Preliminary Assessment of Overwintering Habitat in the Morice Watershed

November 1998 to April 1999

conducted by

Wet'suwet'en Fisheries
Smithers, B.C.

for

Fisheries Renewal B.C.
Smithers, B.C.

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EXECUTIVE SUMMARY

The Morice River preliminary overwintering habitat assessment study was designed and executed by the Wet'suwet'en Fisheries. Data was provided to Regina Saimoto (SKR Consultants) by the Wet'suwet'en Fisheries for analysis and the production of this summary report.

The preliminary data report examines potential indicators of overwintering habitat quality, including:

- fish density (mark recaptured, catch per unit effort and/or biomass estimates),
- condition factor,
- survival,
- growth, and
- species richness and diversity.

The report also examines some potential factors, which may affect overwintering habitat quality. These include:

- size of overwintering habitat,
- dissolved oxygen,
- water temperature,
- presence of LWD and other sources of cover,
- stream gradient,
- discharge
- water clarity,
- water quality,
- invertebrate presence and abundance,
- substrate type,
- seasonal accessibility of habitat, and
- site proximity to lakes.

Potential comparisons, probable results and benefits are discussed for each indicator of overwintering habitat quality, and each factor that may influence overwintering habitat quality. Where possible, the preliminary data was analysed for each of these sections, and results were presented to indicate if the preliminary data supported future examination of the indicator of overwintering habitat quality or the factor influencing habitat quality.

Preliminary data showed that catch per unit effort was variable among sites. Species richness and diversity also showed some variability between sites. Growth was difficult to analyse, and is likely not suitable unless much more intensive data is collected. Density, biomass, condition factor and survival were not evaluated due to a lack of suitable data. Future studies involving catch per unit effort, density, biomass, condition factor and species richness/diversity data should allow for differentiation of better quality overwintering habitat.

The preliminary data was suitable for inferences regarding the affects of water temperature, LWD, water quality, discharge, and substrate type. Although data was collected for dissolved oxygen, the data were generally not useable due to malfunction of the field meter. Temperature appears to affect capture rates, particularly at temperatures below 0°C. The affect of temperature on CPUE may be due to affects on capture rates rather than habitat quality. The presence of LWD indicated significant differences in mean catch per unit effort for salmonids, but not for all species combined. Water velocity appears to affect species presence and catch per unit effort, particularly for salmonids. Substrate composition data were not sufficiently detailed to allow for the detection of marked differences between sites. Preliminary data indicate that water velocity (i.e. gradient) and LWD presence may be important factors that influence overwintering habitat quality. Further study is required for all of the parameters described to indicate which are more useful in determining overwintering habitat quality.

ACKNOWLEDGMENTS

The Morice River Overwintering study was funded by Fisheries Renewal B.C.. The project was designed, and all field sampling was conducted by the Wet'suwet'en Fisheries (Ron Austin, Gary Baptiste, Elgin Cutler and J. Brian Michell). Water quality analysis was conducted by Stefan Schug (Wet'suwet'en Fisheries). Data was entered by J. Brian Michell (Wet'suwet'en Fisheries). Regina Saimoto (SKR Consultants Ltd.) conducted data analysis and reporting. Ron Saimoto (SKR Consultants Ltd.) and Stefan Schug provided helpful editorial comments on the report.

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1.0 INTRODUCTION

The Morice River is a major tributary to the Bulkley River, which drains a significant portion of the Skeena watershed. The confluence of the Morice and Bulkley rivers is located approximately 6.75 km west of the community of Houston, in north central British Columbia (Figure 1). The Morice watershed has been recognized for its fisheries, wildlife, mining and forestry values in the past. The watershed is an important contributor to the commercial, native and sport fisheries in the Skeena drainage and Pacific Ocean. However, fish stocks in the Morice watershed, have been notably depressed. In particular, the decline of coho salmon throughout the Skeena watershed, and the Morice drainage, has raised concerns for the continued survival of several stocks.

Several hypotheses have been raised to explain the decline of salmonids in the Morice and upper Bulkley watersheds. One of these is that the abundance and quality of suitable overwintering habitat limits the overwinter survival of juvenile salmonids. If overwintering habitat is a bottleneck to salmonid survival, then information on the location and characteristics of suitable overwintering habitat will be invaluable to the management of salmonids in this system.

The main objectives of this preliminary overwintering habitat assessment study were to:

- identify measures which can be used to evaluate the relative quality or value of overwintering habitat
- identify physical and biological factors which influence overwintering habitat quality, and
- give direction to future overwintering habitat assessment studies

2.0 MATERIALS AND METHODS

2.1 Site Selection

Sites within the Morice drainage were selected by Stefan Schug (Wet'suwet'en Fisheries). A variety of habitat types were represented among the sample sites in order to distinguish which habitat characteristics may influence species presence, abundance and diversity. All sites are known to be accessible to anadromous salmonids. Sample site selection was also based on two wheel drive or four wheel drive access throughout the winter to facilitate sampling.

Sampling at some of the sample sites initially chosen in the study was discontinued during the study, and some new replacement sites were added. The sample sites and duration of sampling for each site is summarized in Table 1.

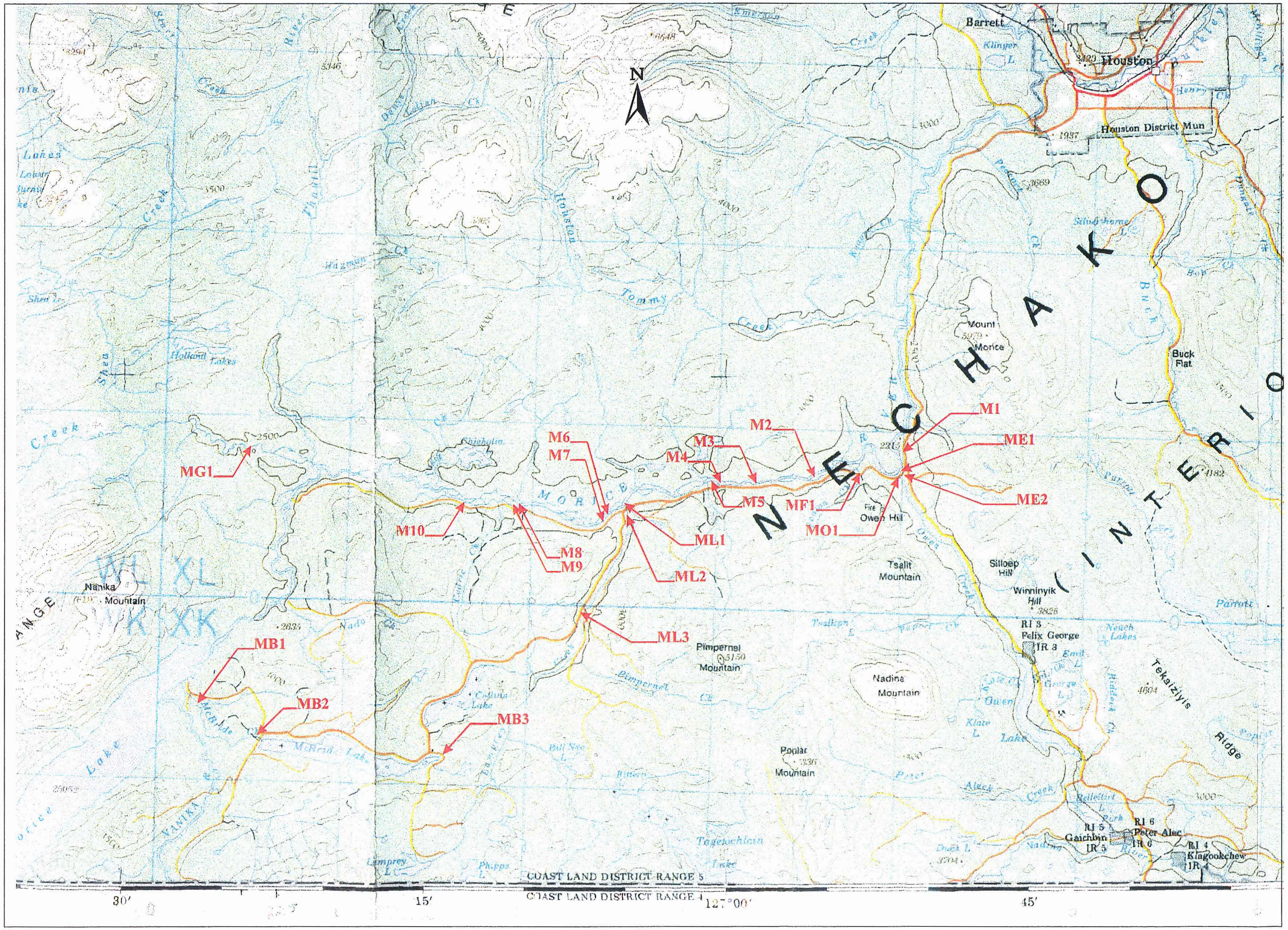


Figure 1.

Locations of sites sampled during the

Morice River Overwintering Study

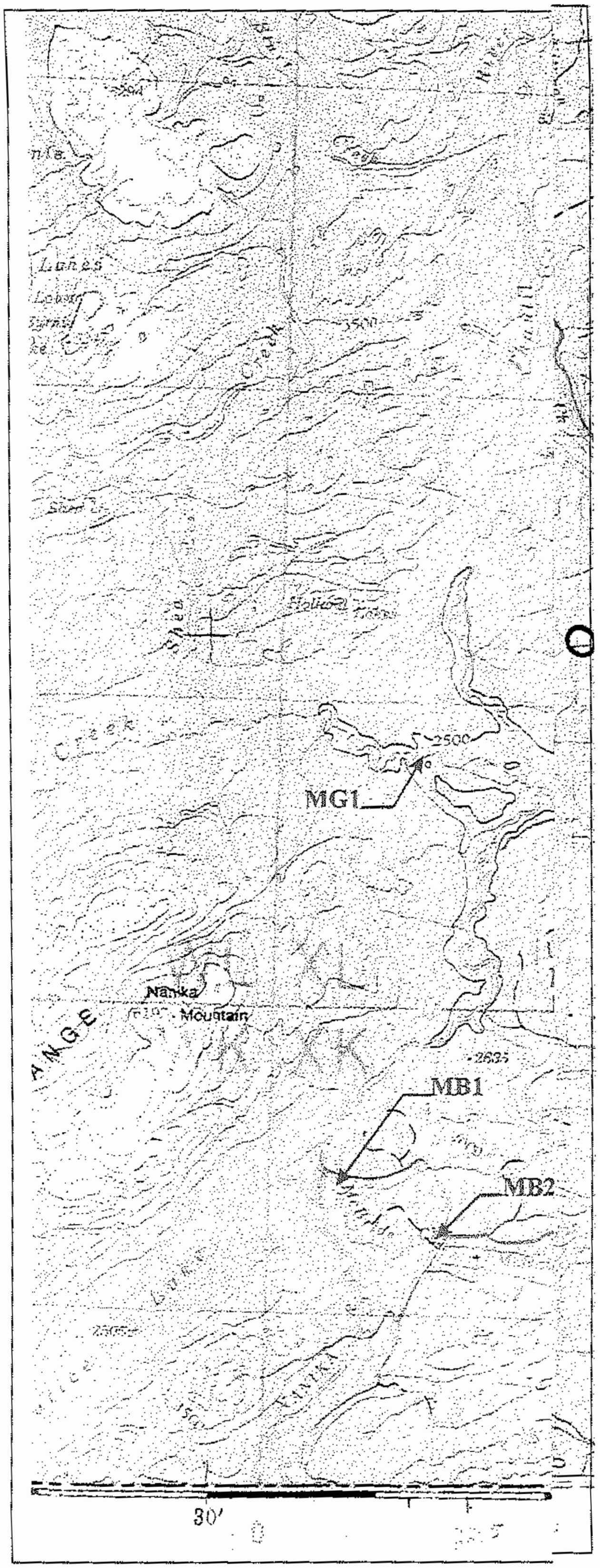
conducted

November 1998 to April 1999

LEGEND

M 1-10 Morice River Sites
MB 1-3 McBride Creek Sites
ME 1-2 Morice Enhancement Sites
MF 1 Morice/Fenton Site
MG 1 Morice/Gosnell Site
ML 1-3 Morice/Lamprey Sites
MO 1 Morice/Owen Site

1:200,000 Scale excerpt from 1:250,000 Scale NTS Map 93L



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1:200,000 Scale excerpt
from
1:250,000 Scale NTS Map 93L

Table 1. Sample site description and duration of sampling for each site during the Morice River overwinter study, November 1998 – April 1999.

Site #	Location (km are distances along FSR)[1]	Habitat	UTM	Altitude (m)	Sample Dates[2]
M1	Morice River sidechannel at 26 km	side channel	9.639925.6008950	766	Nov. 98 & Mar. 99
M2	Morice River at 33 km	side channel, pool	9.635400.6007400	766	Dec. 98 – Feb. 99
M3	Morice River at 35 km	side channel	9.633350.6007350	766	Nov. 98 – Feb. 99
M4	Morice River at 37.5 km	pool	9.631025.6007040	766	March 99
M5	Morice River at 38 km	pool	9.630300.6007100	766	Feb. – Mar. 99
M6	Morice River at 45 km		9.624400.6005400	766	Nov. 98 & Mar. 99
M7	Morice River at 45.5 km	pool	9.624050.6005100	766	Nov. 98
M8	Morice River at 51.5 km	pool-riffle	9.619650.6005550	800	March 99
M9	Morice River at 52 km	pool	9.619100.6005525	800	March 99
M10	Morice River at 55 km	side channel	9.616400.6005625	800	Nov. 98 & Mar. 99
MB1	McBride Creek about 6 km downstream of the Nanika-Kidprice road crossing	pool-riffle	9.603050.6094325	870	Dec. 98 & Mar. 99
MB2	McBride Creek at Nanika-Kidprice road crossing (~ 200 meters downstream of lake)	pool	9.605500.6092500	905	Nov. 98 – Mar. 99
MB3	NE inlet to McBride Lake at Nanika-Kidprice road crossing	pool	9.615450.6091425	922	March 99
ME1	Habitat enhancement back channel site	pool	9.640100.6008350	766	Nov. 98 & Mar. 99
ME2	Habitat enhancement back channel	connector to Owen Creek	9.640100.6008500	766	Nov. 98
MF1	Fenton Creek at Morice FSR crossing	pool-riffle	9.637700.6007850	800	Dec. 98 & Mar. 99
MG1	Gosnell Creek downstream of FSR		9.604850.6008425	835	Dec. 98 & Mar. 99
ML1	Lamprey Creek at Morice FSR crossing		9.625100.6005650	783	Nov. 98 – April 99
ML2	Lamprey Creek 250 meters upstream of Morice FSR crossing		9.625100.6005525	783	Nov. 98
ML3	Lamprey Creek at Bill Nye FSR crossing		9.622950.6000000	853	Dec. 98 – April 99
MO1	Owen Creek at 28 km bridge crossing	pool	9.639625.6007800	766	Nov. 98 – Mar. 99

([1] also see Figure 1 for site locations; [2] no sampling was conducted in January)

2.2 Sampling Methodology

All sampling was coordinated by Stefan Schug and conducted by the technical staff of the Wet'suwet'en Fisheries. Sample sites were accessed periodically during the late fall, winter and early spring. No sampling was conducted in January. Sites initially chosen were sampled at least once a month, but as sampling season progressed, some sites were deleted, and others added (Table 1). Each site was visited by one of two teams, consisting of two technicians each. Ron Austin and Elgin Cutler comprised one sample team, while J. Brian Michell and Gary Baptiste comprised the other team.

2.2.1 Physical Characteristics

Physical and chemical parameters were recorded for each sample site. Parameters examined, and equipment utilized are summarized in Table 2. In addition, water quality analysis was conducted for ten sites. Water quality parameters that were recorded are presented in Table 3. Photographs and/or videos were taken of each site.

Table 2. Physical parameters recorded in the field for each site sampled in the Morice River overwintering study.

