Patterns of summer stream temperature maxima in north Hood Canal, Washington 1992-2001

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Basic Data Report 02-A

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Introduction and Background

The land and waters of north Hood Canal and western Admiralty Inlet constitute the primary management area of the Port Gamble S'Klallam Tribe as set forth under the Point No Point Treaty Council revised Fisheries Management Compact (1999). The health of area rivers and streams is of primary interest to the Tribe, due to their role as nursery habitat for salmon, and as contributing waters to commercially and culturally significant shellfish tidelands. As a primary driver of aquatic ecosystems, water temperature has direct and indirect effects on the health and productivity of native biota, influencing species distribution, migration timing, food resources, growth, competition, predator-prey interactions, disease vulnerability, and other important biological processes.

The decline of regional fish populations has been linked to elevated water temperatures resulting from surface and groundwater extraction, channel simplification, and the clearing of native riparian vegetation (Beschta et al. 1986, Lichatowich 1993, Bahls and Rubin 1996, Gregory and Bisson 1997, Bahls 1998). Lying in the rain shadow of the Olympic mountains, streams of east Jefferson and northwest Kitsap counties are naturally flow limited (Amerman and Osborn 1987), rendering them highly vulnerable to impacts from water withdrawal and poor land use practices (Lichatowich 1993). Ambient stream temperature data is important to the identification and restoration of water quality-limited streams, while long-term records provide information on trends and the frequency/severity of extreme events such as droughts. Simple charts of stream temperature through time can provide resource managers with a valuable understanding of physical factors important to aquatic biota during the summer drought period; when combined with other data (e.g. flow) more complex analyses are supported.

Bahls (1993) summarized one year of maximum temperature monitoring in north Hood Canal and western Admiralty Inlet area streams, Bahls (1998) summarized these data for 1992-1994. Bahls and Rubin (1996) reported on continuous stream temperature monitoring at 22 stations in Chimacum Creek in 1995 and related this data to other habitat and fish population information; this more spatially intensive 1995 data for Chimacum Creek is not included in this report. Since that time, the Port Gamble S'Klallam Tribe and others have continued to monitor water temperatures at select stations, but these data have not been reported or readily available. The purpose of this report is to:

1. provide a concise summary of water quality data collected over the period 1992-2001,
2. consider this information in relation to current and new proposed state water quality standards, and
3. make recommendations for further temperature monitoring and analysis.

Maximum stream temperatures were monitored at 1-2 week intervals during summers 1992-94 to provide a coarse characterization of temperature regimes across a broad network of sites. During 1996-2000 continuous temperature data loggers were employed in three water quality-limited watersheds. In 2001, a drought year, we re-occupied our

original network of monitoring sites with continuous temperature data loggers, and expanded our coverage to include additional sites. Compiled maximum temperature data for 1992-2001 is first evaluated against the current state water quality standards, which are based on annual instantaneous maximum thresholds. Next, more recent data from continuous temperature probes is evaluated against both current and new proposed standards, which are based on more complex summary metrics.

In the State of Washington, the Department of Ecology (WDOE) prescribes water quality criteria that are used for the identification and targeted cleanup of water quality limited water bodies; if a stream, lake, or other water body violates a particular standard (e.g. temperature, fecal coliform, arsenic) it is listed on the federal Clean Water Act's 303-(d) list of impaired water bodies and prioritized for remedial cleanup/restoration actions. Under current water quality standards, the maximum allowable temperature in a stream or lake depends on the water quality classification specific to that waterbody. Most streams in north Hood Canal are classified as AA with a maximum allowable water temperature of 16°C; however, Gamble Bay tributaries are classed as A with a standard of 18°C (Chapter 173-201A WAC). These standards represent the annual instantaneous maximum temperature (AIMT) allowable; that is, if water temperature exceeds the appropriate temperature threshold one or more times during a year, the stream is in violation of water quality standards.

Recently, WDOE has proposed new temperature standards emphasizing different metrics to determine if a water body violates water quality standards (Hicks 2001). For salmon and trout rearing streams during the period June 1-September 15, WDOE has proposed that the highest allowable 7-day average of the daily maximum temperature (7-DADMT) be set at 17°C, the highest allowable 21-day average of the daily average temperature (21-DADT) be set at 14°C, and the annual instantaneous maximum threshold (AIMT) be raised to 22°C. While it is still unclear if WDOE will formally adopt one, two, or all three thresholds, it is anticipated that the new standard(s) when adopted will not vary significantly from what is currently proposed (Dave Peeler, WDOE, personal communication, February 12, 2002). For the purposes of this report, we evaluated our temperature data against all three of the new proposed standards in addition to current standards to better understand the implications of changing water quality criteria on the 303(d) listing status of area streams.

Methods

During the late summer-early fall low flow periods of 1992-94, Taylor maximum-minimum thermometers (Taylor Precision Products, La Cruces, NM) were deployed at 29 sites located in 18 discrete stream systems of north Hood Canal and western Admiralty Inlet (Table 1). Maximum stream temperatures were monitored over the following periods: August 4-October 2, 1992; July 12-September 28, 1993; and June 30-September 29, 1994. Before and after thermometer deployment, accuracy was verified by probe immersion in constant temperature water baths and readings compared to a laboratory reference thermometer. Thermometers were placed at the bottom of a pool, attached to a rock or stick using rubber strapping, and checked at intervals of 7-14 days. Though duration of the monitoring periods varied by year, their timing generally coincided with

the period of maximum stream temperatures observed regionally. Monitoring stations were located in principal salmon streams of north Hood Canal near road crossings to facilitate ease of access.

