lacking habitat complexity (Appendix A). This area is characterized by a wide and shallow stream channel consisting primarily of long runs and riffles. The low gradient aspect of this area is associated with considerable aggradation. This, in combination with minimal large woody debris and lack of pool formation, made it a reasonable location for the introduction of instream structures. Our purpose was to create "digger log" structures to alter portions of stream flow and thereby scour away aggraded gravel in the stream bed and create pools. These structures will also accumulate additional woody debris that is carried by the stream. This will contribute important cover for salmonids.

We were successful in creating fourteen digger log sites within a three mile reach of SFT from Camp 22 to Blind Gulch (Appendix B). Sites with long runs, stable banks and dense canopy were chosen for this project. Trees were felled from the bank into their approximate position and moved as needed by heavy equipment into a position that would optimize the scouring effect of the stream flow. The position of logs was also dictated, in part, by the need to secure them against the forces of high flow during storm events. When possible, they were braced against large trees or stumps. Log structures were then anchored into place with steel cable. Wood shims were used when logs were anchored to living trees in order to prevent girdling. All logs were recruited from riparian areas immediately adjacent to the site where the log was placed. This was necessitated due to the constraints associated with operating equipment in these sensitive areas. No equipment entered the wetted channel and the California Department of Fish and Game was notified of all activities prior to their initiation (Appendix B). In 1997 it is our hope to expand our efforts by continuing to add woody material in areas lacking sufficient habitat.

We have established a monitoring effort to measure the effect of these digger log structures on juvenile salmonid abundance. A multiple pass removal sampling of aquatic vertebrates, using a backpack electrofisher, was used to sample the fish population prior to the changes created by winter high flows. One of the digger log sites was sampled along with an adjacent stream segment (100 meters each) as a control site. Any differences in fish densities between the altered site and the control site in ensuing years will allow the quantification of possible benefits provided by these structures.

Jump Pool

The Center for Education and Manpower Resources (CEMR) constructed a jump pool on the downstream side of a culvert on the Gulch 19 tributary of the north fork TMR (Appendix A). The California Department of Fish and Game, Georgia-Pacific and CEMR evaluated the culvert and determined it to be a barrier to fish passage that effectively closed off 1480 meters of potential salmonid spawning and rearing habitat. A joint decision was made to create a jump pool. Georgia-Pacific provided an excavator and dump trucks for its construction. A pool at the culvert outlet was excavated and boulders were placed along its downstream perimeter to help maintain pool depth. This pool now provides enough depth for spawning salmonids to stage a jump past the previously insurmountable obstacle.

Riparian Hardwood Thinning

Mill Creek, a tributary to the mainstem of the TMR (Appendix A) is a creek dominated by alder trees along its riparian corridor. Hardwoods such as these decompose more rapidly than redwoods and other conifers and therefore are less desirable as woody debris structures in streams. We have started a conifer release effort in this creek to encourage the growth of suppressed redwoods along the stream so they may contribute to future large woody debris recruitment. GP biologists entered this area and girdled selected alders in order to reduce competition with neighboring redwoods. These alders were not removed, but were left to die and remain as snags beneficial to terrestrial wildlife, and as interim large woody debris when they enter the stream. The impact of shade removal to the stream was considered and selections were infrequent enough to maintain a canopy cover of 80% or greater over the stream. This activity will only be conducted in areas like Mill Creek where stream temperatures have not approached the 18.3° C 7DMM threshold for coho salmon.

Upslope Activities

The introduction of fine sediments into the stream system has been identified as a limiting factor in the production of salmonids in the TMRW. Georgia-Pacific has been addressing this problem as outlined in our previous monitoring plans. Improvements proposed for the Patsy Creek area (Figure 1) in the 1995 TMRW monitoring report have been completed (Appendix C). These include the upgrading of culverts, de-watering of potential landslide areas, repair of water bars, repair and improvement of roadside drainage ditches, channelization of drainage areas, repair of road washouts and rip-rap construction. Hopefully, this will contribute to the reduction of sedimentation in the NFT.