Parameter	Methods
Date, Time	chronometer
Air temperature	alcohol thermometer
Water temperature	Oxyguard Handy Gamma
substrate type	visual estimate
ice and snow thickness	meter stick
water depth	meter stick
Oxygen (dissolved)	Oxyguard Handy Gamma
pH	Oxyguard Handy pH
water velocity	Global water flow probe

Table 3. Water quality parameters recorded in the laboratory for selected sites sampled in the Morice River overwintering study.

Parameter	Detection Limit	Methods
pH		LaMotte kit AQ-2
$NO_3 - N$	0.05 mg/L	LaMotte kit AQ-2
$CaCO_3$		LaMotte kit AQ-2
Cl^-	4 mg/L	LaMotte kit AQ-2

2.2.2 Fish sampling

Fish sampling was conducted by setting one minnow trap baited with roe at each of the sample sites during each sampling period. The minnow traps were left for at least 24 hours, and up to 48 hours. Fish were recovered from the traps, identified to species, measured (fork length) and released back into the habitat. Salmonids were marked using a caudal fin clip to allow for a mark – recaptured estimate of population size.

2.3 Data Analysis

Habitat quality was assessed using density and species composition present at each site sampled as indicators of quality. In theory, better habitat will support more fish, and different habitat types should support different species assemblages. In addition, catch per unit effort (a measure of density) was compared to factors that may influence habitat quality.

Data analysis involved primarily non-statistical comparisons between sites. Data collected during the preliminary study was not suitable for statistical testing of hypothesis. However, non-statistical analysis of data using histograms, scatter plots and cluster analysis was used to determine if any of the biological and physical factors recorded showed potential influence on overwintering habitat quality.

Species diversity was determined using the $\log_{10}$ Shannon index of diversity (Zar 1984) (equation 1). The number of potential categories (k) was chosen as the number of species captured among all sites (seven for this study).

Equation 1: $H' = -\Sigma p_i \log p_i$

where H' is the Shannon diversity index, and
p_i is the proportion of observations found in category i

Since the Shannon index is dependent on the number of potential categories (k) (Zar 1984), evenness was also calculated, as shown in equation 2.

Equation 2: $J' = H' / H'_{max}$

where J' is evenness
H' is the Shannon diversity index (equation 1)
H'_{max} is the maximum possible diversity calculated as $H'_{max} = \log k$

3.0 Results and Discussion

The results and discussion section presents aspects of study design along with the data collected during the preliminary study. Indicators of habitat quality, including density, biomass, condition, growth, survival and species assemblages, are described in the following section. Potential comparisons, which could be conducted during future studies, are suggested, and potential outcomes are illustrated and explained. The results and discussion section then describes some factors, which may influence habitat quality. Some of these factors have been recorded in the preliminary study, and results from the preliminary study are presented in applicable sections. It is hoped that an illustration of potential study design(s), combined with preliminary results, will aid in refinement of the study in the future.

3.1 Indicators of Overwintering Habitat Quality

In order to establish which overwintering sites are of higher quality, it is important to identify methods of comparing between overwintering habitats, and monitoring the overwintering habitat quality over time. Fish abundance and health can be used to indicate the suitability of overwintering habitat. Five potential indicators of overwintering habitat quality were considered:

1. fish density,
2. condition factor,
3. growth,
4. survival, and
5. species diversity and richness.

The following sections describe how these indicators may show overwintering habitat quality. Methods for data collection are suggested to allow for the use of each of these indicators of habitat quality. Suggested comparisons among and between sites, and applicable results from the preliminary overwintering study are presented.

3.1.1 Density

Fish density can be used as an indicator for overwintering habitat quality. If fish can move between overwintering habitats, and are capable of choosing the most suitable habitat, a higher density of fish would be expected in habitats of better quality. Conversely, if fish are unable to leave a less than optimum habitat, lower densities may result from increased mortality. Density comparisons between overwintering habitats should indicate which habitat is more suitable, while comparisons of density over time within a habitat will indicate any deterioration in the habitat quality.

3.1.1.1 Density Comparisons Between Sites

Purpose

The main purpose of comparing between overwintering habitats is to determine which habitat is more suitable. For this comparison, it is assumed that better quality habitat will support a greater density of fish. Higher quality habitat will attract and sustain more fish until densities become sufficiently high to lower the quality of the habitat (e.g. competition, depletion of food). Lower quality habitat is assumed to result in greater emigration or mortality. Comparisons of fish densities among sites at a certain time of year may therefore give an indication as to the value of the habitat for different species.

Potential Findings

A site may exhibit similar, lower or higher densities of fish compared to other sites at the same time of year. If the assumptions are true, higher fish densities would indicate better habitat quality, while lower fish densities would indicate a lower habitat quality.

Preliminary Findings

During the preliminary overwintering study, attempts were made to collect data suitable for density estimates using mark-recapture and catch per unit effort information. However, insufficient re-captures were encountered to allow for the estimation of population size by mark-recapture. In addition, the size of the overwintering habitats sampled was not recorded, and density could not be estimated.

However, catch per unit effort (CPUE) data was recorded, and can be utilized for comparisons of apparent abundance between sites. Due to the relatively low sampling intensity (one trap set per site), the total number of fish captured at any one time is low. Catches consisted of a variety of species, including coho (*Oncorhynchus kisutch*), chinook (*O. tshawytscha*), rainbow trout/steelhead (*O. mykiss*), cutthroat trout (*O. clarki*), burbot (*Lota lota*), and sculpin (*Cottus sp.*). Catch per unit effort was determined for each sampling point at each site as the number of fish captured in 24 trap hours. The relative abundance of fish is illustrated in Figure 2, in which catch per unit effort is shown for each site over time. Fish were only captured at a few sites (sites M3, M5, M6, M9 and M10 in the Morice mainstem, site MB2 in McBride Creek, sites ML1 and ML2 in Lamprey Creek and site MO1 in Owen Creek).

Overall, fish appeared to be most abundant at site M10 in the Morice mainstem on November 19, 1998. A total of 17 fish were captured at this site in November (Figure 4). This site is a side channel to the Morice River and offers good cover, large woody debris (LWD), and habitat diversity. However, the majority of this catch consisted of sculpins. The relatively low abundance of salmonids at this site may be due to trapping location, competition/predation by sculpins, or water velocity, among other potential factors.

Catch per unit effort for salmonids may be more indicative of the salmonid productivity at each site than CPUE for all species. When CPUE of salmonids only are compared among sites (Figure 3), site ML1 in Lamprey Creek (Figure 5) has the highest CPUE with 13 salmonids captured on December 1st, 1998. This site also offers abundant large woody debris and cover, implying that large woody debris and cover may be important contributors to overwintering habitat quality for salmonids. However, no fish were captured in the spring at these sites, indicating the potential for a limiting factor, shift in habitat preference or decreased capture efficiency during spring.

In summary, catch per unit effort is variable between sites. This variability implies that densities are also variable. Assuming that CPUE and density are dependent on habitat quality, differences in CPUE and densities may be used to indicate which overwintering habitats are of higher quality, if sampling intensity is increased.

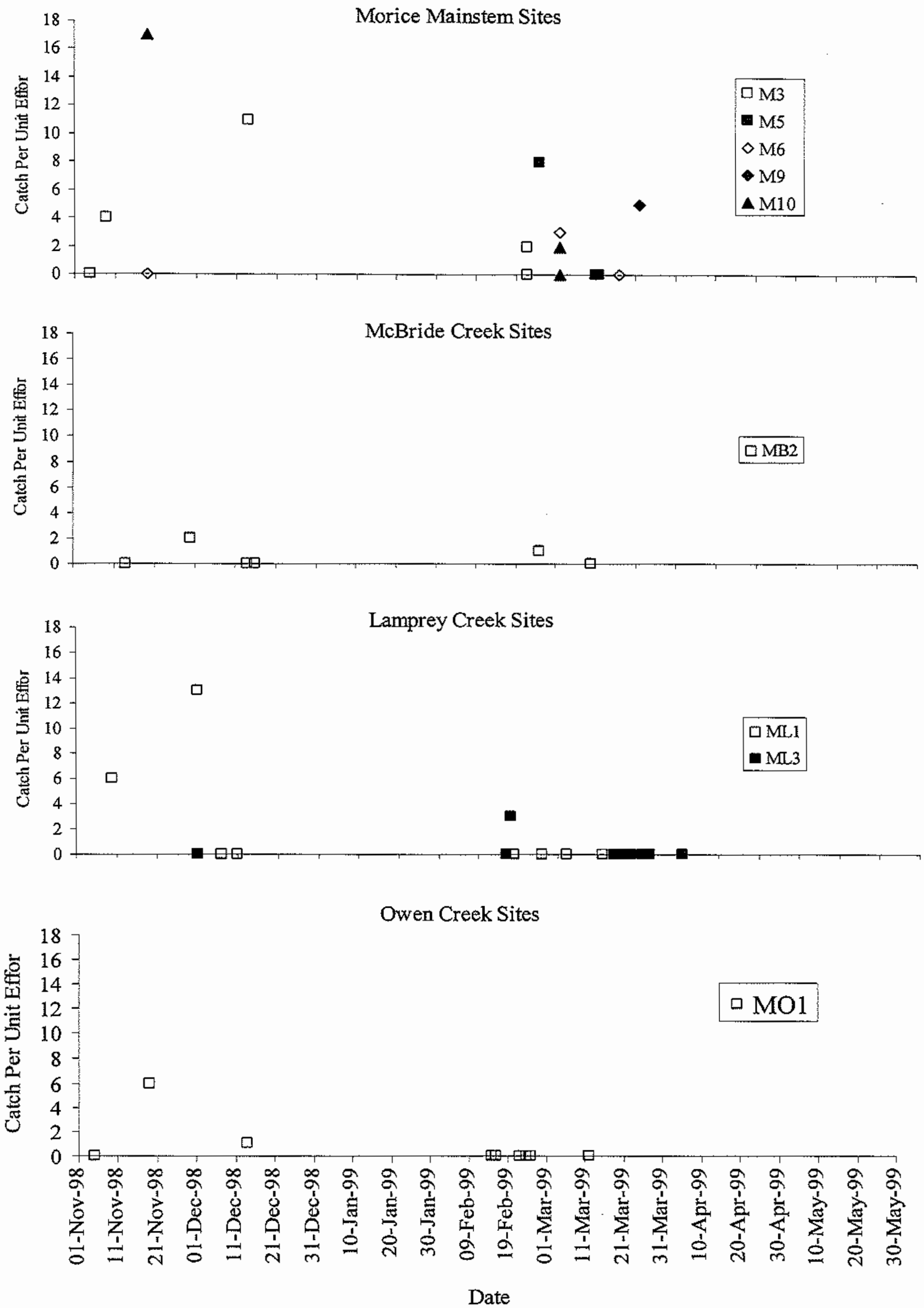

Figure 2. Catch per unit effort for all sites at which fish were captured during the Morice River overwintering study.

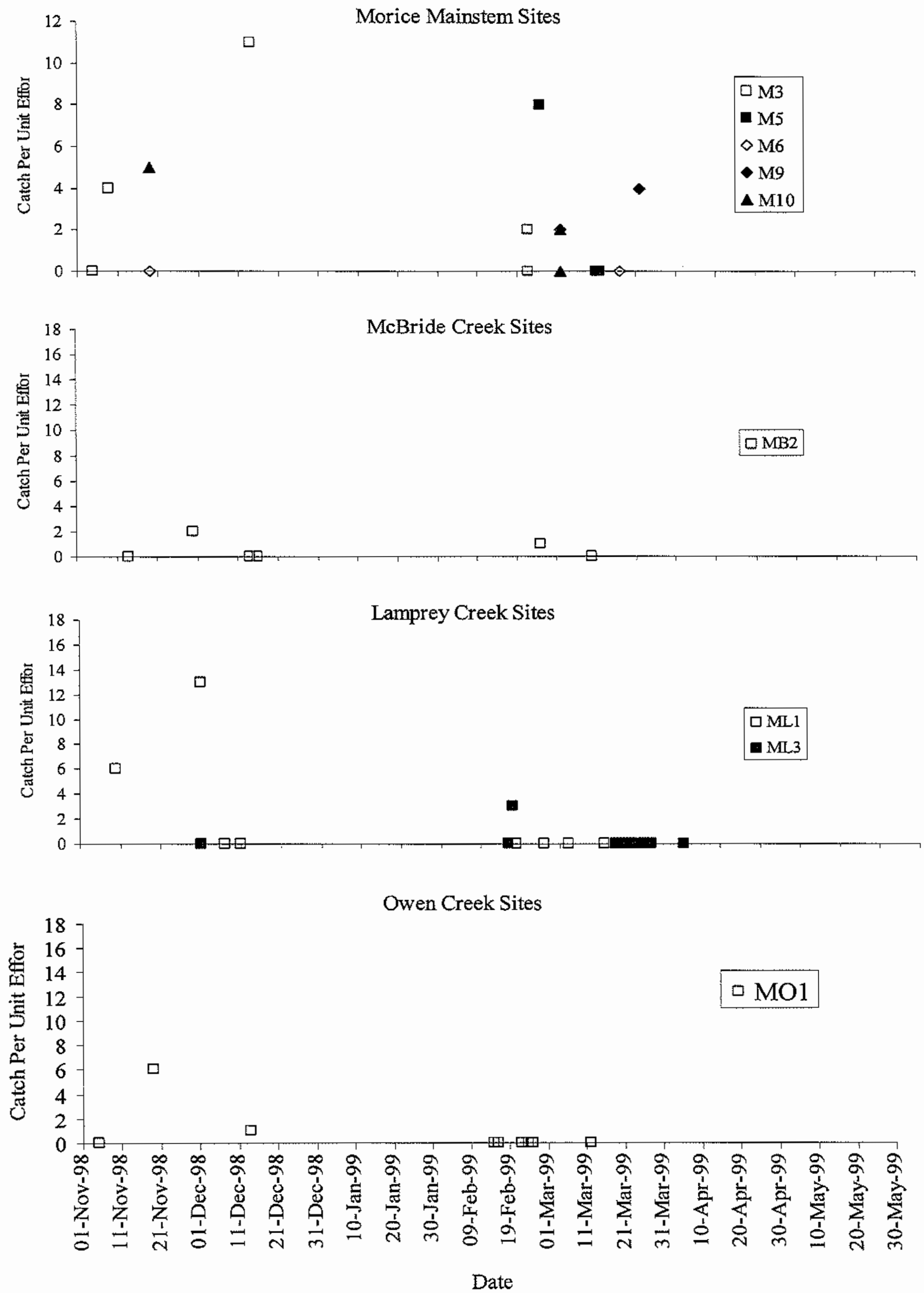

Figure 3. Salmonid catch per unit effort for all sites at which fish were captured during the Morice overwintering study.

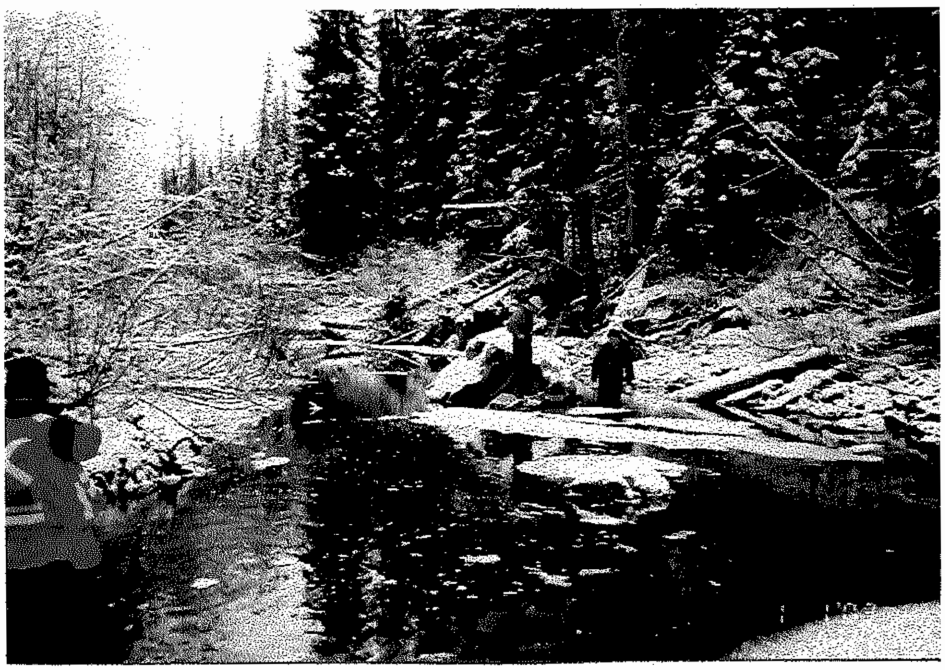

Figure 4. Photograph illustrating site M10 on a side channel of the Morice River mainstem. This site had the highest overall catch per unit effort of the sites sampled, with 17 fish captured on November 19, 1998 (12 sculpin, 3 coho, 1 chinook, 1 rainbow).