During 1996-2001, continuous temperature data loggers (Hobo Temps and StowAway TidBit Temps, Onset Corporation, Pocasset, MA) were deployed at select stations over periods of varying duration in late summer (see Fig. 1 and Table 1 for station locations and monitoring periods). Similarly, temperature probes were placed at the bottom of large, well-mixed pools, attached to rebar stakes or embedded tree roots using plastic lock-ties. Where available, well-shaded locations were selected to avoid probe exposure to direct sunlight. Prior to each summer monitoring period, temperature data loggers were calibrated following procedures outlined in Schuett-Hames et al. (1999). Minimum calibration procedures included immersion of temperature probes in a constant temperature bath and comparison of probe temperature measurements against a laboratory reference thermometer (Model 1003BLS, Ever Ready Thermometer Co., West Paterson, NJ). Calibration checks generally confirmed that temperature data logger measurements were within the required range of +/-0.2 °C as compared to laboratory reference thermometers.

During 1996-2000, temperature monitoring focused on three temperature-limited watersheds: Chimacum, Gamble, and Big Beef creeks. We have included temperature data graciously provided by Jefferson County Conservation District for Chimacum Creek from 1998-2001 at three stations that match ours in earlier years (Chimacum-Lower, Chimacum-Main, and EF Chimacum) to provide more information on temperature conditions across years in this important stream. During 2001, we re-occupied our original network of stations and added sites in additional salmon spawning and rearing reaches of north Hood Canal. In larger streams and rivers, multiple monitoring locations provided information on the spatial variation of temperature regimes and helped characterize longitudinal thermal patterns.

In a few instances, monitoring stations were relocated in later years due to habitat changes, land owner access denial, or to ensure sites were representative; however, comparable new sites were generally selected within 100m of former sites to enable characterizing general patterns across years (see Table 1 for site location details). After the initial 1992-1994 annual maximum temperature characterization, two station locations were changed significantly; the Miller Lake/Martha John station was relocated approximately 800m downstream (away from a large wetland complex with atypically warm summer temperatures), and the Little Anderson station was relocated approximately 200m downstream (due to channel aggradation and lack of deep pool habitat). As a result of these changes, we did not compare annual instantaneous maximum temperatures for these two stations in 1992-1994 to those obtained in later years. Permanent monitoring stations were added at: Little Boston, Gamble-Upper, Big Beef-Kidhaven, Stavis, Harding, Fulton, McDonald, Duckabush, Dosewallips (2), Rocky Brook, Marple, Big Quilcene (3), Little Quilcene (1 additional), Howe, Ludlow, and Naylors. Of the new sites Stavis, Duckabush, and Naylors have not yet been monitored; monitoring at these stations will be initiated in 2002. Old sites that have not yet been re-

occupied with continuous temperature data loggers, but that will be re-occupied in 2002 include Spring and Tarboo. Sites that were discontinued after 1994 include Seabeck-East Trib, Spencer-Upper, and Thorndyke-West Trib. In the text and figures, "permanent" sites represent those where future annual monitoring will continue, while the term "supplemental" is used to refer to sites where less frequent or less intensive monitoring is planned.

Results

During summers 1992-1994 annual instantaneous maximum stream temperatures were monitored at twenty-nine sites in eighteen independent stream systems across north Hood Canal. Seventeen sites violated the current state water temperature standard of 16°C (or 18°C for Gamble Bay tributaries) in 1 or more years. Seven sites (Miller Lk/Martha John, Gamble-Lower, Big Beef-Below Lake, Donavan, Tarboo, Chimacum-Lower, Chimacum-Main, and Chimacum-Upper) had severe water quality violations exceeding their respective standard in 2 or 3 years by more than 2°C.

Annual maximum temperatures monitored in subsequent years largely matched those patterns observed during 1992-1994, though additional stations provided more information on the spatial extent of temperature exceedences. Figure 2 depicts annual instantaneous stream temperature maxima (average and range, for sites with >1 yr of data) across all years for all permanent stations; see Table 1 for detailed information on monitoring years and periods at a given station.

As a result of preliminary summer-time maximum temperature data, continuous temperature monitoring during 1996-2000 focused on three independent watersheds with severe exceedence problems to better characterize the spatial and temporal extent of temperature standard violations. Figures 3A-C depict the pattern of mean 7-DADMT and 21-DADT temperature metrics at stations in Chimacum, Gamble, and Big Beef watersheds over the period 1996-2001. Evaluated temperature metrics were remarkably stable across years, within 1.9°C of the site mean for all sites. Most notably, computed metrics for 2001 (7-DADMT and 21-DADT) were not appreciably warmer than the mean for all other years; in 2001, a drought year, most sites had temperatures that were within 1°C of the mean for previous years. Moreover, in 2001 three sites (Big Beef-Below Lake, Chimacum-Lower, and Chimacum-Main) possessed temperature metrics that were 1-2°C cooler than average, and at only one site (EF Chimacum) was the 7-DADMT metric substantially (e.g. >1°C) warmer than average (18.7°C in 2001 vs. 16.9°C average for 1996 and 1998-2000). In the latter case, short-term elevated water temperatures may have been associated with a channel re-meandering restoration project where riparian plantings were not yet established to provide needed shade.

Across the wider network of sites that were re-occupied and monitored in 2001, patterns of summer temperature extremes generally matched those found during the earlier 1992-1994 period (Fig. 2). Big Beef, Donavan, and Chimacum exhibited chronic, severe temperature regimes in excess of prescribed temperature standards and in range of levels considered lethal for salmon (Bjornn and Reiser 1991). Gamble and Tarboo creeks, as

well as Little Quilcene River (including their tributaries) exhibited moderate stream temperature violations of 1-3°C above their respective threshold standards.