Future erosion control activities will not be restricted to the north fork but will address sedimentation throughout the TMRW. A watershed assessment being , developed as part of Georgia-Pacific's habitat conservation plan (HCP) will help to prioritize our activities in this regard. The contribution of sediment from roads, the extent of gully formation as well as existing and potential mass wasting within the watershed will all be addressed as part of our coordinated basinwide approach to sediment issues.

Stream enhancement has been a popular method for the improvement of fish production in many areas for over 50 years. Next to protection of existing habitat, it has been one of the more effective means of achieving this goal (Meehan 1991). These efforts have been supported by a wide variety of government agencies and private entities (Flosi and Reynolds 1994). This level of commitment by other organizations is a testament to the importance of this activity. Georgia-Pacific recognizes this and shares that commitment to habitat improvements for the purpose of enhancing salmonid production.

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REFERENCE LIST

Adams, P. Personal Communication. January, 1997.

Alt, D. D. and D. W. Hyndman. 1982. Roadside geology of northern California. Mountain Press Publishing Co., Missoula, MT.

Ambrose, J. A., D. Hines, D. Hines, D. Lundby, J. Drew. 1995. Ten Mile River watershed 1995 instream monitoring results. Georgia-Pacific West, Inc. Unpublished Report.

Armour, C. L. 1991. Guidance for evaluating and recommending temperature regimes to protect fish. US Fish Wildl. Serv., Biol. Report. 90(22): 13.

Avtalion, R. R. 1981. Environmental control of the immune response in fish. CRC Critical Review in Environmental Control 11: 163-188.

Azavedo, J., and D. L. Morgan. 1974. Fog precipitation in coastal California forests. Ecology 55(5): 135-141.

Bardach, J. E., and R. G. Bjorklund. 1957. The temperature sensitivity of some American freshwater fishes. Am. Nat. 91: 233-251.

Barton, B. A., and C. B. Schreck. 1987. Influence of acclimation temperature on mterrenal and carbohydrate stress response in juvenile chinook salmon *(Oncorhynchus tshawytscha).* Aquaculture 62: 299-310.

Beschta, R. L. 1982. Comment on "Stream system evaluation with emphasis on spawning habitat of salmonids" by M. A. Shirazi and W. K. Seim. Water Resources Research 18: 1292-1295.

Beschta, R. L., R. E. Bilby, G. W. Brown, L. B. Holtby and T. D. Hofstra. 1987. Stream temperature and aquatic habitat: fisheries and forestry interactions. Pages 191-232 *in* E. 0. Salo and T. W. Cundy, editors. Streamside management:
forestry and fishery interactions. Cont. 57. College of Forest Resources. Univ. Wash., Seattle.

Bisson, P. A., K. Sullivan, and J. Nielsen. 1988. Channel hydraulics, habitat use, and body form of juvenile coho salmon, steelhead and cutthroat trout in streams. Trans. Am. Fish. Soc. 117: 262-273.

Bjornn, T. C. 1969. Embryo survival and emergence studies - Job. No. 5., Salmon Steelhead Invest., Proj. No. F-49-R-7, Ann. Completion Report., Idaho Fish Game Dept.

Brett, J. R. 1952. Temperature tolerance in young Pacific salmon *(Oncorhynchus).* J. Fish. Res. Board Can. 9:265-323.

Brower, J. E., J. H. Zar, and C. N. von Ende. 1990. Unit 3g. removal sampling. Pages 115-118 *in* field and laboratory methods for general ecology third edition. Wm. C. Brown Publishers, Dubuque, IA.

Brown, G. W. 1971. Water temperature in small streams as influenced by environmental factors. Pages 175-181 *in* J. Morris, editor. Proceedings of a symposium on forest land uses and the stream environment. Oregon St. Univ., Corvallis.

Brown, L. R., P. B. Moyle, and R. M. Yoshiyama. 1994. Historical decline and current status of salmon in California. N. Am. J. Fish Manag. 14:237-261.

Bryant, M. D. 1995. Pulsed monitoring for watershed and stream restoration. Fisheries 20(11):6-13.

Bums, J. W. 1972. Some effects of logging and associated road construction on northern California streams. Trans. Am. Fish. Soc. 101: 1-16.