Figure 5. Photograph illustrating site ML1 in Lamprey Creek, just upstream of the Morice FSR bridge crossing. Thirteen salmonids (all coho) were captured at this site on December 1, 1998.

Data Requirements

Estimates of density require an estimate of the population size (section 3.1.1.3) and the area or volume of the habitat. For comparisons between sites, sites to be compared should be visited on approximately the same date. It would be beneficial to compare sites offering different habitats within the same drainage to minimize differences in overall abundance between drainages (e.g. compare sites within Owen Creek rather than between Owen Creek and Gosnell Creek). Trapping effort must be sufficient to result in acceptable capture rates. Effort must be consistent between sample sites, or effort must be carefully recorded. Depending on the choice of population size estimators (mark-recapture and/or CPUE, see section 3.1.1.3), a detailed sampling regime should be established.

Benefits of Density Comparisons Between Sites

Density comparisons between sites may aid in the identification of better value overwintering habitat. By comparing the physical, chemical and biological parameters of higher and lower value overwintering habitat, a set of criteria to identify good overwintering habitat quality may be determined. This will aid in management of overwintering habitat, and in the management of salmonids in the watershed, if overwintering habitat is limiting fish production.

3.1.1.2 Density comparisons within sites over time

Purpose

Densities at a site may vary as the winter progresses. Some habitats may deteriorate in quality (e.g. overcrowding, oxygen depletion, food depletion) at different rates than others. Habitat, which may be of high quality in the beginning of the winter may have sufficiently high fish densities to result in poor habitat quality as the season progresses. Monitoring densities over time should indicate which habitats are deteriorating faster than others.

Potential Findings

Over the winter, fish density at a site may increase, decrease or stay the same. Each of these trends have different implications, and may result from a variety of mechanisms.

Increases in fish density indicate that the overwintering habitat is not closed. Increases in fish density at a site can only result from a rate of immigration of fish to a site which exceeds the rate of emigration and death, since migration is the only method of recruitment in the winter (i.e. no recruitment from births). Good overwintering habitats may show increases in fish densities as fish emigrate from deteriorating habitat over the winter.

Consistent fish densities with no apparent increase or decrease indicate either a closed system with negligible mortality, or an open system in which the rate of immigration is roughly equivalent to the rate of emigration and mortality. Stable densities over time indicate that the habitat is likely not deteriorating significantly, and that the fish density present in the habitat can be supported by the habitat (i.e. density is below the carrying capacity).

Decreases in fish densities are assumed to result from deteriorating habitat quality over the winter. Decreases in fish densities may occur in closed and open systems. In closed systems, the decrease in density is a result of mortality, as there is no immigration or emigration. In open systems, a decrease in density results from the level of mortality and emigration exceeding the rate of immigration. Slight decreases in densities are expected in closed systems, and should not be taken as a definite indicator of deteriorating habitat. However, decreases in density in open systems are probable indicators of deteriorating habitat.

Preliminary Findings

During the preliminary overwintering study, attempts were made to collect data suitable for density estimates using mark-recapture and catch per unit effort information. However, insufficient re-captures were encountered to allow for the estimation of population size by mark-recapture. In addition, the size of the overwintering habitats sampled was not recorded, and density could not be estimated.

However, catch per unit effort data was recorded, and can be utilized for comparisons of apparent abundance over time. Due to the relatively low sampling intensity (one trap set per site), the total number of fish captured at any one time is low. Catches consisted of a variety of species, including coho (*Oncorhynchus kisutch*), chinook (*O. tshawytscha*), rainbow trou/steelhead (*O. mykiss*), cutthroat trout (*O. clarki*), burbot (*Lota lota*) and sculpin (*Cottus sp.*). Catch per unit effort was determined for each sampling point at each site as the number of fish captured in 24 trap hours. The relative abundance of fish is illustrated in Figure 2, in which catch per unit effort is shown for each site over time. Fish were only captured at a few sites (sites M3, M5, M6, M9 and M10 in the Morice mainstem, site MB2 in McBride Creek, sites ML1 and ML2 in Lamprey Creek and site MO1 in Owen Creek).

Most of the sites at which fish were captured showed a relatively high CPUE in late fall/early winter, at the beginning of the sampling season. The highest catch per unit effort was found for M10 on November 19, 1998 (17 fish). Fish catch per unit effort is generally lower in the late winter/early spring. This is expected due to mortality and deterioration in habitat quality. However, the rate of decline is different for different sites. For example, CPUE at ML1 in Lamprey Creek (Figure 5) climbs from 6 fish to 13 fish in the prior to December 1, 1998 (Figures 2 and 3), and then drops to 0 fish by December 7, 1998. The same trend is seen in site MO1 (Owen Creek) where CPUE is highest in the early part of the study (6 fish on November 19, 1998) and declines in December (1 fish on December 14, 1998). Catch per unit effort at this site is also 0 by the end of the study. Catch per unit effort for site M3 on the Morice River also climbs in the first part of the study from 0 fish on November 5, 1998 to 11 fish on December 14, 1998. Catch per unit effort then declines to 2 fish on February 22, 1999 and finally to 0 for the remainder of the study. Increases in catch per unit effort prior to freeze up are likely due to migration, as the sites are not closed. Declines in CPUE after freeze up can be a result of mortality (for closed sites) and mortality combined with net emmigration (for open sites). The difference in the rate of decline of CPUE may indicate which sites are better able to sustain overwintering salmonids.

Of the seven sites sampled in the fall and again in the spring in which fish were captured at some time during the study, two sites show slight increases in catch per unit effort over time. These sites may be open, allowing for a net gain in density during the winter. Site M6 on the Morice River mainstem (Figure 6) and site ML3 on Lamprey Creek exhibit an increase of catch per unit effort from 0 in the beginning of the study to 2 (site ML3 on Feb. 22, 1999) and 3 fish (M6 on March 2, 1999). This increase is slight, and may not be significant. However, the increase in CPUE may show that these two sites are able to sustain an overwintering population of salmonids to ice off in the spring.

Figure 6. Photograph illustrating site M6 in the Morice River, one of the two sites where catch per unit effort appeared to increase between the fall of 1998 and the spring of 1999.

Trends in catch per unit effort are difficult to interpret with large gaps in data. Although some trends can be seen in Figures 2 and 3, the mechanisms operating at each site to cause these trends is difficult to determine. Data collected in January at the sites may help in identifying if catch per unit effort changes are gradual (indicating gradual mortality or migration) or drastic (indicating drastic changes in habitat quality, mortality and migration).

Catch per unit effort at all of the sites falls to 0 by the end of the study. This may be a true indicator of a reduction in density. However, it is more likely that sampling conditions may be less favorable in the early spring, resulting in lower catch efficiency.

Data Requirements

Estimates of density require an estimate of the population size (section 3.1.1.3) and the area or volume of the habitat. Each sample site needs to be clearly marked, and sample sites need to be visited repeatedly at regular intervals (biweekly, monthly). Trapping effort must be sufficient to result in acceptable capture rates, and may need to be adjusted to reflect the size of the area to be sampled (more traps for larger pools). Effort must be consistent between sampling times, or effort must be carefully recorded. Depending on the choice of population size estimators (mark-recapture and/or CPUE, see section 3.1.1.3), a detailed sampling regime should be established. Consideration should be given to repeated application of marks throughout the season to decrease confidence intervals around the estimate.

Benefits of Density Comparisons Over Time

Density comparisons over time may establish which parameters indicate overwintering habitat that can sustain fish throughout the winter, as opposed to habitat which will likely deteriorate in quality and result in death or emigration. Density comparisons over time may also identify approximate carrying capacities for different habitats. An understanding of the carrying capacity of different habitats would help indicate if overwintering habitat is limiting.

3.1.1.3 Methods of estimating densities

Fish densities are generally estimated indirectly, using indices. A mark – recapture estimate (e.g. Peterson, modified Peterson or Schnabel) and/or a measure of density as catch per unit effort can be used to estimate relative densities. The method of choice depends on the number of assumptions that can be met. Mark – recapture estimates have more stringent assumptions than catch per unit effort estimates.

Mark-Recapture Estimates

Mark recapture estimates require that:

- the population is closed (no emigration, immigration, births or deaths)
- marked fish are in every way the same as unmarked fish
- marked fish do not loose their marks
- all marked fish are reported upon re-capture, and
- either the marking or the re-capture sample is random, or that marked and unmarked fish mix randomly (Ricker 1975, Bagenal 1978)

Mark-recapture estimates are more accurate if a larger proportion of the population is marked. This can be achieved by marking a maximum number of fish early in the season, intensive trapping until recaptures are suitable high, and/or continuous marking throughout the winter by applying a series of different marks. It should be noted that mark-recapture estimates will not be valid for open populations, since open populations violate the first assumption of mark-recapture population estimates. Therefore, mark-recapture should only be used in closed systems, or in conjunction with an independent measure of population size that does not require a closed system. Population estimates determined by mark-recapture should include an estimate of standard deviation (Bagenal 1978).

Mark-recapture population estimates are useful approximations of the population size, and can be used to calculate densities. However, applying marks to fish must be done only in cases where there is clear indications for the need of this data. Marking can harm fish, increase mortality, increase stress, and alter a fish's behaviour. However, in some instances, mark-recapture is the method of choice for estimating population size. This method is useful in overwintering studies, where other methods of estimating populations are more difficult or impossible (e.g. depletion methods, total counts). Violations of the assumptions of mark-recapture estimates will influence the accuracy of the estimate, thus it is necessary to establish how severe these violations are. To determine the feasibility of estimating population size by mark-recapture, it is important to determine the minimum number of fish, which need to be tagged. Methods for estimating the minimum number of tagged fish in populations of various sizes are described in the literature (e.g. Ricker 1975, Bagenal 1978). If it is feasible to tag a sufficient number of fish, mark-recapture studies are valuable in estimating densities, biomass (see section 3.1.1.4), and hence, the quality of overwintering habitat.

Catch Per Unit Effort (CPUE) Estimates

Catch per unit effort can be used as an index of population size, as well as to estimate population size. Catch per unit effort is assumed to be directly proportional to population size. Although the absolute population size and catch efficiency is unknown, fluctuations in CPUE can be used to indicate corresponding fluctuations in population size (Murphy and Willis 1996). However, comparisons of CPUE over time are only meaningful if it assumed that catchability of fish is constant over time. This is unlikely with changes in temperature, changes in metabolic rate, and changes in fish activity. In closed systems, the CPUE is assumed to be proportional to the population size present at the time. A series of samples should show a decline in catch. Depletion methods for determining population size and confidence intervals can be utilized in this case (e.g. Leslie method, Moran Zippin method) (Ricker 1975, Bagenal 1978).

Using catch per unit effort in conjunction with mark re-capture may indicate if the population is open or closed. Discrepancies in trends determined from mark-recapture data and catch per unit effort data would indicate an open population, in which assumptions for mark-recapture are clearly violated.

3.1.1.4 Estimating Biomass

Density estimates give an indication of the abundance of fish. However, fish abundance may not be the best indicator of productivity. Biomass estimates the mass of fish produced (grams) per unit area. Biomass is related to density, and can be used as another good indicator of overwintering habitat quality and productivity. Comparisons of biomass over time, and among sites, in conjunction with density comparisons may give a better indication of the value of the habitat. Biomass is estimated as the product of the population size and the mean weight of the fish in the population.

Although biomass and density are related, they may not always show the same trend. Biomass may fluctuate while density remains relatively constant (e.g. fish loose weight or gain weight, but abundance of fish does not change). Biomass may remain constant by fish density may change (e.g. increased mean weight of fish at lower density, decreased mean weight of fish at higher densities). Alternatively, biomass may fluctuate contradictory to density (e.g. density increases while biomass decreases, density decreases while biomass increases), indicating more sever fluctuations in abundance and mean weight.

Most studies estimating productivity use a measure of biomass, usually in conjunction with a measure of density. Biomass is important in allowing comparisons between other systems and other studies on the Morice watershed (e.g. Bustard 1991). Biomass and density can be used to more clearly indicate productivity of sites, and hence, overwintering habitat quality.

3.1.2 Fish Condition Factor

Condition factor is a measure of the "fatness" of the fish (Bagenal 1978). Condition factors are often assumed to be a direct measure of the fish' health. Calculation of condition factors involve a comparison of length to weight. Higher condition is often correlated to abundant food, lower densities, low stress, good growth and forage conditions, and higher survival. Comparisons of condition factors between sites and over time may be useful in identifying sites offering better overwintering habitat.

3.1.2.1 Condition Factor Comparisons Between Sites

Purpose

Condition factors are assumed to be a direct indicator of a fish's health. Presumably, better habitat produces healthier, fatter fish. Comparisons of condition factors between sites may aid in identifying which sites produce healthier fish, and thus offer better overwintering habitat.

Potential Findings

The condition of fish at a site may be lower, similar or greater than that of fish at other sites. If habitat has a direct influence on fish condition, than sites with lower fish condition would be considered of lower quality, while sites with higher condition would be considered of greater quality. Differences in condition factors between sites may indicate differences in habitat quality, crowding, and inter or intraspecific competition.

A lower condition factor may stem from the displacement of lower condition fish to lower quality habitat. Healthier fish are assumed to be better competitors, and defend better quality habitat than less healthy fish. Lower condition may also indicate overcrowding. This would indicate that densities are too high to be supported by the habitat present at the site. Sites with high densities, low condition and similar biomass to other sites are likely overcrowded.

Sites with similar condition factors to other sites may or may not be of similar habitat quality. Comparisons of density and/or biomass in conjunction with condition factor comparisons may identify further differences between overwintering habitat. Sites with similar condition factors may have different densities, resulting in different biomass estimates. Comparisons of density and/or biomass along with comparisons of condition factors will give better indicators of habitat quality and productivity than either comparison in isolation.

Higher condition factors may indicate better forage conditions (e.g. better visibility), better food supply, lower densities and lower stress. Sites with a higher condition factors and low densities may not differ in biomass estimates. Sites with higher condition factors and equal or higher densities likely offer better overwintering habitat than other sites.

Preliminary Findings

The current study did not involve data collection on the weight of fish. No condition factor analysis could therefore be conducted using the preliminary data.

Data Requirements

Condition factor can be a valuable comparison between sites at a given time. Length and weight measurements need to be recorded for individual fish captured of each species at the different sites. The measurements should be conducted in the metric system (e.g. mm for fork length, grams for weight). In combination with density estimates, recording weight for individual fish can also be used to estimate biomass (see section 3.1.1.4).

Benefits of Condition Factor Comparisons Between Sites

It is frequently assumed that healthier fish (i.e. fish with a higher condition factor) exhibit better survival. Identifying habitats that produce or sustain fish exhibiting a higher condition, and which are therefore more likely to survive may aid in identifying the types of overwintering habitat that are most valuable to sustaining various species of salmonids in the Morice watershed.

<u>3.1.2.2 Condition Factor Comparisons Over Time</u>

Purpose

A fish's condition may vary or remain constant over the winter. Decreases in condition over the winter may result from deteriorating habitat (e.g. increased competition, increased stress, decreased food supply). Declines in condition factor over the winter may result in lower survival over the winter and in the spring, and may identify less than optimal overwintering habitat.

Potential Findings

The condition of fish at a site may decrease, remain constant or increase over time. Increases in condition would indicate that the fish increase in "fatness" as the season progresses, while decreases in condition would indicate that the fish become "skinnier" as the season progresses.