When evaluated in relation to new, proposed water temperature standards, the pattern of stream temperature degradation appears similar to that observed in relation to existing standards (Fig 4). The 7-day average daily maximum temperature (7-DADMT) standard of 17°C was violated at twelve of 40 sites monitored during 2001; five sites exceeded this standard by more than 2°C and at nine sites the period of violation lasted 10 days or more. Similarly, thirteen sites violated the 21-day average daily temperature (21-DADT) standard of 14°C; four sites exceeded this standard by more than 2°C and at nine sites the period of violation lasted 30 days or more. Nine sites violated both standards: Gamble-Lower, Big Beef-Kidhaven, Big Beef-Below Lake, Rocky Brook, Leland, Howe, Donavan, Chimacum-Main, and EF Chimacum. Of these, the most severe violations occurred at the Big Beef-Below Lake site where the highest observed 7-DADMT was 24.7°C, temperatures stayed above 17°C for 85 days, and the 21-DADT reached 20.8°C. At the Donavan and Chimacum-Main sites, water temperatures exceeded the 7-DADMT standard for 57 and 69 days, respectively. Five sites (Big Beef-Lower, Fulton, McDonald, Big Quilcene-Lower, Ripley, Chimacum-Upper, and Chimacum-Lower) violated just one of the new proposed 7-DADMT or 21-DADT standards. Only three sites (Miller Lk/Martha John (old), Big Beef-Below Lake, and Chimacum-Main) violated the new AIMT threshold of 22°C.

Discussion

Summer water temperatures are a significant limiting factor across the southernmost ranges of Pacific salmon, especially in areas with low rainfall and human land use impacts (Gregory and Bisson 1997). Though water temperatures are monitored at select stations in major rivers across the region, much of this information lacks sufficient resolution for evaluating patterns of temperature extremes throughout entire stream networks at a scale that is meaningful for stream rearing juvenile salmonids. For example, in north Hood Canal, WDOE maintains only seven water quality monitoring stations at which spot (not continuous) measurements are taken. With the advent of low-cost digital thermographs, this information is now more readily collected and analyzed.

We monitored water temperatures at 50 stations in 32 north Hood Canal tributary streams, encompassing an area with marked gradients of rainfall, topographic relief, and human land use impacts. Stream temperatures were monitored at the bottom of large, well-mixed pools; thus, reported temperature metrics likely offer a conservative representation of the environmental extremes experienced by salmonids in these stream reaches. Twenty-eight (56%) of the sites violated current water temperature standards in one or more years, and nineteen (38%) of the sites had serious violations where annual temperature maxima exceeded current standards by more than 2°C. Of those sites where continuous temperature data was available for one or more years (43 sites), twenty-two (51%) violated one or more of the new proposed Washington State water temperature standards. Comparing observed temperature maxima for these 43 sites against both current and new proposed standards provides some indication of how the management status of area streams is likely to change under new water temperature criteria (Table 2).

Thirty-eight of the 43 sites showed no change in status when evaluated under both sets of criteria; that is, most sites - whether in violation or in compliance with current temperature criteria - retained their current management status under the new criteria. Five sites changed status, with four moving into compliance and one moving into violation under new criteria.

Table 2. Comparison of temperature standard violations for 43 stations in north Hood Canal under current and new proposed Washington Dept. of Ecology criteria.

Management Status	**Current Standard** AIMT≥16/18°C	**New Standards** AIMT≥22°C, OR 7-DADMT≥17°C, OR 21-DADT≥14°C
Total Sites in Compliance	19	22
Total Sites in Violation	24	21
In violation by 0.1-1.0°C	3	6
In violation by >1.0°C	21	15

Continuous temperature monitoring data for the period 1996-2000, as well as maximum temperature data over the period 1992-2000 indicated that stream temperatures in 2001, though a drought year, were not appreciably warmer than average since monitoring began in 1992. Though severe drought conditions prevailed across the region during summer 2001, a large, anomalous rain storm event on August 16 restored stream flows and significantly cooled water temperatures at a critical period.

The most severe temperature standard violations were observed in Big Beef, Donavan, and Chimacum creeks, while less severe, though frequent, exceedences were observed in Gamble, Leland, Ripley, Howe, Tarboo, and EF Chimacum creeks. Notably, temperatures from these streams violated both current and proposed WDOE water quality standards; stations that substantially violated one standard most often also violated the others. Another class of streams exhibited less severe/less frequent temperature standard violations. These included Fulton, McDonald, Rocky Brook, EF Tarboo creeks, and the Big and Little Quilcene rivers.

While temperature regimes at fixed stations along stream networks cannot fully portray the range of conditions experienced by stream-rearing salmonids and other coldwater-dependent biota, they can serve as helpful indicators of stream network-wide habitat conditions. Descriptive habitat information on select stream reaches, where available, provides a link between the observed elevated summer water temperatures, riparian forest conditions, and other important factors like water use. Hatten and Conrad (1995) linked data on elevated stream temperatures with loss of late seral stage forest in streams of the western Olympic Peninsula, and determined that maximum stream temperatures in managed basins violated the Washington State water temperature criterion of 16°C ten times more often, on average, than comparable unmanaged basins. Bahls (1993, 1998) provided compelling data showing the relationship between annual instantaneous maximum temperatures and percent canopy cover and adjacent land use, implicating poorly- or under-regulated agriculture and residential development as major causes of water quality degradation in this region.

Other stream-specific riparian data from watershed analyses and miscellaneous field studies offer additional insight. The Big Quilcene Watershed Analysis (USFS/WA DNR 1994) determined that riparian shade prescriptions were predominantly met in Spencer and Penny creeks (0% and 18.5% of evaluated stream lengths classed as moderate-high impact, respectively), degraded in Marple Creek (46%), and severely degraded in the Big Quilcene River (90.5%). The West Kitsap Watershed Analysis (WA DNR 1995) concluded that riparian shade conditions were moderate-highly degraded in all evaluated stream systems: Big Anderson (70%), Harding (34%), Stavis (51%), Seabeck (75%), Big Beef (74%), and Little Anderson (54%). Meanwhile, field data on stream canopy closure indicates that riparian conditions are generally good in Thorndyke (92%), Shine (96%), and Ripley (90%) but degraded in Howe (73%) and Chimacum (55%) creeks (USFWS 1993, Bahls and Rubin 1996, Bernthal and Rot 2001)[4]. While the link between elevated stream temperatures and degraded riparian forest conditions is strong in some cases, there are clearly other important factors such as groundwater and water extraction for which more data is sorely needed.