Burton, T. A., and G. W. Harvey. 1990. Estimating intergravel salmonid living space using the cobble embeddedness sampling procedure. Water Quality Monitoring Protocols Report 2, Idaho Department of Health and Welfare, Boise, ID.

Cederholm, C. J., L. M. Reid, and E. 0. Salo. 1981. Cumulative effects of logging road sediment on salmonid populations in the Clearwater River, Jefferson County, Washington. *In* proc. conf. salmon-spawning gravel: a renewable resource in the Pacific northwest? State of Wash. Water Res. Center. Washington State University. Center for Streamside Studies, EPA-910/9-91-001. Seattle, Washington.

Chamberlin, T. W., R. D. Harr, and F. H. Everest. 1991. Timber harvesting, silviculture, and watershed processes. Pages 181-205 *in* W. R. Meehan, editor. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society, Special Publication 19, Bethesda, Maryland.

Chapman, D. W. 1988. Critical review of variables used to define effect of fines in redds of large salmonids. Trans. Am. Fish. Soc. 117(1): 1-21.

Coutant, C. C. 1969. Behavior of a sonic-tagged chinook salmon and Steelhead trout migrating past Hanford thermal discharges. Page 74 in EPA, 1991. Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific northwest and Alaska. U.S. Environmental Protection Agency, Center for Streamside Studies, EPA-910/9-91-001. Seattle, WA.

Crisp, D. T., and P. A. Carling. 1989. Observations on siting, dimensions and structure of salmonid redds. J. of Fish Biology 34:119-134.

Daugherty, C. H., and A. L. Sheldon. 1982. Age-specific movement patterns of the frog *ascaphus truei*. Herpetologica 38(4): 468-474.

Dolloff, C. A., and D. G Hankin, and G. H. Reeves. 1993. Basinwide estimation of habitat and fish populations in streams. US Forest Service, Southeastern Forest Experiment Station. General Technical Report SE-83.

Duncan, S. H., and J. W. Ward. 1985. The influence of watershed geology and forest roads on the composition of salmon spawning gravel. Northwest Science 59(3): 204-212.

Eaton, J. G., J. H. McCormick, B. E. Goodno, D. G. O'Brien, H. G. Stefany, M. Hondzo, and R. M. Scheller. 1995. A field information-based system for estimating fish temperature tolerances. Fisheries 20(4): 10-18.

EPA. 1991. Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific northwest and Alaska. U.S. Environmental Protection Agency, Center for Streamside Studies, EPA-910/9-91-001. Seattle, WA.

Everest, F. H., R. L. Beschta, J. C. Scrivener, K. V. Koski, J. R. Sedell, and C. J. Cederholm. 1987. Fine sediment and salmonid production - a paradox. Pages 98-142 *in* E. Salo, and T. Cundy, editors. Streamside management and forestry and fishery interactions. University of Washington, College of Forest Resources, Contribution 57, Seattle.

Flosi, G., and F. L. Reynolds. 1994. California salmonid stream habitat restoration manual. California Dept. of Fish and Game. Inland Fisheries Division.

Fry, F. E. J. 1967. Responses of poikilotherms to temperature. Pages 375-709 *in* A. H. Rose, editor. Thermobiology. Academic Press, San Diego, CA.

Fry, F. E. J. 1971. The effect of environmental on the physiology offish. Pages 1-98 *in* W. S. Hoar, and D. J. Randall, editors. Fish physiology. Vol. VI. Environmental relations and behavior. Academic Press, San Diego, CA.

Georgia-Pacific Corporation Sustained Yield Plan-Draft. 1995. Georgia-Pacific Corporation, Fort Bragg CA.

Groot, C., and L. Margolis, editors. 1991. Pacific salmon life histories. University of British Columbia, Vancouver, BC.

Grost, R. T., W. A. Hubert and T. A. Wesche. 1991. Field comparison of three devices used to sample substrate in small streams. N. Am. J. Fish. Manag. 11: 347-351.

Hall, J. K., and R. L. Lantz. 1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. Pages 355-375 *in* T. G. Northcote, editor. Salmon and trout in streams. H. R. MacMillan Lectures in Fisheries, University of British Columbia, Vancouver.