Decreases in condition factor over the winter may be attributable to several different scenarios. Better condition fish may emigrate to better habitat, which may be indicated by a decrease in abundance and biomass. A difference in density may be negated if immigration of lower condition fish equals the rate of emigration, but a decrease in biomass should persist in this case. Alternatively, a decrease in condition factor may result from selective mortality of higher condition fish (unlikely if health and survival is directly related to condition). In addition, decrease in condition may result from a deterioration in the habitat quality due to excessive immigration (indicated by increased density), food depletion, competition and stress. To identify the cause of a decrease in condition over time, comparisons of density and/or biomass should also be conducted.

Generally stable condition factors over time may indicate that the population is static (no growth due to low metabolism, proportionate growth of length to weight, consistent stress, consistent food supply in relation to demand, consistent competition). This may occur in closed populations where mortality is independent of condition, and where little growth occurs. Condition may also remain generally stable where immigration and emigration are independent of condition.

Increase in condition factor over the winter can result from disproportionate growth, or movement/mortality depending on fish condition. Significant growth is unlikely to occur in the winter. It is more likely that increases in condition result from selective mortality or movement. Selective mortality of lower condition fish would result in an increase of the mean condition factor, in conjunction with a decrease in density and biomass. Selective immigration of higher condition fish to better habitat would result in an increase in average condition in conjunction with an increase in population size and an increase in biomass. In addition, displacement of lower condition fish from the habitat can result in an increase in condition with a decrease in density and biomass. These factors likely do not operate independently. Comparisons of density and biomass in conjunction with condition over time may aid in identifying the cause of changes in condition factor.

Preliminary Findings

The current study did not involve data collection on the weight of fish. No condition factor analysis could therefore be conducted using preliminary data.

Data Requirements

Condition factor can be a valuable comparison over time. Length and weight measurements need to be recorded for individual fish captured of each species at regular intervals (biweekly, monthly). The measurements should be conducted in the metric system (e.g. ± 1 mm for fork length, ± 0.1 grams for weight). Combined with density estimates, recording weight for individual fish can also be used to estimate biomass (see section 3.1.1.4).

Benefits of Condition Factor Comparisons Over Time

Similar to comparisons of density over time, comparisons of condition factor may indicate overwintering habitat more likely to deteriorate over the winter. In conjunction with density and biomass estimates over time, comparisons of condition factors can be helpful in identifying habitat types that is more likely to produce healthier fish at the end of the winter. This information can be useful in managing overwintering habitat in the Morice watershed if good quality overwintering habitat is limiting.

3.1.2.3 Methods for Estimating Condition

There are several different ways to determine condition. The most common are the Fulton's and allometric condition factors (Ricker 1975). Fulton's condition factor is easier to determine, and is the most commonly used estimator of fish condition. Fulton's condition factor calculation is shown in equation 3.

Equation 3: $K = 100w / l^3$

where: K = Fulton's condition factor
w = weight
l = length

Fulton's condition factor is useful where growth is isometric, and/or if the fish to be compared are of approximately the same length. If growth is allometric, and fish to be compared are of different lengths, the allometric condition factor should be used (Ricker 1975, Bagenal 1978). Ricker (1975) gives a detailed explanation for determining the allometric condition factor by regressing length on weight.

Condition factor data is relatively easy to obtain. Lengths and weights for individual fish need to be recorded, but these measures can also be used for other analysis (e.g. biomass estimates and growth). The preliminary study involved length measurements of all fish. Weight measurements are generally less stressful on the fish than length measurements, and can easily be conducted in the field. Weight measurements are easy to obtain, and in conjunction with length measurements, can yield useful information regarding the quality of overwintering habitat.

3.1.3 FISH SURVIVAL

Survival can be a good indicator of habitat quality, since better habitat should yield better survival. However, good habitat may be overcrowded and unable to support the density of fish present, leading to higher mortality and a consequent underestimate of habitat quality. Comparisons of survival, in conjunction with comparisons of absolute densities may be useful in determining overwintering habitat productivity.

Purpose

Different survival rates between habitats throughout the winter may give an indication of overwintering habitat quality. Survival rates must be considered in conjunction with density, since overcrowding will affect survival.

Potential Findings

Survival may be equal among sites, or it may better at some sites than at others. Equal survival may indicate similar habitat quality, or may be a result of other factors. Sites with different fish densities may exhibit similar survival rates. Higher densities at better quality habitat may have similar survival as lower densities at lower quality habitat. However, higher density and better survival likely indicates better quality habitat. Conversely, lower density and lower survival may indicate lower quality habitat. Lower density and higher survival may not be due to habitat quality, but due to densities being well below carrying capacity, resulting in reduced competition, more abundant food and lower stress.

Monitoring survival during the winter may also identify significant bottlenecks or times of significant mortality. Significant mortality may, for example, result from depleted oxygen just prior to ice off. Times of significant mortalities may aid in the identification of critical characteristics in determining overwintering habitat quality.

Preliminary Findings

Data collected in the current study is not suitable for estimating survival rates. Some of the sites appear to be open to migration (e.g. sites M3 and M6 on the Morice mainstem, and site ML3 on Lamprey Creek). Survival estimates at open sites is much more difficult than at closed sites. In general, density comparisons would be similar to estimates of survival rates for closed sites. Some sites may be closed to migration, and survival estimates at these sites would be feasible.

Data Requirements

Survival is probably the most difficult parameter to estimate. Data required for estimates of survival differ between closed and open populations. For closed population, regular monitoring of density (biweekly, monthly) can give estimates of survival. In conjunction with condition factor data and/or growth data, survival data for closed systems can indicate if mortality is selective. Survival is much more difficult to determine for open populations, and is likely beyond the scope of this study.

Benefits of Survival Comparisons

If good estimates of survival exist, comparisons of survival rates between sites would give a relatively clear indicator of habitat quality. However, it is difficult to estimate survival rates, particularly for open populations. Comparisons of density in conjunction with comparisons in biomass, condition and growth can be used instead of comparing survival.

3.1.4 GROWTH

For the purpose of this report, growth is defined as an increase in length. Length is a better estimator of growth than weight, since length can generally only increase, while weight can increase or decrease. Since an increase in length is established by adding length to the vertebrae, fish cannot reduce their length when conditions become less favorable. However, the rate of growth can reflect the quality of conditions over the winter.

Purpose

Growth rate is dependent on habitat quality, among other factors. If growth is assumed to be directly related to habitat quality, the rate of growth can be used to differentiate between habitats of different quality.

Potential Findings

Due to low water temperatures and consequent low metabolic rates, fork length is unlikely to increase significantly over the winter months. However, some increase may be present. Monitoring changes in fork length over time document an increase, decrease or no change in length at a given site. Each of these findings have different explanations and implications.

An increase in fork length can result from growth, or selective movement/mortality of fish. In a closed population, mean fork length can only increase by growth of the fish, and/or by selective mortality of smaller fish. A decrease in density, and a skewed fork length distribution illustrate selective mortality. An increase in growth is illustrated by no change in density, and by an unchanged fork length distribution pattern. In open populations, and increase in fork length can result from growth (illustrated by no change in fork length distribution between months), selective mortality/emigration (illustrated by decreased density and skewed fork length distribution) and/or selective immigration (illustrated by increased density and skewed fork length distribution). Increases in mean fork length due to death or emigration may not be a result of better habitat quality.

Consistent fork length may indicate a lack of growth, or may stem from the confounding effects of emigration, immigration, mortality and growth. Consistent fork length in a closed population can be attributed to a lack of growth and a lack of size selective mortality. Consistent fork length in an open population may be a result of growth and immigration of smaller fish and emigration of larger fish to more optimal habitat.

Decreases in fork length can be a result of size selective mortality or migration between sites. Decreases in fork length in closed populations can result from the selective mortality of larger fish. This is unlikely, although possible. In open populations, a decrease in fork length can result from the emigration of larger fish to more optimal habitat (decrease in abundance and biomass), and/or immigration of smaller fish, which have been displaced from more optimal habitat (increase in density and potential increase in biomass). Decreases in fork length over time indicate that the population is likely open to migration.

Preliminary Findings

During the preliminary overwintering study, fork length measurements were collected for all fish captured. Fork length data was analysed for all species captured. Since different species respond differently to environmental conditions, species are discussed separately, and in the following order:

1. coho,
2. chinook,
3. rainbow trout,
4. cutthroat trout,
5. Dolly Varden,
6. burbot, and
7. sculpin.

Fork length data for coho is summarized in Table 4 and illustrated in Figure 7. Fork length appears to be relatively consistent over time and between sites. The highest mean fork length was recorded for site M3 (Morice River mainstem). However, the greatest variation in fork length was also recorded for this site. It is possible that two age classes of coho are present at this site. The potential presence of more than one age class of coho at each site increases the complexity of the data. Increased sampling effort, resulting in larger sample size may allow for size frequency analysis to determine the age/size distribution present at each site.

A slight decrease in fork length appears to be present at site M9 towards the end of the sample season. This coincides with a general decrease in catch per unit effort (Figures 2 and 3) and may be due to size selective migration early in the spring.

Overall, the fork length data for coho appears to be similar over time and among sites. Little difference over time is expected, since growth over the winter should be minimal, due to low water temperatures causing low metabolic rates. However, larger size fish may utilize better overwintering habitat due to the their competitive advantage over smaller fish. This does not appear to be the case for the overwintering sites selected for this study. Based on the preliminary data, coho fork length data alone does not appear to be a good predictor of overwintering habitat quality, due to a lack of variability. However, a combination of length and weight data (e.g. condition factor analysis, see section 3.1.2) may show differences between sites and over time.

Table 4. Summary of fork length data for coho during the Morice overwintering study.

Site	Date	Fork Length (cm)			
		N	Range	Mean	SD
M3	Nov. 10, 98	2	7.5-12.5	10	3.536
M3	Dec. 15, 98	4	7.5-9	8.38	0.750
M3	Feb. 24, 99	2	7.5-10.5	9	2.121
M5	Feb. 26, 98	3	7.6-7.6	7.6	1.19×10^{-7}
M9	Mar. 23, 99	1	6.5	6.5	n.a.
M10	Nov. 19, 98	3	8-10	9	1
M10	March 3, 99	2	6-9.5	7.75	2.475
ML1	Nov. 10, 98	3	8.5-9	8.83	0.289

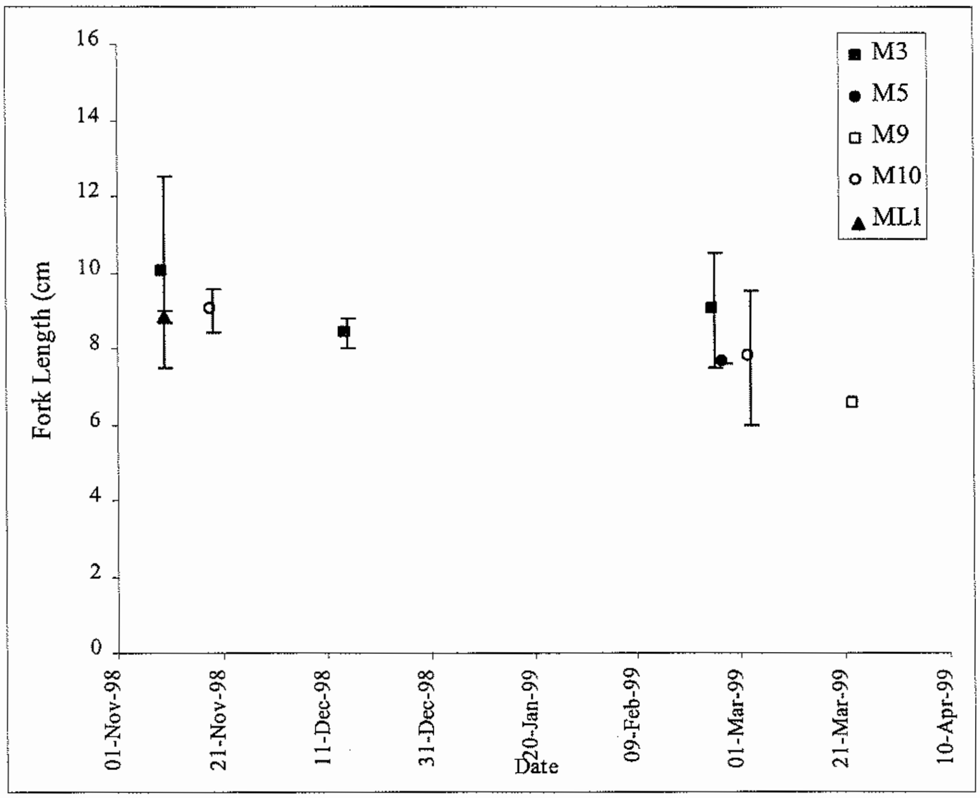

Figure 7. Mean and standard error of fork length for coho captured in the Morice River overwintering study. For details see Table 5.

Few chinook salmon were captured during the overwintering study. The apparent lack of chinook may be due to sample site selection, since chinook may have different overwintering habitat preferences than coho or rainbow trout. Chinook fork length data are summarized in Table 5 and Figure 8. In total, only five chinook were captured among the 21 sites sampled over the winter of 1998/1999 in the Morice watershed. Fork lengths are similar for M10 and ML1 in which chinook were captured in November (see Table 5, Figure 8). Chinook were only captured in one site towards the end of the sampling season (M9 on Mar. 13, 99). The

Table 5. Summary of fork length data for chinook salmon captured during the Morice overwintering study.

Site	Date	Fork Length (cm)			
		N	Range	Mean	SD
M9	Mar. 23, 99	3	9-9	9.0	0.0
M10	Nov. 19, 98	1	13	13	n.a.
ML1	Nov. 10. 98	1	13	13	n.a.

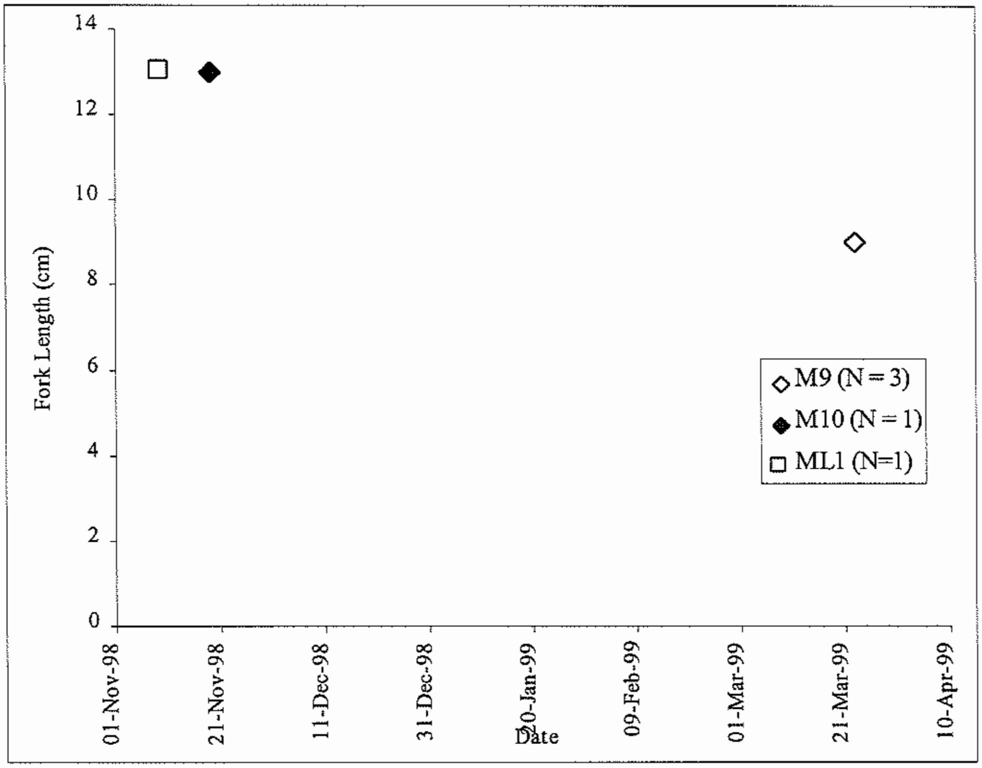

Figure 8. Mean fork length for chinook captured in the Morice River overwintering study. Standard error for all sites was 0 or not applicable. For details see Table 5.

three chinook captured at this site show little variance in fork length, with a mean of 9 cm. This is lower than the fork length for fish captured at sites M10 and ML1 in the late fall (mean = 13 in November). This may be due to larger fish being present at better overwintering habitat (i.e. M10 and ML1), or size selective migration towards the end of the winter as indicated by the general decrease in catch per unit effort (see Figures 2 and 3). Chinook appear to be less abundant at the sample sites than other species of salmonids (e.g. coho and rainbow), and are likely not suitable for an analysis of changes in fork length over time.