Recommendations

Continuous temperature data should continue to be monitored at our extensive network of sites to provide long-term trend information. To ensure that the full period of summer stream temperature extremes is documented, the monitoring period should be lengthened to include the months of June-September. Where feasible, longitudinal thermal "profiles" should be conducted to better delineate temperature-limited reaches, similar to the intensive work performed by P. Bahls in Chimacum Creek during summer 1995 (Bahls and Rubin 1996). This could be accomplished by synchronous temperature measurements along a stream by teams of trained volunteers similar to the effort being led by the University of Washington Center for Urban Water Resources Management (http://depts.washington.edu/cssuw/Research/tempsurvey.html). Target streams for this work include: Gamble (RM 0-2.5), Big Beef (RM 0-5.2), Donavan (RM 0-1.0), and Tarboo (RM 0-2.5) creeks, as well as Little Quilcene River (RM 0-5.5) and its principal tributaries (Leland, Ripley, and Howe creeks).

Once new water temperature standards are formally adopted by Washington Department of Ecology, available summer temperature data for north Hood Canal streams should be reviewed to assess the CWA 303(d) listing status of all waterbodies. Ultimately, WDOE is required to develop Total Maximum Daily Load estimates to determine acceptable temperature loadings for all contributing land uses in temperature-impaired streams. In the meantime, information from this long-term monitoring effort should be used to develop restoration projects and condition forestry, development, and water use proposals in documented temperature-impaired streams to ensure that summer water temperature regimes are not further degraded.

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[4] Percentages are average canopy closure evaluated at 6 sites over 11.5 km in Thorndyke Cr., at 2 sites over 2 km in Shine Cr. (both from USFWS 1993), at 2 sites over 2 km in Ripley Cr., at 5 sites over 4 km in Howe Cr. (both from Bernthal and Rot 2001), and at 22 sites throughout Chimacum and EF Chimacum creeks (from Bahls and Rubin 1996)

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Table 1 - Temperature monitoring station names, locations, periods, and summary statistics by year for 50 stations, plus 3 additional stations where monitoring will begin in 2002. Exceedences of temperature standards (current AIMT=16/18°C, as well as proposed 7-DADMT=17°C, and 21-DADT=14°C) by 0.1-1.9°C are in **bold**, 2-3.9°C are in bold orange, and 4+°C are in bold red.

