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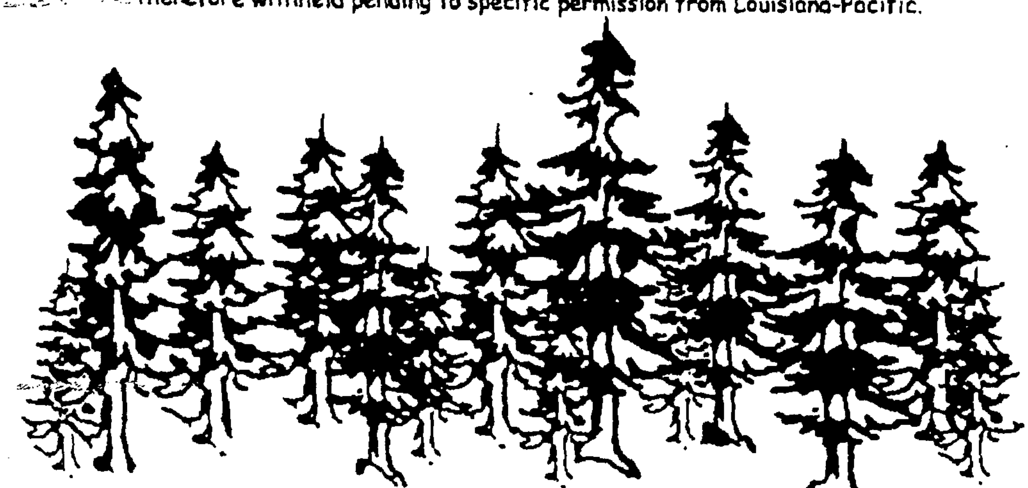
STREAM TEMPERATURES FOR WATERSHEDS IN LOUISIANA-PACIFIC'S COASTAL MENDOCINO/SONOMA MANAGEMENT UNIT, 1994-'96

Report Prepared For:
Forest Resources Division
Louisiana-Pacific Corp.
(Western Region)

Report Prepared By:
Wildlife & Fisheries Sciences Group
Louisiana-Pacific Corp.
(Western Region)

December 1997



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MENDOCINO REDWOOD COMPANY, LLC
STREAM TEMPERATURE REPORT

IMPORTANT INFORMATION

In response to inquiries from members of the community, Mendocino Redwood Company (MRC) is releasing a variety of previously collected data.

The Stream Temperature Reports present data collected from 1989-1993 and 1994-1996. Summer stream temperatures are graphically displayed showing mean and maximum daily temperatures. The data is also presented in tabular format screened by certain temperature parameters.

The purpose of stream temperature data collection was to establish baseline data for streams flowing through MRC's forested ownership.

At the time of data collection and continuing today there is no single, accepted standard for interpreting stream temperature data.

The data presented within these reports show a range of daily stream temperatures. Data describing physiographic features of the streams that influence temperature regimes where temperature monitoring sites were established were not collected. Without this information, it is not possible to describe stream conditions based solely on stream temperature.

MRC does not consider data collected from 1989-1993 to be comparable to data collected from 1994-1996. Monitoring sites were different, different equipment was used for collection, and there were differences in methodologies.

This data has value, used as baseline information in the future assessment of temperatures of streams flowing through MRC's property. More information must be collected to understand the nature of stream temperatures. Through continuing monitoring stream temperatures and initiating stream temperature trend analysis. MRC will be able to better understand stream temperatures on MRC property.

MRC will continue to monitor stream temperatures and will consider additional studies to better understand stream conditions on MRC property.