Rainbow trout/steelhead was the most common species captured during the Morice River overwintering study. Rainbow trout/steelhead fork length data are summarized in Table 6 and Figure 9. Figure 9 illustrates some differences in fork length among sites. Fork lengths

Table 6. Summary of fork length data for rainbow trout/steelhead captured during the Morice overwintering study.

Site	Date	Fork Length (cm)			
		N	Range	Mean	SD
M3	Nov. 10, 98	2	7.5-17	12.25	6.718
M3	Dec. 15, 98	7	7.5-15	9.81	2.675
M3	Feb. 24, 99	2	7.5-17	12.25	6.718
M5	Feb. 26, 99	5	7.6-14	10.68	3.077
M6	Mar. 3, 99	1	14.5	14.5	n.a.
M9	Mar. 24, 99	1	13	13	n.a.
M10	Nov. 19, 98	1	8	8	n.a.
ML1	Nov. 10, 98	2	12-13	12.5	0.707
ML1	Dec. 1, 98	13	7-13.5	10.65	2.536
ML3	Feb. 18, 99	3	9-13	10.67	2.082

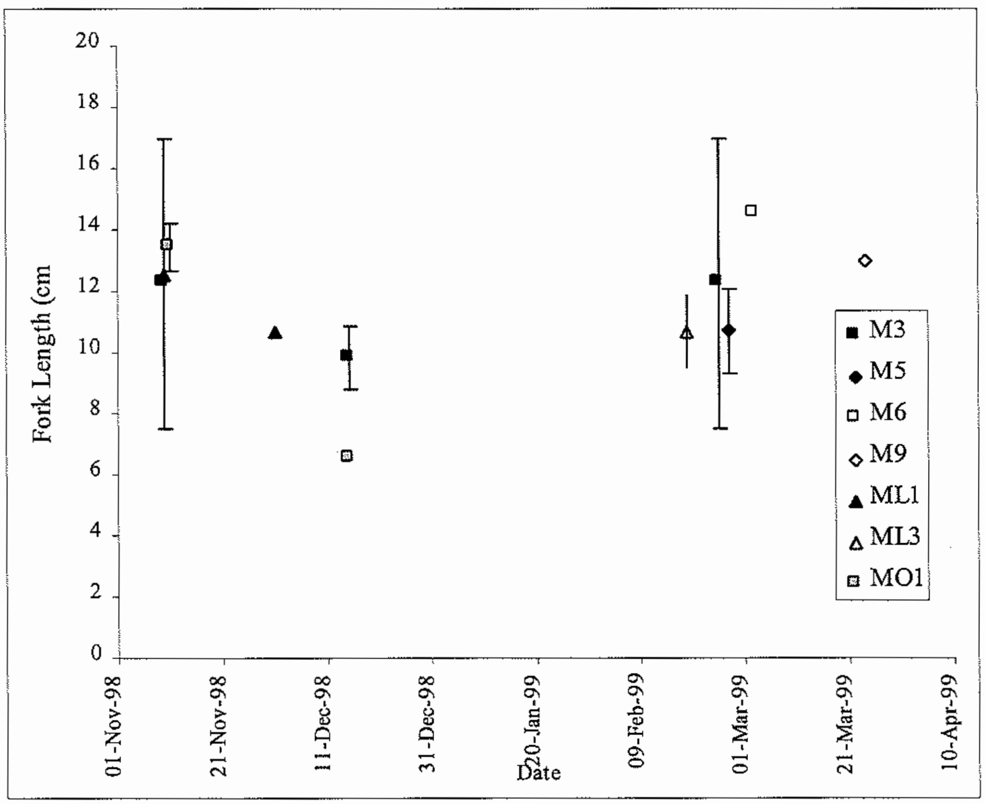

Figure 9. Mean fork length and standard deviation for rainbow trout/steelhead captured in the Morice River overwintering study. For details see Table 6.

generally appear to decrease early in the winter, likely due to size selective migration. Increases in fork length towards the end of the season may be due to migration or growth, as temperatures and metabolic rates increase. Size comparisons of rainbow trout over time may give indications as to which sites are open (decreases in mean length), and which sites offer higher quality overwintering habitat.

Few cutthroat trout were captured during the Morice overwintering study. In total, only four cutthroat trout were identified, all in the McBride drainage, and all on November 30, 1998. The fork lengths between the two sites at which cutthroat trout were captured (MB1 and MB2) are identical (Table 7). Preliminary data indicate that cutthroat trout are not abundant at the overwintering sites sampled, and that length for cutthroat trout is not variable. Comparisons of cutthroat trout fork length between sites and over time will likely not be useful in identifying good quality overwintering habitat, due to low abundance and lack of variability.

Table 7. Summary of fork length data for cutthroat trout captured during the Morice overwintering study.

Site	Date	Fork Length (cm)			
		N	Range	Mean	SD
MB1	Nov. 30, 98	2	14-15	14.5	0.707
MB3	Nov. 30, 98	2	14-15	14.5	0.707

A total of two Dolly Varden were captured, both in sites on the Morice mainstem. Fork length data for these two fish are summarized in Table 8. Fork length of the Dolly Varden captured in March is slightly higher than the Dolly Varden captured in December (20 cm versus 17.5 cm). This may be due to growth over the winter, and particularly towards the end of the winter, size selective migration, or habitat quality differences between the two sites. It is difficult to determine if comparisons of fork lengths data for Dolly Varden will be useful in identifying quality differences between overwintering habitat. However, the apparent low abundance of this species at the sites sampled imply that fork lengths of coho and rainbow trout are likely better indicators of habitat quality.

Table 8. Summary of fork length data for Dolly Varden captured during the Morice overwintering study.

Site	Date	Fork Length (cm)			
		N	Range	Mean	SD
M1	Dec. 15, 98	1	17.5	17.5	n.a.
M6	Mar. 3, 99	1	20	20.0	n.a.

Burbot were captured at only two sites. Since burbot are primarily lacustrine (Scott and Crossman 1973, McPhail 1997), their apparently low abundance in most of the fluvial sites sampled is not surprising. Burbot are known to spawn in streams near lakes or in the mainchannels of rivers in the winter (McPhail 1997). The two sites at which burbot were captured during the overwintering study coincide with expected burbot spawning locations. Site MB3 is located just upstream of McBride Lake, and site M9 is located along the Morice River mainstem. Burbot abundance appears to be relatively low at the sites sampled during the overwintering study, and are likely not suitable for comparisons of fork length over time and among sites.

Table 9. Summary of fork length data for burbot captured during the Morice overwintering study.

Site	Date	Fork Length (cm)			
		N	**Range**	**Mean**	**SD**
M9	Mar. 23, 99	1	12.5	12.5	n.a.
MB3	Feb. 25, 99	1	7	7.0	n.a.

Sculpins were captured at three sites, all along the Morice River mainstem (Sites M4, M6 and M10). Fork length data for sculpin are summarized in Table 10. There appears to be little variability in fork length among the sites. Management of overwintering habitat is primarily concerned with the continued survival of salmonids, but sculpins may have different habitat preferences in the winter. Although sculpins may show differences in fork lengths, coho and rainbow trout/steelhead would be a better indicator of overwintering habitat quality for salmonids.

Table 10. Summary of fork length data for sculpins captured during the Morice overwintering study.

Site	Date	Fork Length (cm)			
		N	**Range**	**Mean**	**SD**
M4	Mar. 4, 99	1	14	14.0	n.a.
M6	Mar. 3, 99	1	9.5	9.5	n.a.
M10	Nov. 19, 98	12	10-15	12	1.651

In summary, rainbow trout and coho are the most abundant salmonids at the sites sampled. Of these two species, rainbow trout appears to show the greatest variability in fork length. Fork lengths comparisons of both of these species may be useful in identifying better quality overwintering habitat, but rainbow trout will likely show greater differences between sites and over time. Chinook and cutthroat trout may also show differences in fork lengths, if sample sizes are sufficiently large. Fork length measurements, in conjunction with weight information is more likely to differentiate between overwintering habitats of different quality than fork lengths alone.

Data Requirements

Comparisons of growth require that fork length be recorded at regular intervals (biweekly, monthly). Sample sizes should be sufficient to allow for statistical comparisons. Comparisons of fork length data are most valuable when used in conjunction with other comparisons (e.g. density, biomass, condition).

Benefits of Growth Rate Comparisons

Better growth is a result of better conditions, of which habitat quality is a main contributor. Growth rates can therefore be a good indicator of habitat quality. However, changes in fork length may not be the result of growth, but may be the result of size selective migration and/or mortality. Comparisons of growth rates in conjunction with changes in density, biomass and/or condition may give good indications for habitat quality.

3.1.5 Species Diversity and Species Richness

Species diversity and species richness are likely not good indicators of overall habitat quality, but may be useful measures in determining preferred habitat dependent on the management objectives. If a multi-species management objective is adopted, high species diversity and species richness would be desirable for overwintering habitat. However, if a single species approach is adopted, the habitat supporting only or mainly the target species may be more desirable.

Purpose

Depending on the management strategy, species richness and species diversity may be desirable. If so, then overwintering habitat with a high species richness and/or species diversity would be more valuable than overwintering habitat with lower species richness and/or species diversity (e.g. habitat supporting only one species).

Potential Findings

Some overwintering habitats are likely to support different species assemblages than others. Differences in species richness and species diversity indicate the variety of fish species present at each habitat. Higher species richness indicates a greater number of species, while higher species diversity indicates a better mix of species. Species richness may be the same for two sites, but species diversity may differ. For example, species diversity will be lower in sites where one species is dominant, compared to sites where species are present at equal strengths.

Species diversity may change over time. Species diversity at a site can be contingent on the intraspecific competitive ability of each species, and on the vulnerability of species to extremes in environmental conditions. A species that is better able to compete may become dominant in more favorable habitat as the season progresses. Species more vulnerable to environmental factors may decrease when the environmental conditions deteriorate.

Preliminary Findings

Species diversity and richness can be calculated for all sites at which species were captured. Sites and sampling periods where no species were captured have a species richness of 0, and no diversity or evenness. The species richness, diversity and evenness is summarized in

Table 11. Species evenness is consistently greater than species diversity, since species evenness adjusts the measure of diversity by the maximum obtainable diversity at the site (see equation 3) (Zar 1984). It is also apparent that there is no consistent relationship between species richness at sites where more than one species was captured, and species diversity or evenness, since diversity and evenness measures the homogeneity of distribution among species.

Table 11. Summary of species richness, diversity and evenness for all sites at which fish were captured during the Morice overwintering study.

Site	Date	Species Richness	Species Diversity	Evenness[1]	Species present[2]
M4	Nov. 9, 98	2	0.301	0.356	2 CO, 2 RB
M4	Dec. 14, 98	3	0.373	0.441	3 CO, 1 DV, 7 RB
M4	Feb. 22, 99	2	0.301	0.356	2 CO, 2 RB
M5	Feb. 25, 99	2	0.287	0.340	3 CO, 5 RB
M6	Mar. 2, 99	3	0.477	0.565	1 RB, 1 DV, 1 CC
M9	Mar. 23, 99	3	0.413	0.488	3 CH, 1 CO, 1 BB
M9	Mar. 24, 99	1	0	0	1 RB
M10	Nov. 19. 98	4	0.384	0.455	12 CC, 3 CO, 1 CH, 1 RB
M10	Mar. 2, 99	1	0	0	2 CO
MB1	Nov. 30, 98	1	0	0	2 CT
MB3	Feb. 25, 99	1	0	0	1 BB
ML1	Nov. 10, 98	3	0.439	0.520	3 CO, 1 RB, 1 CH
ML1	Dec. 1, 98	1	0	0	13 CO
ML3	Feb. 17, 99	1	0	0	3 RB
MO1	Nov. 19, 98	1	0	0	6 RB
MO1	Dec. 14, 98	1	0	0	1RB

[1] Evenness has a maximum value of 1.
[2] Species codes are BB = burbot, CC = sculpin, CH = chinook, CO = coho; CT = cutthroat, DV = Dolly Varden, RB = rainbow trout/steelhead

Although richness, diversity and evenness in themselves do not indicate overwintering habitat quality, Table 11 illustrates that some sites have much greater diversity than others. Of the sites sampled, site M6 on the mainstem Morice had the highest species diversity (H' = 0.477 on Mar. 2, 1999) and the greatest evenness (J' = 0.565). This is due to the fact that the three fish captured represented three different species. Species richness was highest at site M10 on the Morice mainstem, sampled on November 19, 1998, where a total of 4 species were captured.

Species richness and diversity data is useful in identifying the most valuable sites under different management strategies. If management strategies have identified a single species for management, for example coho, one of the more suitable sites for overwintering habitat would be ML1 on Lamprey creek, where 13 coho were captured on December 1, 1998. No other species were captured at this site, indicating low intraspecific competition. However, if management goals are multi – species oriented, other sites may be more suitable. For example, sites M4 and M9 show relatively good diversity and evenness, but overall relatively low abundance of fish. Species richness, diversity and evenness can therefore be good indicators of suitable habitat to meet different management objectives.

Data Requirements

Comparisons of species richness and species diversity require that catch composition is carefully recorded to species for all fish captured. Adequate sampling intensity is required to allow for meaningful comparisons between sites. The Shannon-Index and measures of evenness (or heterogeneity) can be used to compare species diversity (see methods section and Zar 1984).

Benefits of Species Richness and Species Diversity Comparisons

Species richness and species diversity can be used as an indirect indicator of overwintering habitat quality. This is only possible where the competitive ability and vulnerability to environmental factors are known for each species, and where the differences between species are large enough to affect species richness and species diversity. Comparisons of species richness and diversity will aid in identifying sites more suited to achieve different management objectives.

3.2 Factors Determining Overwintering Habitat Quality

Many factors can impact the quality of potential overwintering habitat. The following factors are described in more detail in the following sections:

1. size of overwintering habitat
2. dissolved oxygen,
3. large woody debris and cover,
4. water temperature,
5. stream gradient,
6. discharge,
7. insect presence and diversity,
8. water clarity,
9. water quality,
10. substrate,
11. seasonal accessibility, and
12. proximity to lakes.

This list of potential factors is not exhaustive. Other potential factors may become apparent as the study progresses.

3.2.1 Size of Overwintering Habitat

The size of the overwintering habitat (surface area, volume) can influence the quality of the habitat, since larger overwintering habitat may be able to support a greater density of fish, with greater species diversity and richness. Small pools may freeze solid, or may suffer severe oxygen depletion. Small pools may also not offer the type of habitat diversity suitable for supporting a higher density and variety of fish.

Potential Findings

Density, biomass, condition, growth and species assemblages may all be impacted by the size of the overwintering habitat. All of these factors may be greater, smaller or similar between habitats of different size. Size alone is likely not a good indicator of habitat quality, and is confounded by a variety of other factors. However, it is reasonable to assume that a minimum size is required to support fish throughout the winter. It is important to consider sampling implications for habitats of different sizes. Larger habitat may require a greater sampling intensity by setting a larger number of minnow traps since fish may be less likely to encounter a particular minnow trap in a larger area than in a small pool.

Preliminary Findings

No data on the size of the overwintering habitat sampled was recorded. No analysis for the affect of habitat size could be conducted.

Data Requirement

The surface area and depth of each site should be recorded. For comparisons between sites, and within a site over time, it is important to visit precisely the same site during each sampling period. It is also important to adjust sampling intensity to the size of the pool, particularly if CPUE is to be used to indicate fish abundance.

3.2.2 Dissolved Oxygen

Dissolved oxygen is likely a factor that limits the suitability of several sites for overwintering. Salmonids are sensitive to the concentration of dissolved oxygen in the water. Low oxygen concentrations will result in mortality (e.g. winterkill), and render overwintering habitat unsuitable.