WRIA	Stream No.	Stream Name	AIMT			AIMT / 7-DADMT / 21-DADT						Location	303(d) Listing Status	Recommend
			92	93	94	96	97	98	99	00	01			
15	350	*Little Boston									14.1 / 13.7 / 12.7	at Little Boston Rd		
15	352	*Middle	15.0	14.4	11.7						13.8 / 13.3 / 12.3	at Little Boston Rd		
15	353	*Miller Lk/Martha John									15.8 / 15.3 / 13.5	near NE 288th St		
15	353	* Miller Lk/Martha John (old)	24.4	21.1	21.7							at NE 288th St	On list	
15	356	*Gamble-Lower	**19.4**	20.0	21.1	**18.5 / 18.1 / 15.8**					**18.8 / 18.0 / 15.1**	at Bond Rd/SR 307	On list	
15	356	* Gamble @ Stevens-Uhler				**19.8** / 19.0 / 16.1						at Stevens-Uhler Rd		List
15	356	*Gamble-Upper				13.6 / 13.4 / 12.1					13.4 / 13.0 / 12.3	at Rova Rd		
15	356	* Gamble @ Iverson				13.6 / 13.2 / 12.0						at Iverson Rd		
15	none	* Gamble Trib @ Rova				21.2 / 20.7 / 18.2						at Rova Rd		Watch
15	364	Spring	13.3	14.4	12.8			Monitoring to resume at this station in 2002.				at Scenic View Dr		
15	368	Cougar-Kinman	15.6	13.3	12.8						15.1 / 13.7 / 12.5	at Kinman Rd		
15	377	Little Anderson									18.6 / 14.9 / 11.8	at Anderson Landing Rd		Watch
15	377	Little Anderson (old)	13.9	12.2	12.8							at Anderson Hill Rd		
15	389	Big Beef-Lower	15.6	18.3	**16.1**	**16.7** / 16.2 / **14.1**	**17.0** / 16.6 / **14.9**				**17.3** / 16.5 / **14.1**	at UW Research Station	On list	
15	389	Big Beef-Kidhaven					19.4 / **18.7** / 17.1				21.1 / 19.6 / 16.3	at Kidhaven Ln		List
15	389	Big Beef-Below Lake	21.1	26.7	26.7	26.9 / 26.1 / 22.7	26.8 / 25.6 / 23.0				25.9 / 24.7 / 20.8	below Lake Symington	On list	
15	389	Big Beef-Above Lake	14.4	**17.8**	15.6	15.8 / 15.3 / 13.8	18.7 / **17.5** / **15.9**				**16.8** / 15.8 / 13.7	at NW Holly Rd		
15	400	Seabeck	13.3	13.3	15.6						13.6 / 13.3 / 11.3	at Miami Beach Rd		
15	none	Seabeck-East Trib	13.3	12.8	12.2							at Miami Beach Rd		
15	404	Stavis						Monitoring to begin at this station in 2002.				near Stavis Bay Rd		
15	408	Harding									12.5 / 12.4 / 11.0	near stream mouth		
15	412	Big Anderson	15.0	12.8	13.9						14.1 / 13.8 / 11.8	near Seabeck-Holly Rd		
16	332	Fulton									**17.3** / 16.9 / **14.7**	near Highway 101		Watch
16	349	McDonald									15.4 / 14.9 / **14.3**	near Highway 101		
16	351	Duckabush						Monitoring to begin at this station in 2002.				near BPA powerline crossing		
16	442	Dosewallips-Lower									**16.4** / 16.2 / 13.0	at Dosewallips State Park		
16	442	Dosewallips-Upper									14.5 / 14.2 / 11.8	near 6 Mile Bridge		
16	449	Rocky Brook									**17.4 / 17.0 / 14.5**	near stream mouth		Watch
17	001	Marple									**17.8** / 16.7 / 13.1	near Bee Mill Rd		
17	004	Spencer	13.3	14.4	13.3						13.2 / 12.9 / 12.2	near Bee Mill Rd		
17	004	Spencer-Upper	15.6	15.0	**16.1**							near BPA powerline crossing		
17	012	Big Quilcene-Lower									18.0 / **17.7** / 13.4	at Rodgers St		Watch
17	012	Big Quilcene-Middle									**16.4** / 16.2 / 12.6	at Highway 101		
17	012	Big Quilcene-Upper									13.1 / 12.8 / 11.5	at Falls View Campground		
17	014	Penny	13.3	13.3	13.9						12.7 / 12.5 / 11.2	at Big Quilcene River Rd (FR 27)		
17	076	Little Quilcene-Lower	**17.2**	15.6	**17.8**						**16.0** / 15.7 / 13.2	at Highway 101	On list	
17	076	Little Quilcene-Upper									14.6 / 14.4 / 12.0	at Road PT Q (FR 3039)		
17	077	Leland	**16.7**	18.3	**17.2**						18.1 / **17.7** / **15.4**	at Rice Lake Rd	On list	
17	089	Ripley	**16.7**	18.9	**16.1**						19.1 / **18.3** / 13.5	at Lords Lake Loop Rd	On list	
17	090	Howe									19.9 / 19.4 / **15.8**	at Lords Lake Loop Rd		Watch
17	115	Donavan	18.9	22.8	22.8						20.1 / 19.3 / 16.3	at McInnes Rd	On list	
17	129	Tarboo	18.9	18.9	19.4			Monitoring to resume at this station in 2002.				at Old Tarboo Rd	On list	
17	130	EF Tarboo	**17.2**	15.6	**16.1**						**16.8** / 15.8 / 13.4	at Coyle Rd	On list	
17	170	Thorndyke	15.0	14.4	15.0						14.3 / 13.6 / 12.2	at Thorndyke Rd		
17	171	Thorndyke-West Trib	**16.1**	**16.1**	15.6							near stream mouth	On list	
17	180	Nordstrom	15.0	13.9	14.4						14.0 / 13.5 / 12.1	at Thorndyke Rd		
17	181	Shine	15.0	**16.7**	14.4						14.5 / 13.5 / 12.6	at Highway 104		
17	192	Ludlow									15.4 / 14.9 / 13.5	near Phillips Rd		
17	203	Chimacum-Lower	18.3	18.9	18.3	18.3 / **17.6 / 15.4**				18.7 / **17.3** / 16.0	**16.3** / 15.8 / **14.7**	at Irondale Rd		List
17	203	Chimacum-Main	22.2	22.8	22.2	23.4 / 22.5 / 18.8		23.4 / 22.2 / 19.2	22.4 / 20.4 / 17.2	24.1 / 22.3 / 18.2	21.7 / 20.6 / 17.0	at Rhody Dr/Mustin Property	On list	
17	203	Chimacum-Upper	20.6	20.0	21.1						18.0 / **17.4** / 13.8	at Eaglemount Rd	On list	
17	205	EF Chimacum	**17.2**	**16.7**	**17.2**	**16.2** / 15.9 / 13.7		**17.9 / 17.0 / 15.2**	**17.1** / 15.6 / **14.1**	19.7 / 19.1 / **15.3**	19.2 / **18.7 / 14.5**	at Beaver Valley Rd	On list	
17	208	Naylors						Monitoring to begin at this station in 2002.				not yet determined		
Monitoring Period Start			8/4	7/12	6/30	7/13	7/19-7/23	6/1	6/1	6/1	7/1 **			
Monitoring Period End			10/2	9/28	9/29	9/7	9/21-9/22	9/30	9/30	9/30	9/30			