Hall, J. D., and H. J. Campbell. 1969. The effects of logging on the habitat of coho salmon and cutthroat in coastal streams. Pages 5-28 *in* Northcote (1969).

Hausle, D. A., and D. W. Coble. 1976. Influence of sand in redds on survival and emergence of brook trout *(Salvelinus fontinalis).* Trans. Am. Fish. Soc. 105:57-63.

Headrick, M. R., and R. F. Cariine. 1993. Restricted summer habitat and growth of northern pike in two southern Ohio impoundments. Trans. Am. Fish. Soc. 122: 228-236.

Hokanson, K. E. F. 1977. Temperature requirements of some percids and adaptations to the seasonal temperature cycle. J. Fish. Res. Board Can. 34: 1524-1550.

Hopkirk, J. Personal communication. October, 1995.

Hutchinson, V. H. 1976. Factors influencing thermal tolerances of individual organisms. Pages 10-16 *in* Proceedings of *the* second sauana river ecology laboratory conference, April 1975, Augusta, GA. Available from NTIS, CONF.-750425.

Hynes, H. B. 1972. The ecology of running waters. University of Toronto Press, Canada.

Johnson, R. A. 1980. Oxygen transport in salmon spawning gravels. Can. J. of Fish. and Aq. Sci. 37: 155-162.

Kaya, C. M., L. R. Kaeding, and D. E. Burkhalter. 1977. Use of a cold-water refuge by rainbow and brown trout in a geothermally heated stream. Prog. Fish Cultur. 39: 37-39.

Kondolf, G. M., and M. G. Wolman. 1993. The sizes of salmonid spawning gravels. Water Resources Research. 29(7): 2275-2285.

Koski, K. V. 1966. The survival of coho salmon *(Oncorhynchus kisutch)* from egg deposition to emergence in three Oregon coastal streams. Master's thesis. Oregon State University, Corvalis.

Lisle, T. E., and R. E. Eads. 1991. Methods to measure sedimentation of spawning gravels. US Forest Service Research Note PSW-411.

Lotspeich, F. B., and F. H. Everest. 1981. A new method for reporting and interpreting textural composition of spawning gravel. US Forest Service Research Note PNW-369.

Maahs, M 1996a. A spawning habitat evaluation for portions of the Ten Mile River, Caspar Creek and Garcia River. Salmon Trollers Marketing Association. Fort Bragg, CA.

Maahs, M 1996b. 1996 South Fork Ten Mile River and Little North Fork Noyo outmigrant trapping. Salmon Trollers Marketing Association. Fort Bragg, CA.

MacCrimmon , H. R., and B. L. Gots. 1986. Laboratory observations on emergent patterns of juvenile rainbow trout *(Salnw gairdneri)* relative to test substrate composition. Pages 63-76 *in* Fifth trout stream habitat improvement workshop. Lock Haven University, Lock Haven, PA.

McNeil, W. J. 1964. A method of measuring mortality of pink salmon eggs and larvae. US Fish and Wildl. Serv; Fisheries Bulletin. 63(3) 575-588.

McNeil, W. J., and W. H. Ahnell. 1964. Success of pink salmon spawning relative to size of spawning bed materials. US Fish and Wildl. Serv. Spec. Sci. Report Fish. #469.

McNeil, W. J. 1976. Potential for salmon aquaculture in Alaska. Proceedings of the Conference on Salmon Aquaculture and the Alaska Fishing Community. Alaska Sea Grant Report 76-Z.

Meehan, W. R., and T. C. Bjomn. 1991. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19: 47-82.

Moore, E. Personal communication. January 1996.

NCASI (National Council of the Paper Industry for Air and Stream Improvement). 1984. A laboratory study of the effects of sediments of two different size characteristics on survival of rainbow trout *(Sal/no gairdneri)* embryos to fry emergence. National Council of the Paper Industry for Air and Stream Improvement Technical Bulletin 429.

Neilsen J. L., T. E. Lisle, and V. Ozaki. 1994. Thermally stratified pools and their use by steelhead in northern California streams. Trans. Am. Fish. Soc. 123:613-626.