Potential Findings

Trends in oxygen concentrations are relatively predictable in the winter. Oxygen in pools will likely remain relatively unchanged or decrease as the winter progresses. At sites where ice cover is complete, oxygen can only enter the system from upstream. However, oxygen is depleted through respiration and decomposition. Therefore, there is likely a net loss of oxygen at the overwinter site. Oxygen levels are likely to be lowest just prior to ice off.

Low oxygen concentrations can result in increased mortality (lower density, lower biomass, lower survival) and lower condition due to stress. Species richness and diversity may also be impacted since some species may be more susceptible to depleted oxygen levels than others. Monitoring of density, biomass, condition factor and species diversity in conjunction with monitoring oxygen levels may indicate if oxygen levels are limiting habitat quality.

Preliminary Findings

Although oxygen levels were recorded during the study, the oxygen meter gave erroneous results during the majority of the sampling season. The data is not suitable for analysis of the effects of oxygen levels on density, abundance or catch composition. However, the oxygen readings that appeared to be accurate indicated that oxygen levels generally do not drop below critical levels (4-5 ppm). However, the lowest concentration of oxygen recorded (3.6 ppm for site M2 on December 7, 1998) falls below the critical level. Severe production impairment or acute mortality are commonly found at such low concentrations of oxygen (Canadian Council of Ministers of the Environment 1991). No fish were captured at this site. Oxygen is therefore likely a limiting factor at some sites.

Data Requirement

Regular monitoring of oxygen is essential for identifying if oxygen is limiting. At the very least, oxygen should be recorded at the beginning of the winter and just prior to ice off (likely the lowest oxygen levels throughout the winter). Recording oxygen on a regular basis and at consistent sites is essential. If using an auger to penetrate the ice, care must be taken to disturb the water surface as little as possible in order to avoid elevating oxygen levels. Oxygen should be recorded before other activities at the site. Oxygen meters must be calibrated. A LaMotte or Hach Kit can be used in the field to verify results obtained from the Oxygen meter.

3.2.3 Large Woody Debris and Cover

Large woody debris (LWD) and structural diversity of the overwintering habitat increase habitat quality by offering cover and potential food sources/nutrient inputs.

Potential Findings

Larger amounts of woody debris and cover are often correlated with greater density, greater species diversity and better condition of fish. It is expected that a larger amount of woody debris would allow a site to support a greater density (and biomass) of fish than a similar site lacking woody debris. Similarly, fish at sites with greater woody debris levels would be expected to exhibit higher condition, due to reduced competition (visual separation of competitors) reduced stress, and increased food sources. Lowered stress and increased condition can result in better survival and greater biomass. Species diversity may be greater at sites with greater levels of larger woody debris and cover since intra-specific competition is also reduced. Fish densities, condition and biomass may also be higher at sites with LWD since fish in better condition will migrate to better quality habitat (e.g. sites with LWD).

Preliminary Findings

Some large woody debris measurements were recorded for the sites sampled (Table 12). The measurements do not appear to be consistent between sites, making comparisons of the relative availability of LWD cover at different sites difficult. However, based on field notes collected by the Wet'suwet'en Fisheries, some sites appear to be lacking LWD while others offer cover from LWD. In general, fish were more likely to be captured at sites with LWD than sites without LWD (Table 12). Of the seven sites with LWD, fish were captured at five sites (71%), while fish were only captured at four of the 14 sites lacking LWD (29%). This indicates that fish are more likely to be present at sites with LWD.

Table 12. Large organic debris estimates and species captured for sites sampled in the Morice overwintering study.

	Site	Large Organic Debris (LOD) Measurements	Species captured at site throughout study
sites with LWD	M1	10 m by 12 m by 2 m	-
	M3	LOD in side channel (13 m by 4 m by 2 m)	coho, rainbow, Dolly Varden
	M5	pool with submerged log	coho, rainbow
	M8	6 m by 10 m by 2.5 m	-
	M9	18 m by 5 m by 3 m	chinook, coho, burbot
	ML1	8 m by 5 m by 2 m	chinook, coho, rainbow
	MO1	LOD present, no measurements	rainbow
sites without LWD	M2	no Large organic debris	-
	M4	no Large organic debris	-
	M6	alder offers cover	rainbow, Dolly Varden, sculpin
	M7	no Large organic debris	-
	M10	no Large organic debris reported	chinook, coho, rainbow, sculpin
	MB1	no Large organic debris	-
	MB2	no Large organic debris	cutthroat, burbot
	MB3	no Large organic debris	-
	ME1	no Large organic debris	-
	ME2	no Large organic debris	-
	MF1	no LOD offering cover	-
	MG1	no Large organic debris	-
	ML2	no Large organic debris	-
	ML3	no large organic debris noted	rainbow

Since LWD adds to the complexity of habitat, and is generally correlated with fish abundance, a higher capture rate is expected for sites with LWD. The average CPUE of all fish for all sites containing LWD is 1.647 compared to a mean CPUE of 0.651 for sites lacking LWD (Table 13). Variance for the CPUE at sites with LWD and sites without LWD is equal (F=0.616, df = 42, p = 0.069; Table 13). One tailed T-test assuming equal variance indicates that the difference in CPUE for all species combined is not statistically significant (t=-1.444, df – 43, p = 0.076; Table 13). Although CPUE for all species combined does not appear to differ significantly between sites with LWD and sites without LWD, CPUE of salmonids does appear to differ significantly. Catch per unit effort of salmonids averages 1.617 for sites with LWD, compared to 0.349 for sites without LWD (Table 13). Variance of salmonid CPUE is significantly different between sites with LWD and sites without LWD (Table 13). Mean CPUE is significantly lower for sites lacking LWD than sites with LWD (Table 13). It is somewhat surprising that CPUE for all species combined does not differ significantly between sites with LWD and sites without LWD, while catch per unit effort does differ significantly. However, two of the five sites lacking LWD at which fish were captured included the presence of sculpin, while only one of the five sites with LWD included a non-salmonid species (burbot) (Table 12). In addition, no LWD was noted at site M10, but Figure 4 of the site shows that some LWD is present. If site M10 is included in the sites having LWD, CPUE for all species, and for salmonids only differs significantly (Table 13). Although the data collected in this study is preliminary, a significant difference in catch per unit effort between sites with and without LWD indicates that LWD presence is a significant factor in determining overwintering habitat quality.

Data Requirement

Prior to freeze up, the amount and size of large organic debris should be documented for each site using consistent methodologies. This can be repeated at ice off, if there has been a change (unlikely). Other sources of cover should also be reported. The approximate percentage of habitat that has cover should be estimated, and the types of cover (and their contribution) should be documented for each site. In order to compare the affect of LWD on habitat quality, paired sites that are similar in all aspects except the abundance of LWD can be chosen within close proximity of each other. These sites can than be compared using paired t-tests, multivariate statistics or other similar methods.

3.2.4 Water Temperature

Salmonids require a minimum temperature to be maintained. Temperatures below the minimum make some habitats unsuitable for overwintering.

Potential Findings

Low water temperatures may impact the quality of overwintering habitat. Low water temperatures may result in mortality and/or emigration. Metabolic rate is lower in colder temperatures, and this will reduce growth. Temperature can affect the catchability of fish since fish are less active at lower temperatures. If CPUE is used to estimate population size, population size may appear to decrease due to a lower catchability over time.

Table 13. Summary of catch per unit effort information for sites with LWD and sites without LWD sampled during the Morice River Overwintering study.

	sites with LWD			sites without LWD			F-test			t- test			Comments
	Mean	**SD**	**n**	**Mean**	**SD**	**n**	**F**	**df**	**P**	**t**	**df**	**P**	
all species	1.647	3.392	31	0.651	2.662	43	0.616	42	0.069	1.444	43	0.076	site M10 considered to lack LWD
salmonids only	1.617	3.367	34	0.349	0.997	43	0.088	42	1.965×10^{-12}	2.125	38	0.020*	
all species	2.027	4.126	37	0.225	0.733	40	0.032	39	0	2.618	38	0.006*	site M10 considered to have LWD
salmonids only	1.675	3.28	37	0.200	0.657	40	0.025	39	0	2.686	39	0.005*	

* t-tests assumed unequal variance, as indicated by significant differences in variance (F-statistic).

Preliminary Findings

Water temperature was recorded at most sites and sampling times during the preliminary study. Water temperatures are consistently higher at the Habitat Enhancement site (ME 1 and ME 2), however, no fish were captured at these sites. For other sites, CPUE appeared to be somewhat correlated with water temperature (Figure 10). Capture rates dropped significantly at water temperatures (below 0°C). A reduced capture rate at colder temperatures is more likely due to a lack of activity, and resultant lowered capture efficiency, than a preference in overwintering habitat. However, very low water temperatures will affect survival rates of fish. The captured of salmonids at sites M10 and ML3 at temperatures of –2 and –4°C is surprising. These temperature readings may be inaccurate due to mis-calibration of the meter, or errors in reading and recording water temperature. Water temperatures can indicate the lower level of suitable temperatures at overwintering habitat, and can help in adjusting catch per unit effort at temperatures where capture rates are expected to be lower.

Data Requirement

A detailed record of water temperature must be maintained over the winter. Data may be available from nearby temperature data loggers (e.g. Barry Finnegan, DFO, has deployed data loggers in a variety of locations). Condition, growth, density and biomass should be recorded as very low water temperatures may influence these. The estimate of CPUE is reduced due to temperature, a second estimator of fish density and/or population size should also be used.

3.2.5 Stream Gradient

Habitats with some gradients are unsuitable for fish habitat and fish passage (e.g. 21%; ~15% on the Morice watershed). Lower gradient reaches may be passable to fish, but may not offer preferable overwintering habitat. Gradient can affect the location, quantity, and quality of suitable overwintering habitat.

Potential Findings

Gradient, in part, determines ice cover, water velocity, substrate type and channel morphology. Gradient is easy to measure, and is an indirect indicator of water velocity. Some species may be unable to overwinter in systems of certain gradients, while other species may gain a competitive advantage at some gradients. Gradients can therefore affect species diversity and richness.

Higher gradient reaches exhibit faster water currents and may freeze later in the year than lower gradient reaches (e.g. wetlands). Gradient may determine the duration of ice cover, which may effect habitat quality (see oxygen, section 3.2.2). Also, high gradient systems require a greater expenditure of energy on the part of the fish to maintain position in the water. During the winter, where metabolic rates and food supplies, and energy reserves are low, extra energy expenditures may decrease condition and increase mortality.

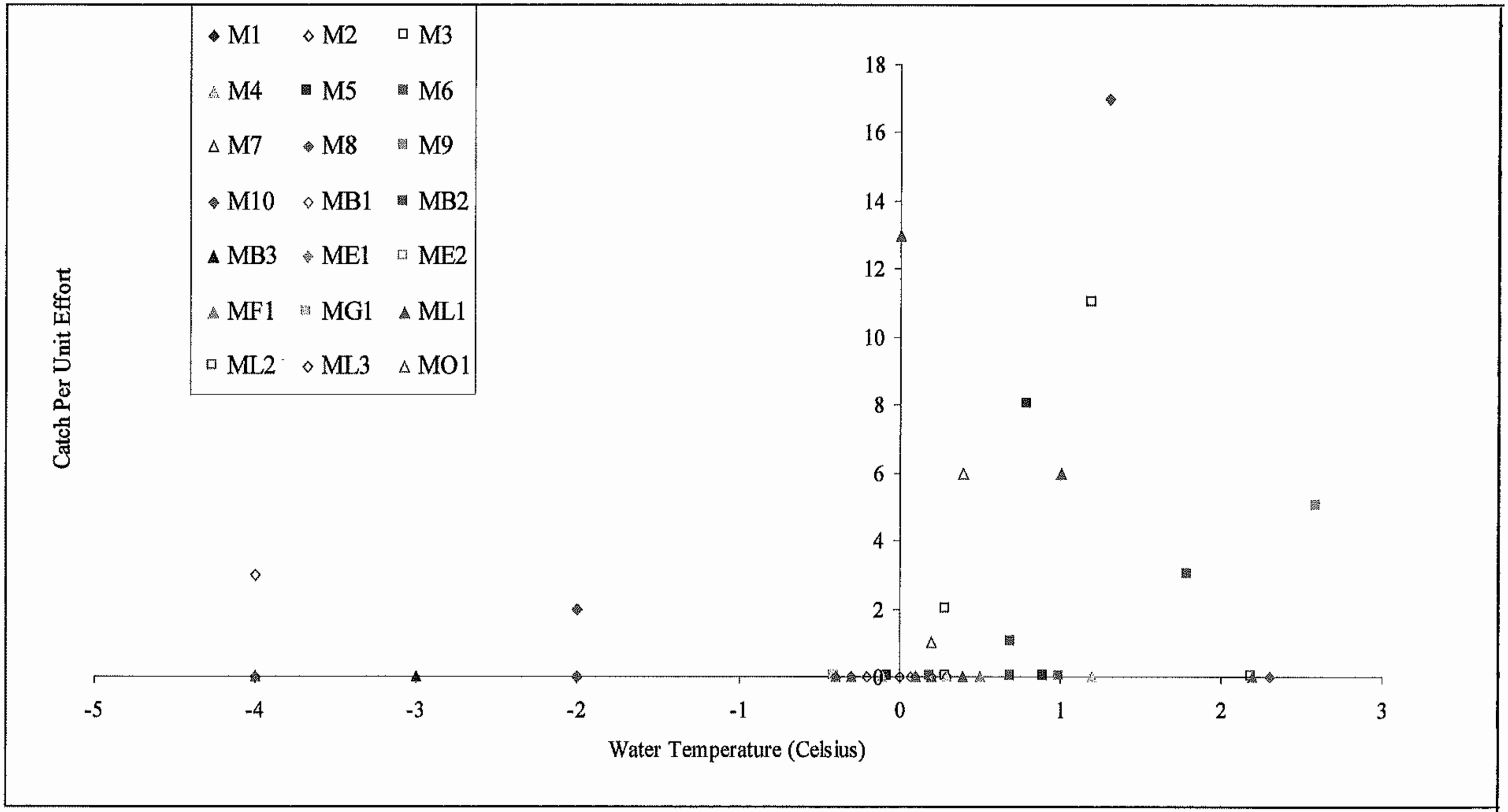

Figure 10. Catch per unit effort (all species) and temperature for the 21 sites sampled during the Morice River Overwintering Study.

Preliminary Findings

Gradient was not recorded in the preliminary study, and the data is unsuitable for an analysis of gradient as a factor determining overwintering habitat quality. Gradients may not differ significantly among sites, since all sites are located within the Morice River valley flats, or low gradient areas associated with larger tributaries (e.g. ML3 on Lamprey Creek).

Data Requirement

Gradient is easily measured at each site using an Abney level and/or clinometer. Gradient influences several factors which may determine overwintering habitat quality, including water velocity, access, substrate types and size, pool frequency and size, duration of ice cover and dissolved oxygen levels. Gradient can be measured for each site at the beginning of the sampling season. It is also useful to note the type of habitat sampled (e.g. step-pool, cascade-pool, pool, riffle, run, glide, wetland).

Water velocity can be measured periodically to evaluate seasonal differences in flow, but does not need to be measured at all sampling times. It would be useful to measure water velocities at all sample sites at a similar time of year (e.g. November, February and March/April) to allow for comparisons among sites.

3.2.6 Discharge

Discharge is dependent on the size of the stream and water velocity, which is partly dependent on gradient. Discharge may affect overwintering habitat quality as a combination of the affects of habitat size (section 3.2.1) and gradient (section 3.2.2).

Potential Findings

Since discharge is a complex measure, combines several factors that may affect overwintering habitat quality independently, it is difficult to identify how discharge may affect overwintering habitat quality. High discharge may be due to high water velocity in a relatively small system (implying low overwintering habitat quality) or low water velocity in a large area (implying more benign overwintering habitat).