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STREAM TEMPERATURES FOR WATERSHEDS IN LOUISIANA-PACIFIC'S COASTAL MENDOCINO/SONOMA MANAGEMENT UNIT, 1994- '96

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STREAM TEMPERATURES FOR WATERSHEDS IN LOUISIANA-PACIFIC'S COASTAL MENDOCINO/SONOMA MANAGEMENT UNIT, 1994-'96

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STREAM TEMPERATURES FOR WATERSHEDS IN LOUISIANA-PACIFIC'S COASTAL MENDOCINO/ SONOMA MANAGEMENT UNIT, 1994-'96

BACKGROUND

Stream temperature is a key water quality parameter and one that can be altered as a result of streamside forest management practices. Concern over abnormal warming of stream temperatures as a result of streamside vegetation removal has generally focused on the impacts to coldwater inland fisheries (see Literature Review). The California Forest Practice Rules addresses the effects of streamside timber harvesting activities on water temperatures and dictates the implementation of Best Management Practices to minimize impacts on water quality within forested watersheds.

In summer 1994, Louisiana-Pacific initiated intensive stream temperature monitoring within its forestlands in northern California. Stream temperature monitoring continued during the summer months (June- September) in 1995 and 1996. The primary objectives of the stream temperature monitoring were to establish baseline temperature conditions and identify temperature limited stream segments. Primary assumption for stream temperature monitoring is that increases in stream temperature conditions are primarily associated to streamside shade canopy conditions, as they affect local air temperature, solar radiation, and relative humidity. Stream temperatures are monitored to obtain average water temperature conditions.

Priority for stream temperature monitoring was based on the amount of Louisiana-Pacific's forestland within an individual watershed and baseline data needs for fish-bearing streams. Number of monitoring sites within a watershed was based on stream length and flow accumulation area. In longer streams (> 8 km), stream temperature monitoring sites were located in the lower, middle and upper reaches of the stream. On streams or tributaries that were shorter in length, lower and upper stream temperature monitoring sites were located. In certain cases, only one stream temperature monitoring recorder was placed on the lower part of the stream reach. Stream tributaries draining into the same sub-watersheds were monitored concurrently. Air temperatures were monitored at limited sites for the purpose of evaluating the influence of ambient temperatures or maritime effect on stream water temperature conditions.

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Stream water temperatures were monitored continuously (2-hour interval) during summer (June-September) each year using remote electronic temperature recorders. The stream temperature recorders were placed in shallow pools (< 1 m in depth) directly downstream of riffles. Placement of temperature recorders in these areas ensured monitoring water that was adequately mixed and prevented dewatering of the monitoring devices. Each data recorder was held in place with a 45 cm piece of rebar that was driven into the streambed substrate with a sledge hammer and a post driver. Plastic coated 12 gauge wire was used to attach the data recorders to the rebar stakes.

Quality control procedures were developed and implemented to ensure accurate readings by the temperature data recorders and check for potential instrument errors. All temperature data recorders were calibrated pre- and post-data recording activities. Calibration of the temperature data recorders was accomplished by placing the equipment in five-gallon bucket of ice bath or sand for one hour. Temperature readings recorded by the data recorder were compared with the temperature readings of a certified reference thermometer (Cole-Parmer Instrument Company, Vernon Hills, Illinois) placed in the same medium in the bucket. Quality assurance goals were accomplished by training individuals for data recorder handling and calibration, deployment and in-stream placement of data recorders, and data synthesis.

Once baseline stream temperature condition is established for a watershed, a pulsed monitoring strategy will be developed and implemented as part of the long-term monitoring program. Overall stream temperature monitoring goal was to obtain a two consecutive year dataset for each site and complete the initial ownership-scale baseline temperature condition evaluation within four or five years.

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STREAM TEMPERATURES FOR WATERSHEDS IN LOUISIANA-PACIFIC'S COASTAL MENDOCINO/ SONOMA MANAGEMENT UNIT, 1994-'96

LITERATURE REVIEW

Temperature Fluxes In Small Forested Streams

Stream water temperature responds to the input of solar radiation and is directly proportional to stream surface area and inversely proportional to discharge (Sullivan et al. 1990). Wide streams receive more radiation than narrow ones. For the same surface area and energy input, the temperature change expected of a high-discharge stream will be less than that of a low discharge stream.