* The AIMT threshold for Gamble Bay tributaries = 18°C

** For all JCCD sites (Chimacum-Lower, -Main, and EF Chimacum) the monitoring period in 2001 began 6/1

AIMT = Annual Instantaneous Maximum Temperature

7-DADMT = 7-Day Average Daily Maximum Temperature

21-DADT = 21-Day Average Daily Temperature

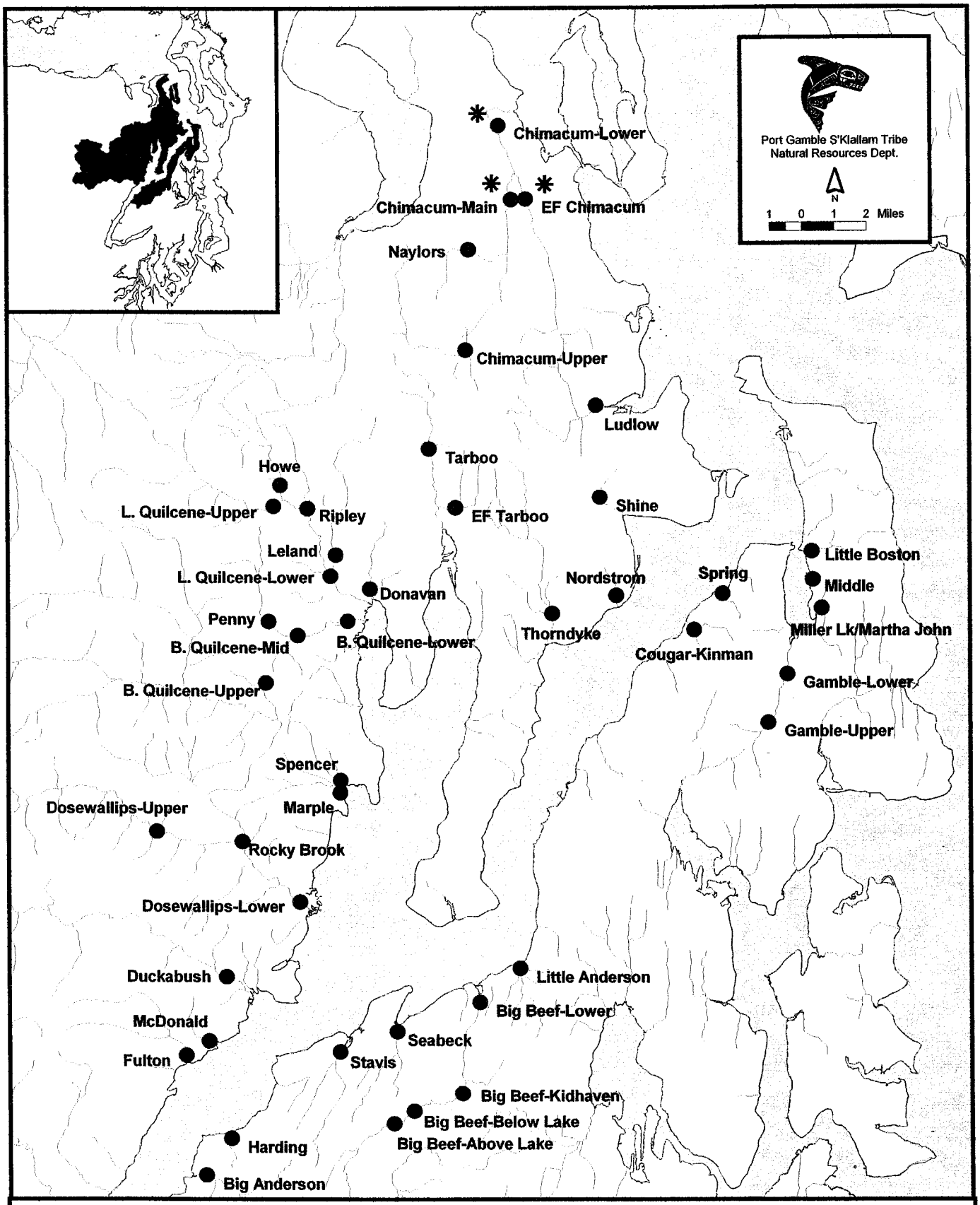


Fig 1 - Stream Temperature Monitoring Sites 1992-2001. Supplemental monitoring sites in Miller Lake/Martha John, Gamble, Little Anderson, Seabeck, Spencer, and Thorndyke creeks are not depicted. Temperature data for starred sites (Chimacum) for 1998-2001 graciously provided by Glenn Gately, Jefferson County Conservation District.