Preliminary Findings

Discharge was evaluated at some of the sites during some of the sampling times. Discharge was measured periodically at 11 of the 21 sites sampled, but could not be recorded during all sampling intervals due to a lack of current meters for both crews. Discharge was not recorded for pools, and discharge data is therefore biased. Catch per unit effort is plotted against mean discharge in Figure 11. Catch per unit effort is highest at site M10, with a mean discharge of 2.4 m^3/sec. Most of the remaining fish were captured at discharge readings below 1 m^3/sec. High discharge at site M10 may stem from faster water flow, or greater area of habitat. Larger overwintering habitat may increase densities and species diversity (see section 3.2.1). Higher water velocity may be less advantageous to some

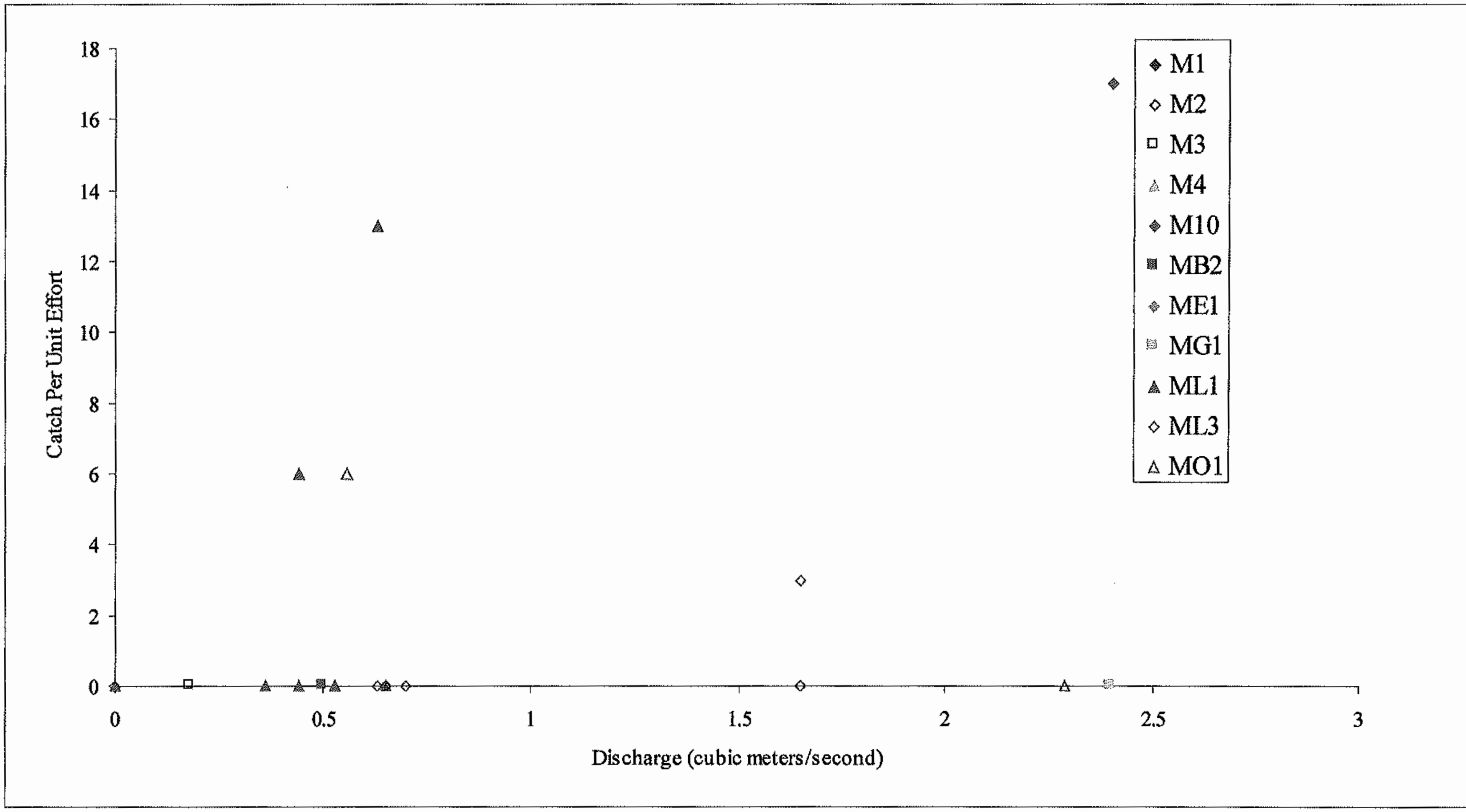

Figure 11. Catch per unit effort of all species and average discharge at the time of sampling for the 11 sites at which velocity was measured.

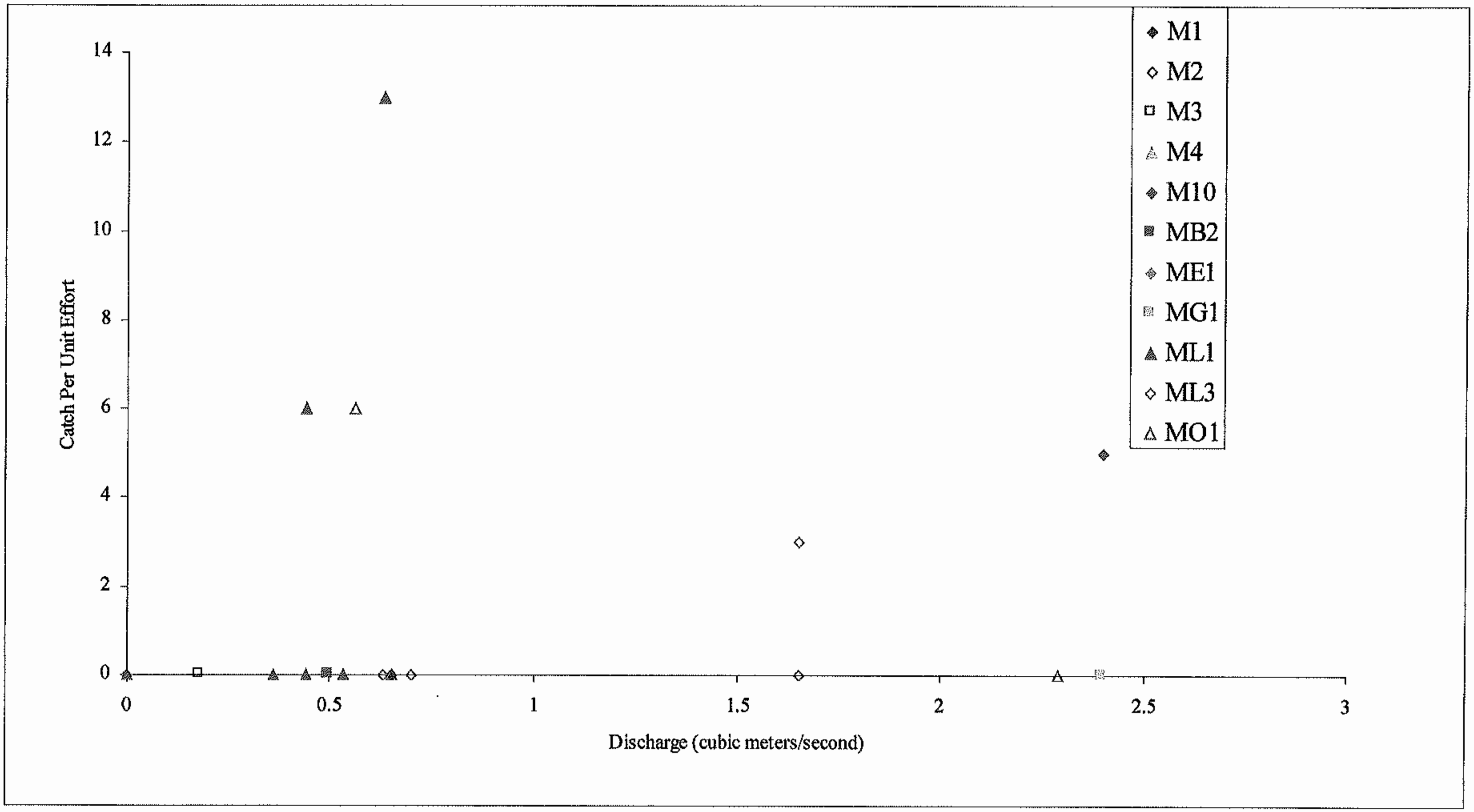

Figure 12. Catch per unit effort of salmonids and average discharge at the time of sampling for the 11 sites at which velocity was measured.

species, but give other species a competitive advantage. Catch per unit effort at site M10 is high despite discharge due to the presence of sculpins (12 sculpin of a total of 17 fish captured). Sculpin are commonly found in faster flowing water. Once non-salmonids are removed from the analysis of catch per unit effort versus velocity (Figure 12), it is clear that catch per unit effort is higher at discharges less than 1 m^3/sec.

Preliminary data show that discharge appears to affect catch per unit effort. Capture rates may be higher at lower discharge due to habitat preference. Very high water velocities (and consequently higher discharge) will reduce capture efficiency, and may underestimate the actual density of fish at the site. Differences in CPUE at sites exhibiting different discharges indicate that water velocity, and/or habitat size may be a factor determining overwintering habitat quality.

Data Requirement

Discharge is derived by measuring average water flow along a transect (using a flow meter) and a measure of the cross sectional area at the transect where flow is measured. Surface flow differs from water velocity in the middle of the column, and adjustments can be made if flow is measured at or near the water surface. These adjustments require that substrate composition is recorded.

Since both size of the overwintering habitat and velocity have been identified as potential factors affecting overwintering habitat quality, it would be beneficial to record cross sectional area, surface area and water velocity. Discharge requires that cross sectional area and water velocity be determined, but confounds the potentially conflicting affects of these two parameters.

3.2.7 Insect Presence and Diversity

Juvenile salmonids primarily prey on insects. The presence of insects suitable for juvenile salmonids is in indicator of food availability, an important influence on the condition and survival of the fish. Also, insect diversity can be an excellent indicator of water quality.

Potential Findings

Insect density and diversity may differ between sites and/or over time. A higher abundance of insects indicate a greater availability of food, and may result in increased density, increased biomass, increased growth and/or increased condition.

Insect diversity and species types are a measure of water quality. Some insect classes are more susceptible to less than pristine conditions than others. Species assemblages may be a direct indicator of water quality, which is an important constituent of overwintering habitat quality.

Preliminary Findings

No insect data was collected for any of the sites examined during the preliminary overwintering study.

Data Requirement

Insect densities and species composition are required for this analysis. Regular evaluation of insect abundance and species composition on a biweekly or monthly basis would be valuable. Insect diversity and abundance can be correlated to water quality information and predation levels. In addition, data collected on fish species diversity and richness, fish condition, density and biomass are valuable in establishing if insect diversity and abundance is a good indicator of overwintering habitat quality.

3.2.8 WATER CLARITY

Salmonids are visual predators. Low water clarity (primarily in late fall and in early to late spring) can reduce feeding efficiency and result in lower condition. Severe turbidity can injure fish. Water clarity is of greater concern in the spring than winter. Water clarity is probably not a good indicator of overwintering habitat quality, but may indicate the quality of the habitat in early spring.

Potential Findings

Water clarity may be reduced in the fall and after ice off until summer low flows. Over the winter, water clarity will remain relatively constant. Reduced water clarity in the spring may result in emigration of fish (lower density, lower biomass), increased stress resulting in lower condition, and decrease species diversity (some species may be able to tolerate higher turbidity than others). Conversely, relatively clear water during spring run off may result in increased fish density and biomass as fish access sites for refuge from more turbid waters. This is often the case for mainstem fish using tributary sites and side channel areas for refuge areas during spring high flows.

Preliminary Findings

No data on water clarity was collected during the preliminary overwintering study.

Data Requirement

Water clarity should be collected in the fall, prior to freeze up, and again in the spring, after ice off. Water clarity should be recorded on a regular basis at these times, and may also be recorded during high discharge events. Water clarity can be measured as visibility (measured with a meter stick) or suspended solids (TSS or NFR).

3.2.9 Water Quality

Water quality can determine the suitability of overwinter habitat. Nutrient levels (nitrogen and phosphorus) can be a measure of productivity and/or indicate if the system is relatively pristine. Salmonids have lethal levels for pH (both on the acidic and basic end of the scale), metals, chloride and other chemicals.

Potential Findings

Water quality approaching lethal limits for salmonids will increase stress and reduce condition as well as survival of fish. Overwintering habitat quality will be reduced by less than optimal water quality measurements, and may result in emigration to more suitable habitat. Low water quality may result in decreased density, biomass and condition.

Preliminary Findings

Water quality was measured at ten sites at the beginning of the preliminary overwintering habitat study, and near the end of the study. Water quality data are summarized in Table 14.

Table 14. Water quality measurements at ten sites sampled during the Morice River Overwintering study.

Site	late October / early November 1998				March 1999			
	pH	NO_3-N (mg/L)	$CaCO_3$ (mg/L)	Cl^- (mg/L)	pH	NO_3-N (mg/L)	$CaCO_3$ (mg/L)	Cl^- (mg/L)
M3	7	<.05	24	8	7	<0.5	24	8
M6	7	<.05	30	8	7	<.05	30	8
M10	6.5	<.05	28	8	6.5	<.05	28	8
MB1	7	<.05	28	8	7	<.05	28	8
ME1	6.5-7	<.05	28	8	6.5-7	<.05	28	8
MF1	7	<.05	60	4	7	<.05	60	4
MG1	6.5	<.05	40	12-16	6.5	<.05	40	12-16
ML1	6.5	<.05	28	8	6.5	<.05	28	8
ML3	6-7	<.05	28	8	6.7	<.05	28	8
MO1	7	<.05	68	12	7	<.05	68	12

The sites sampled for water quality exhibit pH readings within the normal range, near a pH of 7. Waters appear to be slightly acidic to neutral, with pH readings varying between 6 and 7. However, pH readings recorded in the field indicate that waters are slightly basic, ranging in pH between 7.3 and 7.64 (Appendix 1). Generally, pH readings taken in the field are more accurate since water samples are unstable, and pH will deteriorate over time. A consistent difference in pH is therefore not surprising, and points to the need for calibrating field meters daily, as well as processing water samples quickly in the laboratory.

Nitrate levels for all sample sites were below the detection limit of the LaMotte kit used in the fall and spring samples. No national limits for nitrate concentrations have been set for aquatic life, but limits of ammonia (NH_3) have been determined. This is due to the fact that un-ionized ammonia has toxic effects. No numerical guidelines for nitrate are given since elevated nitrate does not have harmful effects other than prolific weed growth (Canadian Council of Ministers of the Environment 1991). Ammonia and/or nitrite may be better indicators of water quality than nitrate. However, the low levels of nitrate indicate that nitrogen in organic or inorganic form is likely low at the sites sampled.

Calcium carbonate ($CaCO_3$) is a measure of water hardness, and a good indicator of the alkalinity of the water. The concentration of calcium carbonate indicates the buffering ability of the water. Concentrations of calcium carbonate below 24 mg/L indicate a low buffering ability (Canadian Council of Ministers of the Environment 1991). Moderate concentrations of calcium carbonate, as those present at sites sampled in the overwintering study, indicate a moderate buffering ability of the water.

Chloride concentrations are generally low, ranging between 0.1 and 27 ppm for the Pacific region (Canadian Council of Ministers of the Environment 1991). Chloride concentrations reported for the sites sampled in the Morice watershed fall within the range normally found in the area, indicating good water quality.

In general, water quality appears to be representative of pristine environments in the Pacific region. None of the water quality parameters evaluated approached restrictive or lethal levels. Levels of pH, calcium carbonate, nitrate or chloride do not appear to be restricting overwintering habitat quality. The low variation in the water quality parameters evaluated in among the sites examined indicate that water quality is not a critical factor in overwintering habitat quality.

Data Requirement

A routine water sample should be analysed for some systems to indicate which parameters should be monitored more closely. Some drainages may require monitoring of metals, while others may be susceptible to increases in other parameters. In addition to oxygen and water temperature, routine parameters (e.g. pH, nitrogen, phosphorous, calcium carbonate, conductivity) should be monitored. Water quality should be monitored at least three times, just prior to freeze up, just prior to ice off, and during periods of high run off.

3.2.10 SUBSTRATE

Substrate type can restrict the type of species expected to overwinter in a habitat. For example fine substrate may not be suitable for some species (e.g. Dolly Varden). Substrate is correlated with gradient.

Potential Findings

Species diversity and richness is likely affected by substrate type. Insect presence and diversity will also be affected by substrate type.