Other factors controlling stream water temperature include ground water inputs, air temperature, inflow from tributaries, and substrate type. The previously mentioned factors each involve specific energy transfer processes, such as radiation, evaporation, convection, conduction, and advection. The sum of these factors represents the net gain or loss of heat in a stream (Brown 1983). Heat gain or loss from evaporation or convection depends on the vapor pressure and gradients respectively between the water surface and air (Beschta et al. 1987). Conduction of heat between the water and the streambed depends on substrate type, with bedrock being the most conductive substrate. Advection occurs as tributaries of differing temperatures enter a stream.

Canopy cover is important in reducing the net gain of solar radiation in the summer, but less important in the winter. In winter, short days, low sun angles, and cloudy weather combine to keep stream temperatures low, regardless of canopy. In summer, long days, higher sun angles, clear skies, and low discharge are factors that can cause elevation of stream water temperatures. Several studies have shown that an intact streamside forest canopy will shade streams and minimize increases in summer water temperature. Brown and Krygier (1970), found diurnal variations in a well-shaded coastal Oregon stream to be less than 1°C. However, complete removal of a forest canopy has been shown to increase summer maximums 3-8°C (see review by Beschta et al. 1987). A comparison of 20 years of temperature records from Steamboat Creek basin, Oregon, was done for logged and unlogged streams. Hostetler (1991) found that streamside canopy cover was the trend variable most important to changes in stream temperature.

Thermal energy in streams is not easily lost through reradiation, convection, advection and conduction (Beschta et al. 1987). Increases in stream water temperature are additive, and an alteration of shaded and unshaded reaches are not an effective strategy to minimize increased summer temperatures (Brown et al. 1971). Possible increases in stream temperature from streamside canopy removal can be predicted using formulas in Brown (1983).

Effects Of Stream Temperature On Aquatic Biota

The optimal temperature range for Pacific salmonids has been shown to range between 12 and 14°C (Brett 1952). Temperatures lethal to salmonids have been determined in the laboratory and range from 23-29°C (Beschta et al. 1987). These values were determined over long periods of time under different acclimation temperatures. Though these temperatures are possible in some small forested streams, they would generally only occur for short periods of time in the summer. In addition, cool water refugia may be found in deep pools (Matthews et al. 1994) and seeps. In a laboratory study, Combs and Burrows (1957) found the upper lethal limit for chinook salmon (*Oncorhynchus tshawytscha*) eggs to be 14-15.5°C. In some spring-spawning salmonids, egg development may overlap with harmful high summer temperatures (Beschta et al. 1987).

Increased water temperatures that are not lethal may also affect stream biota. The metabolic energy requirements of fish must be met before they will grow (Warren and Davis 1967). A reduced growth rate may occur at higher temperatures. As a fish's metabolic rate increases with temperature, dietary intake must also increase for growth to occur (Beschta et al. 1987). Increased water temperatures can also be conducive to the growth and virulence of fish pathogens harmful to fish (Beschta et al. 1987).

Timing of development and certain life history stages of salmonids (Holtby et al. 1989) and invertebrates (Moore 1980) can be affected by changes in stream temperature. Holtby et al. (1989) found emigration timing for coho salmon (*Oncorhynchus kisutch*) and chum salmon (*Oncorhynchus keta*) fry was strongly temperature dependent. Some evidence shows that early emergence, due to increased water temperatures, is associated with higher fry to smolt survival (Holtby et al. 1989). However, early emergence might have risks associated with increases in mortality within the marine environment (i.e., winter storms) (Hartman et al. 1987).

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Water temperature changes can affect primary and secondary production in streams. Increases in water temperature have been shown to increase algal production (Phinney and McIntire 1965, Kevern and Ball 1965) and invertebrate production. Herbivore abundance may increase concurrently with algae, resulting in a higher rate of decomposition of allochthonus material, and, consequently, in increases in numbers of other invertebrates (Beschta et al. 1987). Larger populations of invertebrate fauna may benefit salmonids. Such changes in productivity come at the expense of lowered diversity, community stability (Gregory et al. 1987), and timing of emergence (Moore 1980). Salmonid fish prey heavily on emerging adults, and accelerated insect development may benefit fish by making more food available earlier in the year. However, for many salmonids the emergence of fry from spawning gravel and the onset of active feeding coincides with spring and early summer hatches of aquatic insects (Beschta et al. 1987).