Nickelson, T. E., J. D. Rodgers, S. L. Johnson, M. F. Solazzi. 1991. Seasonal changes in habitat use by juvenile coho salmon *(Oncorhynchus kisutch)* in Oregon coastal streams. Can. J. Fish. Aquat. Sci. 49: 783-789.

Oregon Dept. of Environmental Quality. 1994. 1992-1994 water quality standards review-draft.

Omduff, R. 1974. California plant life. University of California Press, Berkeley, CA.

Phillips, R. W., R. T. Lantz, E. W. Claire, and J. R. Moring. 1975. Some effects of gravel mixtures on emergence of coho salmon and steelhead trout fry. Trans. Am. Fish. Soc. 104:461-466.

Platts, W. S., M. A. Shirazi, and D. H. Lewis. 1979. Sediment particle sizes used by salmon for spawning with methods for evaluation. US Environmental Protection Agency, EPA-600/3 -79-043, Corvalis, Oregon.

Platts, W. S., and thirteen co-authors. 1983a. Livestock interactions with fish and their environments. Pages 36-41 *in:* Menke (1983).

Platts, W. S., and W. F. Megahan, and G. W. Minshall. 1983b. Methods for evaluating stream, riparian, and biotic conditions. US Forest Service General Technical Report INT-138.

Priede, I. G. 1985. Metabolic scope in fishes. Pages 33-64 *in* P. Tytler, and P. Calow, editors. Fish energetics: new perspectives. Johns Hopkins University Press, Baltimore, Maryland.

Reeves, G. J., F. H. Everest, T. E. Nickelson. 1989. Identification of physical habitat limiting the production of coho salmon in western Oregon and Washington. US Forest Service Pacific Northwest Research Station. General Technical Report PNW-GTR-245.

Reiser, D. W., and T. C. Bjomn. 1979. Influence of forest and rangeland management on anadromous fish habitat in western North America: habitat requirements of anadromous salmonids. Idaho Cooperative Fisheries Research Unit. University of Idaho, Moscow. US Forest Service Technical Report PNW-96.

Reiser, D. W., and R. G. White. 1988. Effects of two sediment size-classes on survival of steelhead and chinook eggs. N. Am. J. of Fish. Man. 8:432-437.

Reynolds, J. B. 1983. Chapter 8; electrofishing. Pages 147-163 *in* Nielsen et al., editors. Fisheries Techniques. Trans. Am. Fish. Soc.

Schuett-Hames, D., A. Pleus, L. Bullchild, and S. Hall, editors. 1994. Timber-fish-wildlife ambient monitoring program manual. Northwest Indian Fisheries Commission. Olympia, WA.

Schuett-Hames, D., B. Conrad, A. Pleus, D. Smith. 1996. Timber-fish-wildlife ambient monitoring program report; field comparison of the mcneil sampler with three shovel-based methods used to sample spawning substrate composition in small streams. Northwest Indian Fisheries Commission, Olympia, WA.

Shirazi, M. A., and W. K. Seim. 1979. A stream system's evaluation - an emphasis on spawning habitat for salmonids. EPA 600/3-79-109.

Shirazi, M. A., W. K. Seim, and D. H. Lewis. 1981. Characterization of spawning gravel and stream system evaluation. Pages 227-228 *in* Cassidy, director. Salmon-spawning gravel: a renewable resource in the Pacific northwest? Wash. Wat. Res. Center. Report No. 39.

Snieszko, S.F. 1974. The effects of environmental stress on outbreaks of infectious diseases of fishes. J. Fish. Biol. 6:197-208.

Sowden, T. K. 1983. The influence of groundwater and spawning gravel composition on the reproductive success of rainbow trout in an eastern Lake Erie tributary. Master's thesis. University of Waterloo, Waterloo, Ontario.

Stebbins, R. S. 1985. A field guide to western reptiles and amphibians. Houghton Mifflin Company. Boston, MA.

Stowell, R., A. Espinosa, T. C. Bjomn, W. S. Platts, D. C. Bums, and J. S. Irving. 1983. Guide for predicting salmonid response to sediment yields in Idaho batholith watersheds. US Forest Service, Northern and Intermountain Regions, Ogden, Utah.