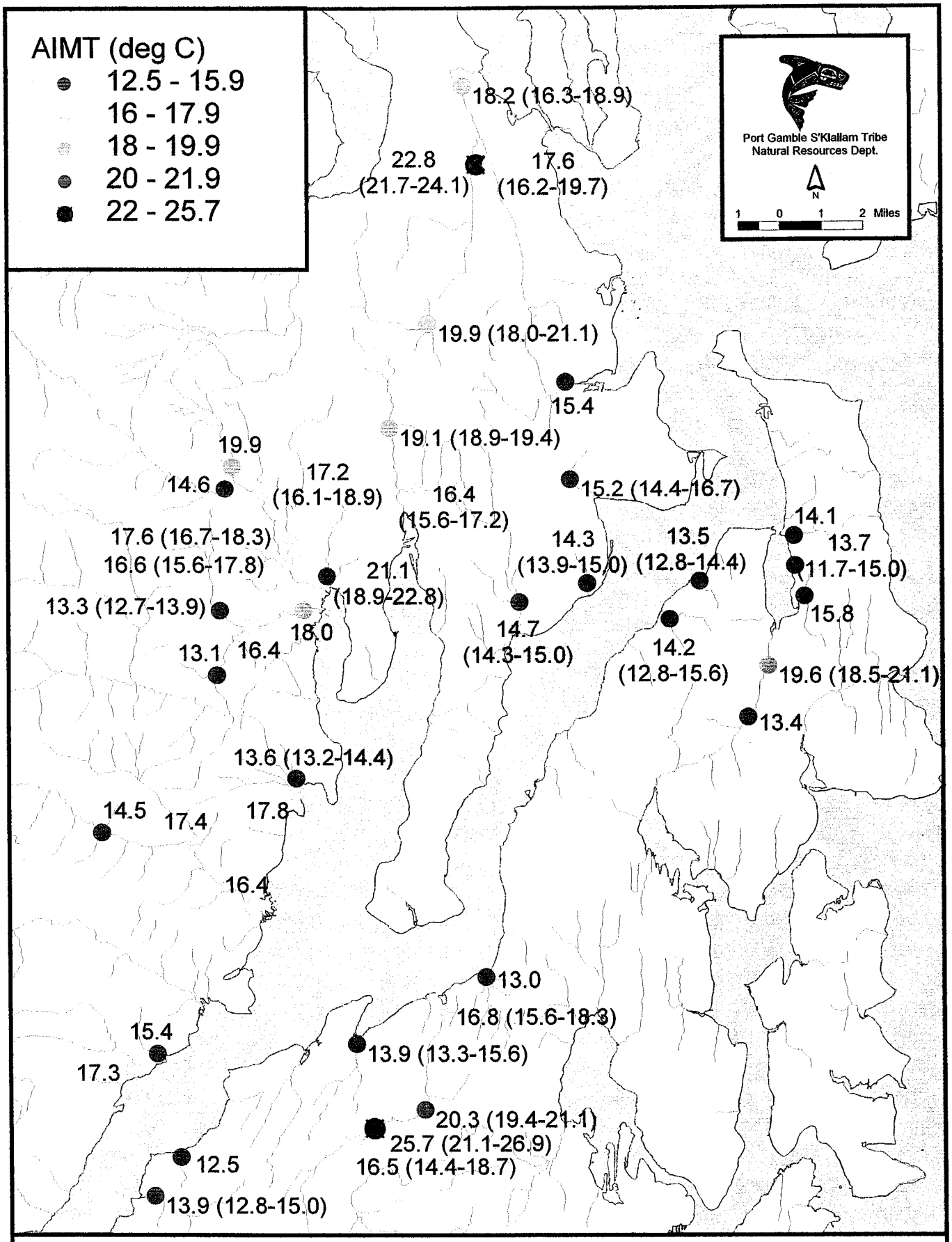
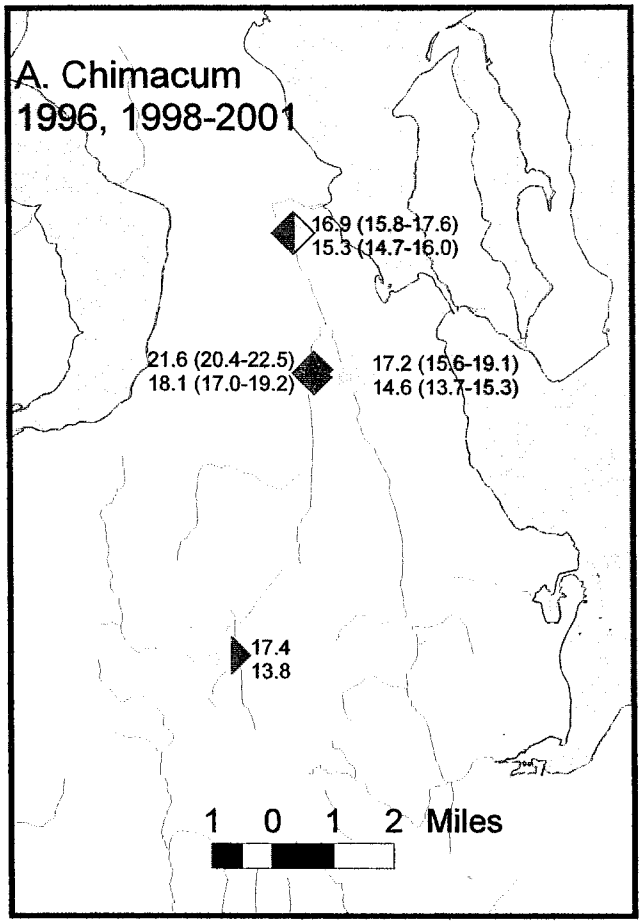
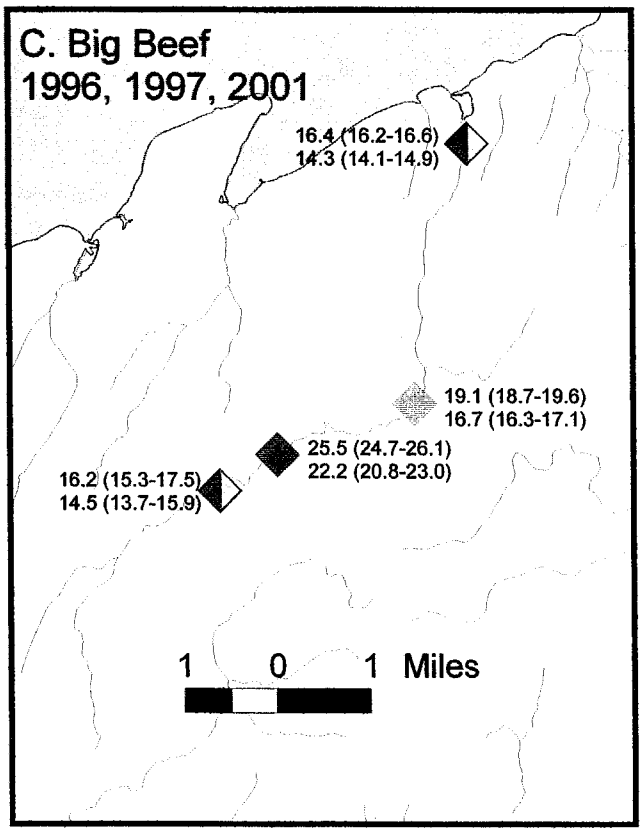
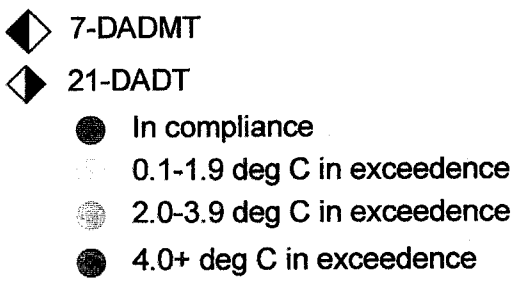


Fig 2 - Annual Instantaneous Maximum Temperature (AIMT), 1992-2001. Average and range (where >1 yr of data was available) for all permanent stations.