The role of water temperature in the functioning of stream ecosystems is extremely complex. Trophic dynamics, behavior, growth, and development of stream biota are all affected by changes in water temperature. The effects of sub-lethal water temperatures on salmonids and invertebrates are difficult to distinguish, even with continuous stream temperature data. Negative effects of increased temperatures on salmonids may be offset by gains in primary and secondary production. The importance of temperature in aquatic ecosystems suggests that sound land management decisions (i.e., appropriate buffer strips) should be based on appropriate long-term monitoring programs.

LITERATURE CITED

Beschta RL., RE. Bilby, GW. Brown, LB. Holtby, and TD. Hofstra. 1987. Stream temperatures and aquatic habitat: Fisheries and forestry interactions. Pages 191-232 in E.O. Salo and T.W. Cundy, editors. Streamside management: Forestry and fishery interactions. Contribution 57, University of Washington, College of Natural Resources, Seattle, Washington.

Brett JR. 1952. Temperature tolerances in young Pacific salmon, (*Oncorhynchus*). Journal of Fishery Resources Board Canada 9: 268:323.

Brown GW., and JT. Krygier. 1970. Effects of clearcutting on stream temperature. Water Research Resources 6(4): 1133-1139.

Brown GW., LW. Swank, and J. Rothacher. 1971. Water temperature in the Steamboat drainage. United States Department of Agriculture Forest Service Resource Paper PNW-119. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. 17pp.

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Brown GW. 1983. Forestry and water quality. Oregon State University Bookstore, Incorporated, Corvallis, Oregon. 142pp.

Combs BD., and RE. Burrows. 1957. Threshold temperatures for the normal development of chinook salmon eggs. Progressive Fishery Culturist 19: 3-6.

Gregory SV., GA. Lamberti, DC. Erman, KV. Koski, ML. Murphy, and JR. Sedell. 1987. Stream temperatures and aquatic habitat: Influences of forest practices on aquatic production. Pages 233-257 in E.O. Salo and T.W. Cundy, editors. Streamside management: Forestry and fishery interactions. Contribution 57, University of Washington, College of Natural Resources, Seattle, Washington.

Hartman GF., JC. Scrivner, and TE. McMahon. 1987. Saying that logging is either 'good' or 'bad' for fish doesn't tell you how to manage the system. The Forestry Chronicle 163(3): 159-164.

Holtby LB., TE. McMahon, and JC. Scrivner. 1989. Stream temperatures and inter-annual variability in the emigration timing of coho salmon (*Oncorhynchus kisutch*) smolts and fry and chum salmon (*Oncorhynchus keta*) fry from Carnation Creek, British Columbia. Canada Journal Fisheries and Aquatic Sciences 46: 1396-1405.

Hostetler SW. 1991. Analysis and modeling of long-term stream temperatures on the Steamboat Creek Basin, Oregon: Implications for land use and fish habitat. Water Resources Bulletin 27(4): 637-647.

Kevern NR., and RC. Ball. 1965. Primary productivity and energy relationships in artificial streams. Limnology and Oceanography 10: 74-87.

Matthews KR., NH. Berg, and DL. Azuma. 1994. Cool water formation and trout habitat use in a deep pool in the Sierra Nevada, California. Trans-American Fishery Society 123: 549-564.

Moore JW. 1980. Factors influencing the composition, structure and density of a population of benthic macroinvertebrates. Arch. Hydrobiology 88: 202-218.

Phinney HK., and CD. McIntire. 1965. Effect of temperature on metabolism of periphyton communities developed in laboratory streams. Limnology and Oceanography 10: 341-344.

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Sullivan KJ., TK. Doughty, JE. Caldwell, and P. Knudsen. 1990. Evaluation of prediction models and characterization of stream temperature regimes in Washington. TFW-WQ3-90-006. Washington Department of Natural Resources Olympia, Washington.