Strange, R. J., C. B. Schreck, and J. T. Golden. 1977 Corticoid stress responses to handling and temperature in salmonids. Trans. Am. Fish. Soc. 106(3): 213-218.

Sullivan, K., T. E. Lisle, C. A. Dolloff, G. E. Grant, and L. M. Reid. 1987. Stream channels: the link between forests and fishes. Pages 39-97 *in* E. 0. Salo and T. W. Cundy, editors. Streamside management: forestry and fishery interactions. Cont. 57. College of Forest Resources. Univ. Wash. Seattle.

Tagart, J. V. 1976. The survival from egg deposition to emergence of coho salmon in the Clear-water rivers Jefferson County, Washington. Master's Thesis, University of Washington, Seattle.

Tagart, J. V. 1984. Coho salmon survival from egg deposition to emergence. Pages 173-182 *in J. M.* Walton and D. B. Houston, editors. Proceedings of the Olympic wild fish conference. Peninsula College, Fisheries Technology Program, Port Angeles, Washington.

Tappel, P. D., and T. C. Bjomn. 1983. A new method of relating size of spawning gravel to salmonid embryo survival. N. Am. J. Fish. Manag. 3:123-135.

Taylor, R. J. 1997. Statistical analysis of the 1993-1996 sediment data from the Ten-Mile River watershed. A report to Georgia-Pacific West, Inc. The Endangered Species Group, Orangevale, CA.

Taylor, R. N. 1996. Aquatic field protocols adopted by the fish, forests, and farms community (fffc) technical committee. A Fish, Forests, and Farms Community Technical Committee report, Sacramento, CA.

Tripp, D., and V. A. Poulin. 1986. The effects of logging and mass wasting on salmonid habitat in streams on the Queen Charlotte islands. Land Manag. Report. No. 50. BC Ministry of For. and Lands. Vancouver.

Valentine, B. E., 1993. Stream substrate quality for salmonids: guidelines for dampling, processing, and analysis, (perpetual draft-October 13, 1993). California Dept. of Forestry and Fire Protection. Region 1. Santa Rosa. CA.

Valentine, B. E., and M. Jameson. 1994. Little north fork noyo fishery study, 1992. California Dept. of Forestry and Fire Protection. Region 1. Santa Rosa. CA.

Van Deventer, J. S., and W. S. Platts. 1989. Microcomputer software systems for generating population statistics from electrofishing data. Users guide for Microfish 3.0. US Forest Service Gen. Tech. Report INT-254.

Waters, T. F. 1995. Sediment in streams, sources, biological effects, and control. Trans. Am. Fish. Soc. Monograph 7. Am. Fish. Soc. Bethesda, Maryland.

Weitkamp. L. A., T. C. Wainwright, G. B. Milner, D. J. Teel, R. G. Kope and R. S. Waplis. 1995. Status review of coho salmon from Washington, Oregon, and California. NOAA Technical Memorandum NMFS-NWFSC-24.

Welsh, H. H., A. J. Lind, L. M. Olivier, and D. L. Waters. 1993. A hierarchical analysis of the habitat associations of the tailed frog *(Ascaphus truei)* in the mixed coniferous/hardwood forests of northwestern California. Redwood Sciences Laboratory Pacific Southwest Experiment Station. US Forest Service.

White, D. Personal Communication. January, 1997.

Wishkovsky, A., and R. R. Avtalion. 1982. Induction of helper and suppressor function in carp *(Cyprinus capio)* and their possible implication in seasonal disease in fish. Develop. Compar. Immunol. Supple. 2; 81-91.

Witzel, L. D., and H. R. MacCrimmon. l983b. Embryo survival and alevin emergence of brook chair *(Salvelinus fontinalis)* and brown trout *(Saimo truttd)* relative to redd gravel composition. Can. J. of Zoology 61: 1783-1792.

Young, M. K., W. A. Hubert, and T. A. Wesche. 1991. Selection of measures of substrate composition to estimate survival to emergence of salmonids and to detect changes in stream substrates. N. Am. J. of Fish. 11: 339-346.