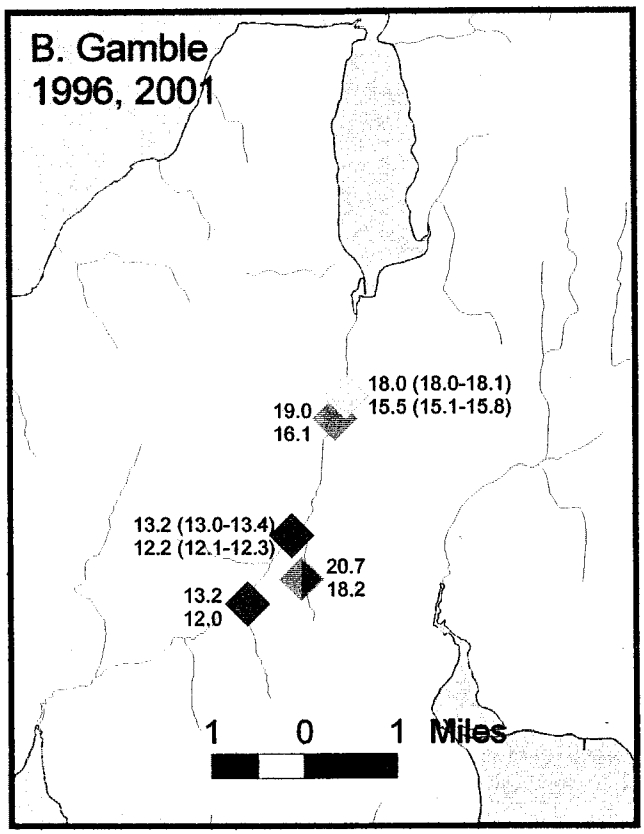


Fig 3 - Stream temperature maxima in select watersheds, 1996-2001. Left diamond halves and upper numbers are mean 7-Day Average Daily Maximum Temperatures (7-DADMT). Right diamond halves and lower numbers are mean 21-Day Average Daily Temperatures (21-DADT). Ranges are in parentheses for sites with >1 yr of data. Temperature data for Chimacum Creek for 1998-2001 was provided by Glenn Gately, Jefferson County Conservation District.

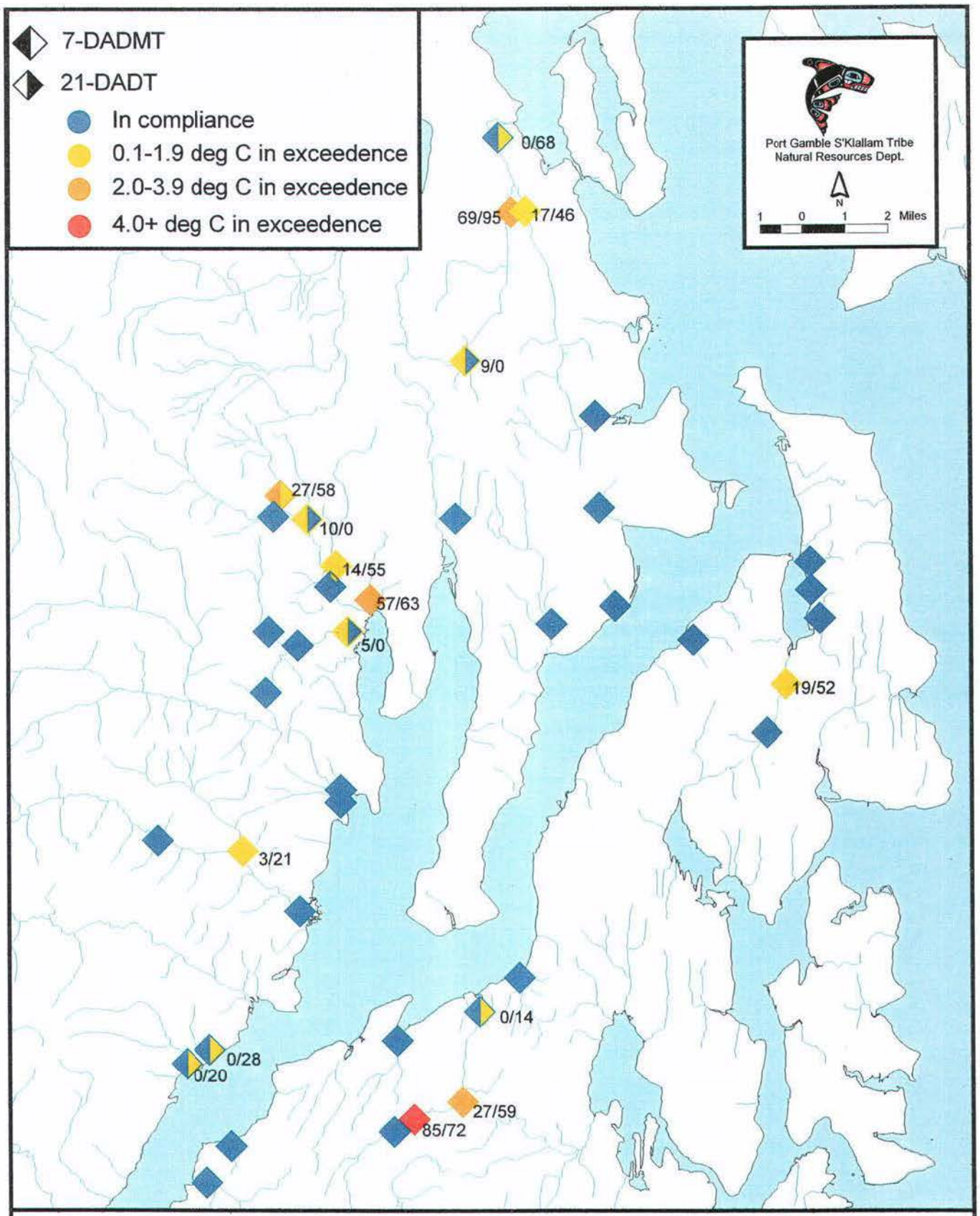


Fig 4 - Stream temperature maxima, 2001. Left diamond halves indicate the 7-Day Average Daily Maximum Temperature (7-DADMT) with respect to 17 deg C. Right diamond halves indicate the 21-Day Average Daily Temperature (21-DADT) with respect to 14 deg C. Where temperature exceedences occurred, numbers before and after slash marks indicate days water temperatures exceeded the 7-DADMT and 21-DADT standards, respectively.