Warren CE., and GE. Davis. 1967. Laboratory studies on the feeding, bioenergetics, and growth of fish. __in SD. Gerking, editor. The biological basis of freshwater fish production. Blackwell Sciences Publication, Oxford, England.

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STREAM TEMPERATURES FOR WATERSHEDS IN LOUISIANA-PACIFIC'S COASTAL MENDOCINO/ SONOMA MANAGEMENT UNIT, 1994-'96

RESULTS

This report summarizes the temperature data collected from streams draining forested watersheds in Louisiana-Pacific's coastal Mendocino/ Sonoma management unit during the summers of 1994-'96. Stream temperature information presented in this report will be used to evaluate water quality limited stream segments, and develop and implement improved streamside management prescriptions in these problem areas.

Currently, established water quality standards and guidelines for stream temperature evaluation are lacking. Mean, maximum, and minimum daily stream temperatures were reported for each dataset. For further stream temperature analysis, the following data screening criteria were used: (1) mean daily water temperature (MDWT) over 18°C, (2) MDWT over 20°C, (3) MDWT over 20°C for 4 consecutive days, (4) daily maximum water temperature (DMWT) over 23°C, (5) DMWT over 23°C for 4 consecutive days, and (6) diurnal temperature fluctuations ≥ 10°C. The stream temperature screening criteria can be used for long-term trend analysis and establish level-of-concern for coldwater fish guild.

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Quick facts for stream temperature monitoring (1994-'96) in Louisiana-Pacific's coastal Mendocino/ Sonoma management unit:

WWAA NO.	CWPW NO.	STREAM NAME	MONITORING SITE NO.	LOCATION MAP REF.	MONITORING YEAR(S)
41	111.32032	Hollow Tree (lower)	41-1	Map-1	1994, 1995
41	111.32031	Redwood Creek	41-2	Map-2	1994, 1995
41	111.32031	Bond Creek	41-3	Map-2	1996
41	111.32030	Michaels Creek	41-5	Map-2	1994, 1996
41	111.32030	Huckleberry Creek	41-6	Map-2	1994, 1995
41	111.32030	Hollow Tree (upper)	41-7	Map-2	1994, 1995
47	113.12011	South Fork Cottaneva Creek	47-1	Map-3	1994, 1995
47	113.12011	Cottaneva Creek (lower)	47-2	Map-3	1995, 1996
47	113.12011	Cottaneva Creek (upper)	47-3	Map-3	1994, 1995, 1996
47	113.12012	Hardy Creek	47-4	Map-4	1994
47	113.12013	Juan Creek	47-5	Map-4	1994, 1995
47	113.12020	Howard Creek	47-6	Map-4	1996
70	113.20015	North Fork Noyo @ Noyo River	70-1	Map-5	1994, 1995, 1996
70	113.20015	Marble Gulch	70-2	Map-5	1994, 1995, 1996
70	113.20013	Hayworth Creek @ N. Fk. Noyo River	70-3	Map-5	1994, 1995, 1996
70	113.20013	North Fork Hayworth Creek	70-5	Map-5	1994, 1995, 1996
70	113.20013	Hayworth Creek @ N. Fk. Hayworth	70-6	Map-5	1996
70	113.20013	N. Fk. Noyo @ Hayworth Creek	70-7	Map-5	1994, 1996
70	113.20014	M. Fk. N. Fk. Noyo River	70-8	Map-5	1994, 1995, 1996
70	113.20014	N. Fk. Noyo River (upper)	70-10	Map-5	1995
70	113.20015	Noyo River @ N. Fk. Noyo River	70-11	Map-5	1994, 1995, 1996
70	113.20011	Redwood Creek	70-12	Map-5	1994, 1995, 1996
70	113.20010	Burbeck Creek	70-13	Map-5	1996

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Quick facts for stream temperature monitoring (1994-'96) in Louisiana-Pacific's coastal Mendocino/ Sonoma management unit:

WWAA NO.	CWPW NO.	STREAM NAME	MONITORING SITE NO.	LOCATION MAP REF.	MONITORING YEAR(S)
74	113.30022	Big River @ Wildhorse Opening	74-1	Map-7	1994
74	113.30022	Russell Brook	74-2	Map-7	1994, 1995
74	113.30022	Big River @ Pig Pen Gulch	74-3	Map-7	1994, 1995
75	113.30038	E. Br. N. Fk. Big River	75-1	Map-6	1995
76	113.30040	Big River @ Black Fly Opening	76-1	Map-8	1994
79	113.30013	South Fork Big River	79-1	Map-9	1996
79	113.30013	Ramoan Creek	79-2	Map-9	1996
79	113.30012	Daugherty Creek	79-4	Map-9	1994, 1995
78	113.40013	Albion River @ Duck Pond	78-1	Map-10	1994, 1995
78	113.40012	South Fork Albion (lower)	78-3	Map-10	1994, 1996
78	113.40012	South Fork Albion (upper)	78-4	Map-11	1994, 1996
78	113.40013	Albion River @ Albion River Confluence	78-5	Map-10	1994, 1996
78	113.40010	Albion River @ N. Fk. Albion River Confluence	78-6	Map-11	1994, 1996
77	114.73020	Jack Smith Creek	77-1	Map-12	1996
81	113.50062	N. Br. N. Fk. Navarro River (lower)	81-1	Map-13	1994, 1995
81	113.50061	John Smith Creek	81-2	Map-13	1994
81	113.50060	N. Br. N. Fk. Navarro River (upper)	81-3	Map-13	1994, 1995
82	113.50077	Marsh Gulch	82-1	Map-14	1994
82	113.50075	Flynn Creek	82-2	Map-14	1994
82	113.50073	Navarro River @ Dimmick Park	82-3	Map-14	1994
85	113.50052	S. Br. N. Fk. Navarro River (lower)	85-1	Map-15	1995, 1996
85	113.50051	S. Br. N. Fk. Navarro River (upper)	85-2	Map-15	1994, 1995, 1996

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Quick facts for stream temperature monitoring (1994-'96) in Louisiana-Pacific's coastal Mendocino/ Sonoma management unit:

WWAA NO.	CWPW NO.	STREAM NAME	MONITORING SITE NO.	LOCATION MAP REF.	MONITORING YEAR(S)
86	113.50041	North Fork Indian Creek (lower)	86-1	Map-19	1994, 1995, 1996
86	113.50041	North Fork Indian Creek (upper)	86-2	Map-19	1994, 1995, 1996
88	113.50043	Navarro River @ Hendy Woods	88-1	Map-21	1994
83	114.31015	Ackerman Creek	83-1	Map-16	1996
84	113.61011	Greenwood Creek (lower)	84-1	Map-18	1995
84	113.61010	Greenwood Creek (upper)	84-3	Map-17	1994, 1995
87	113.62011	Elk Creek	87-1	Map-20	1994
89	113.63011	Alder Creek (lower)	89-1	Map-22	1994, 1995, 1996
89	113.63011	Alder Creek (upper)	89-2	Map-22	1995, 1996
93	113.70024	Garcia River	93-1	Map-23	1994, 1995
93	113.70024	Rolling Brook	93-2	Map-23	1995, 1996
93	113.70023	South Fork Garcia River	93-4	Map-23	1994, 1995
94	113.70030	Schooner Gulch	94-1	Map-24	1996
97	113.84033	Annapolis Falls Creek	97-1	Map-25	1995, 1996
97	113.84032	Fuller Creek	97-2	Map-25	1994, 1995
98	114.11041	Willow Creek (lower)	98-1	Map-26	1994, 1995, 1996
98	114.11041	Willow Creek (upper)	98-3	Map-26	1994, 1995, 1996
98	114.11040	Freezeout Creek	98-4	Map-26	1996

(Note: Air Temperatures @ Monitoring Site No. 41-4, 47-4, 70-4, 70-9, 75-2, 76-1, 78-2, 78-6, 79-3, 81-4, 82-1, 82-2, 82-3, 84-2, 87-1, 88-1, 93-3, & 98-2)