Preliminary Findings

Substrate data collected in the study consisted of a list of substrate types present. The substrate types for each site are summarized in Table 14. Substrates are not listed in order of dominance, however, and no indication of percent substrate composition or particle size (e.g. D_{90}, D_{50}) was recorded. There appears to be no clear trend in substrate type and species absence or presence. However, substrate consisting of smaller particles (e.g. fines and small gravels) appear to have lower capture success than sites with larger substrate types. Not surprisingly, the two sites where Dolly Varden were captured included larger particles (i.e. small cobbles) in the substrate. Substrate preferences is species specific. Differences in overwintering habitat suitability may be apparent once the collection of substrate data has been refined and standardized, and if sample sites representing diverse substrate types are included (e.g. fines only etc.).

Table 14. Substrate recorded for each of the sites sampled in the Morice River Overwintering study.

	Site	Substrate	Species Captured
sites where no fish were captured	M1	fines, small gravels	none
	M2	fines, small gravels	none
	M4	fines, small gravels	none
	M7	fines, small gravels	none
	M8	small gravels, small cobbles	none
	MB1	fines, small gravels	none
	MB3	fines, gravels	none
	ME1	fines, gravels	none
	ME2	fines, gravels	none
	MF1	small gravels, large gravels, cobbles	none
	MG1	fines, gravels, small cobbles	none
	ML2	not recorded	none
sites where fish were captured	M3	small gravels, small cobbles	coho, rainbow, Dolly Varden
	M5	fines, gravels, small cobbles	coho, rainbow
	M6	large gravels, large cobbles	rainbow, Dolly Varden, sculpin
	M9	gravels, small cobbles	chinook, coho, burbot
	M10	large gravels, cobbles	chinook, coho, rainbow, burbot
	MB2	fines, large gravels	cutthroat trout, burbot
	ML1	fines, small gravels	chinook, coho, rainbow
	ML3	fines, small gravels	rainbow
	MO1	fines, small gravels, small cobbles	rainbow

Data Requirement

Substrate should be recorded at the beginning of the field program. Substrate composition should be indicated in order of dominance (i.e. list dominant substrate first), or percent composition should be indicated. Measures of D_{90} and/or D_{50} would also be helpful in describing substrate type. Species diversity and richness should be evaluated in conjunction with substrate type.

3.2.11 Seasonal Accessibility

Seasonal access for juvenile fish may determine if habitat is utilized for overwintering. Some habitat may be suitable for overwintering, but may not be accessible to fish at certain times of year, and may thus be unutilized.

Potential Findings

Some habitat, which appears to be suitable for overwintering, may not be utilized or may appear to be under utilized. In such cases, barriers, which may be present, may restrict seasonal access to the habitat. Beaver dams, low flow, intermittent and/or ephemeral channels, or permanent barriers to fish migration may render suitable fish habitat unavailable to fish.

Preliminary Findings

No data exists on the presence of seasonal or potential barriers for the sites examined during the preliminary overwintering study.

Data Requirement

The presence of all temporary and potential barriers, as well as permanent barriers should be documented in the system.

3.2.11 Proximity to Lakes

Proximity to lakes can partly determine water quality (for lakes located upstream of the overwintering habitat). Proximity to lakes can also affect fish density and species composition depending on the species preference for lakes as overwintering habitat.

Potential Findings

Lakes act as moderators (temperature, turbidity, and chemical disturbances). The presence of lakes may be correlated with water quality and turbidity measurements. The presence of proximate lakes upstream of the site may be correlated with moderated temperatures (i.e. less severe fluctuations in temperature), less severe increases in turbidity, and moderated chemical disturbances. In turn, this would moderate the affects these factors have on fish condition, density, biomass and species diversity and richness.

Some species may prefer lake habitat for overwintering (e.g. coho) and may move to lakes near the chosen sample site for overwintering. Other species may not be affected in the same way (e.g. Dolly Varden). The proximity to lakes may reduce density (e.g. for coho) and may affect species richness and species composition.

Preliminary Findings

Three of the 21 sites sampled were located near a lake. All of these sites were found in the McBride system, with site MB1 located just upstream of Morice Lake, site MB2 just downstream of McBride Lake and site MB 3 just upstream of McBride Lake (Figure 1). Of these three sites, fish were only captured in site MB2, just downstream of McBride Lake (Table 14). Both of the species captured at this site (cutthroat trout and burbot) are closely tied to lakes, and exhibit a lacustrine-adfluvial life history. Other species may not have been captured at the sites during the overwintering study because they may prefer overwintering habitat offered by the lakes over that offered in the streams. Proximity to lakes should be an important consideration in the selection of sites used to determine factors affecting overwintering habitat quality.

Data Requirement

Distance to the nearest upstream and/or downstream lake should be recorded. Upstream and downstream lakes need to be distinguished between as only upstream lakes can influence water quality at the site.

4.0 Recommendations

Recommendations for study design and data analysis are presented throughout the report. Recommendations affecting future studies of this type in the Morice watershed are contingent on refinement of study objectives. However, some general recommendations for future studies can be made, based on the results of the preliminary study summarized in this report.

1. Determining factors influencing overwintering habitat quality is a large project that is difficult to plan and execute effectively. Studies with vague hypotheses have a potential to become large, and un-managable. It is important to decide on which parameters are most likely to yield tangible data, and prioritize factors to be assessed prior to collecting data in upcoming studies of this type. A planning meeting, involving representatives of different agencies can be invaluable in identifying potential parameters which likely affect overwintering habitat quality. This meeting can also be used to determine suitable methods for measuring these parameters, and identifying feasible study design that will allow for comparisons within this study, and between similar studies (e.g. upper Bulkley River Overwintering study). Representatives of the following agencies, among others, should be included in a planning meeting to aid in the refinement of study objectives:
    - Wet'suwet'en Fisheries
    - Department of Fisheries and Oceans
    - B.C. Environment (fisheries and environmental protection branch)
    - knowledgeable consultants, guides, long time residents of the area
    - local stakeholders (if interested)
    - groups conducting similar studies in other areas, particularly nearby.

2. Field data collection can be the most expensive and time consuming aspect of a study of this type. Especially for temporal comparisons, consistency in data collection is essential. Compiling a complete data collection form and training session prior to the commencement of an overwintering study will aid in the generation of a complete data set over the entire winter. Crews should be trained in data collection, completing data forms, loading data into spreadsheets, and calibrating equipment. Data need to be confirmed and finalized as soon as possible after collection to ensure that data are complete and accurate. It may be beneficial to have crews check each other's data, and also have the project leader spot check data on a regular (e.g. monthly basis). Calibrating equipment is essential in ensuring that data are accurate, and the field meters are operating properly. Back up meters or kits for water quality should be available to the crews.

3. Sampling intensity in the preliminary study was insufficient to show many differences among sites. Trapping intensity should be increased to increase capture rates of fish.

4. Sample sites need to be clearly marked and consistent over time. Deviations in sample site location necessitate a new site number, and a new set of baseline data. Determining temporal variations in habitat quality and utilization depends on consistency in sampling methodology and site location.

5. Although the preliminary study has striven to collect a maximum amount of data, the lack of sampling in January (no sampling between December 16, 1998 and February 15, 1999) increased difficulties in data interpretation. Sampling should occur at regular, predetermined intervals. Large gaps in data collection will reduce the effectiveness of the study.

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Appendix 1. Habitat Data For Sample Sites Examined During The Preliminary Morice River Overwintering Habitat Study.

MORICE RIVER
OVERWINTERING HABITAT 1998/99

Date	Air temp. C^0	Crew	Time	Site	Location	Substrate	Snow pack (cm)	Ice (cm)	Ice cover (cm)	H2O (cm)	H2O temp C0	O2 (% sat.)	O2 mg/l	Velocity (m/s)	Avg. (m/s)	Max (m/s)	Frame #	pH
05-Nov-98		RA,EC,BM	13:57	M1	26 huck	fns,smgv			free flow	100	6.4	162	19.1		0.65	1.5	8	
06-Nov-98		RA,EC,BM	14:27	M1	26 huck	fns,smgv			anchor		6.2	229	26.2		0.93	1.9	14-15	
10-Mar-99	sun/clouds	RA,Bm	14:00	M1	26 huck	fns,smgv											14	7.44
11-Mar-99		RA,BM	14:00	M1	26 huck	fns,smgv											12,13	7.43

MORICE RIVER
OVERWINTERING HABITAT 1998/99

Date	Air temp. C^0	Crew	Time	Site	Location	Substrate	Snow pack (cm	Ice (cm)	Ice cover cm	H_2O (cm)	H_2O temp C^0	% sat.	O_2 mg/l	Velocity	Avg	Max	Frame #	pH
07-Dec-98	-5	GB,GG	14:00	M2	Morice River at 33km	sm grv,fines	7.62	10.16		109	0.3	31	3.6	0			19-24	
17-Feb-99		RA,BM	14:25	M2	Morice River at 33km	sm grv,fines	23	48	9	137	0.2	119	15.7	0	0	0		
18-Feb-99	-6	RA,BM	14:20	M2		sm grv,fines	4 on ice		4	137								
19-Feb-99		RA,BM	13:20	M2	Morice River at 33km	sm grv,fines	45			137	0.9	142	18	0	0	0		7.3
19-Feb-99		RA,BM	13:40	M2	75m ds of 33km	sm grv,fines				3.5	1.3	142	18.1					
19-Feb-99		RA,BM	13:50	M2	110 m ds of 33km	Grvl,fines				50	1.1	130	16.7					

Date	Air temp. C	Crew	Time	Site	Locatio	Substrate	Snow pack (cm	Ice (cm)	Ice cover c	H_2O (cm)	H_2O temp C	% sat.	O_2 mg/	Velocit	Avg	Max	Frame #	pH	
05-Nov-98		RA,EC,BM	14:32	M3	35	sm grv,sm cob			free	300	6.3	167	18.6		0.18	0.2		see debris dimensions below'	
06-Nov-98		RA,EC,BM		M3	35	sm grv,sm cob			anchor		6.2	209	24.1		0.93	1.9	14,15		
10-Nov-98	5	RA,EC,BM	14:36	M3	35	sm grv,sm cob				80	4.2	178	22					spawning CO present	
09-Nov-98	4.5	EC,GB	12:34	M3	35	sm grv,sm cob	0	0	anchor	300	5	209	24.3				1-3,4-9		
14-Dec-98	-6	GB,BM	13:08	M3	35	sm grv,sm cob	18		anchor	150	1.2	144	16					side channel dry, traps set in debris area	
15-Dec-98	-4	GB,BM	13:26	M3	35	sm grv,sm cob	8.5		anchor	150	1.8	125	14.4						
22-Feb-99	0	RA,BM	13:34	M3	35	sm grv,sm cob	60	15		150	0.3	162	23.7				3 photos take	7.49	
24-Feb-99		RA,BM	13:37	M3	35	sm grv,sm cob	60	15		150	0.7	180	24				video	7.44	
22-Feb-99	0	RA,BM	12:04	M3	35	Cob,fines	60	15		150	0.3	162	24				3	7.5	
24-Feb-99	-2	RA,BM	13:37	M3	35	Cob,fines				150	0.7	180	24					7.44	
05-Nov-98	debris:																		
	width	height	length		site #														
	24 m	12 m	80 m		2														
	12 m	2.3 m	35 m		02B														

MORICE RIVER
OVERWINTERING HABITAT 1998-1999

Date	Air temp. C^0	Crew	Time	Site	Location	Substrate	Snow pack (cm)	Ice (cm)	Ice cover cm	H_2O (cm)	H_2O temp C^0	% sat.	O_2 mg/l	Velocity	Avg	Max	Frame #	pH			
03-Mar-99	-1	WN,GB	14:59	M4	37.5	smgv,fns	43		1.27	60.96	0.3	88	11.8								
04-Mar-99	-1	WN,GB		M4	37.5	smgv,fns	35.6		1.27	60.96	0.2	115	16.6								
18-Mar-99	-1	GB,WN		M4	37.5	smgv,fns	60.96		0.3	152	1.2	104	13.4					CWD 65 cm diameter log in eddy			
19-Mar-99	-1	SS,GB	11:21	M4	37.5	smgv,fns	60.96		1	152	0.5	71	9.3								

MORICE RIVER
OVERWINTERING HABITAT 1998/1999

Date	Air temp. C^0	Crew	Time	Site	Location	Substrate	Snow pack (c	Ice (cm)	Ice cover	H_2O (cm)	H_2O temp	% sat.	O_2 mg/l	Velocity	Avg	Max	Frame #	pH
25-Feb-99	-1	WN,GB		M5	38	grv,fns,smcb	24.8		1.27	118.11	0.8	101	13.2					
26-Feb-99	0	WN,GB	10:44	M5	38	grv,fns,smcb	25.4	38	1.9	66.04	0.5	92	12.1				cam malf	
12-Mar-99	4	BM,GB	14:00	M5	38	grv,fns,smcb	33	40		109	1.5	65	8.4					
11-Mar-99	1	GB,WN	13:35	M5	38	grv,fns,smcb	33	40	1.27	109	0.9	92	12.1				21	
12-Mar-99		GB,WN	14:25	M5	38	grv,fns,smcb	22.86 on ice		7.65	50.8	-0.06		48	4.8				

MORICE RIVER
OVERWINTERING HABITAT 1998/99

Date	Air temp. C^0	Crew	Time	Site	Location	Substrate	Snow pack (cm)	Ice (cm)	Ice cover cm	H_2O (cm)	H_2O temp C^0	% sat.	O_2 mg/l	Velocity:	Avg	Max	Frame #	pH
19-Nov-98	-3	RA,BM		M6	45	lgcb,lggv	6.5	anchor	1	48	6.3	50	5.5				video	
02-Mar-99	-4	RA,BM	14:15	M6	45	lgcb,lggv	70			53	1.8	malfunc						7.47
03-Mar-99		RA,BM		M6	45	lgcb,lggv	70			48	0.9							7.45
17-Mar-99	-9	BM,DT	10:26	M6	45	lgcb,lggv	74	anchor	free	48	0.2	88	11.6					7.37
18-Mar-99	0.7	BM,DT	11:04	M6	45	lgcb,lggv	74	anchor	free	48	0.7	96	12.6					

MORICE RIVER
OVERWINTERING HABITAT
1998/1999

Date	Air temp. C	Crew	Time	Site	Location	Substrate	Snow pack (cm	Ice (cm)	Ice cover c	H_2O (cm)	H_2O temp C	% sat.	O_2 mg/l	Velocity	Avg	Max	Frame #	pH
19/11/98	oc -3	RA,BM,GB,EC		M7	45.5 km	fns,smgvl		sheet	1	48	6.3	50	5.5	pool			video	

MORICE RIVER
OVERWINTERING HABITAT 1998/99

Date	Air temp. C^0	Crew	Time	Site	Location	Substrate	Snow pack (c	Ice (cm)	Ice cover cm	H_2O (cm)	H_2O temp C	% sat.	O_2 mg/l	Velocity:	Avg	Max	Frame #	pH
23/03/9	2	RA BM		M8	51.5 mwes	sm grv,sm cb	80	free flow		170	2.3	100	12.6					
23/03/9	3.5	RA,BM	14:11	M8	51 mwest	fns,sm grv				60							24	

MORICE RIVER
OVERWINTERING HABITAT 1998/99

Date	Air temp. C^0	Crew	Time	Site	Location	Substrate	Snow pack (cm	Ice (cm)	Ice cover c	H_2O (cm	H_2O temp C	% sat.	O_2 mg/l	Velocity	Avg	Max	Frame #	pH
22/03/99	6	RA,BM	10:20	M9	52km mwest	smcb,grvs	75	free flow		100	2.6	101	12.5					
23/03/99	4	RA,BM	11:27	M9	52km mwest	smcb,grvs	75	free flow		100								

MORICE RIVER
OVERWINTERING HABITAT 1998/99

Date	Air temp. C^0	Crew	Time	Site	Location	Substrate	Snow pack (cm	Ice (cm)	Ice cover cm	H_2O (cm)	H_2O temp C^0	% sat.	O_2 mg/l	Velocity	Avg	Max	Frame #	pH		
19-Nov-98	-3	GB,BM,EC,R	14:26	M10	55.5 mwest	cb, lggr	5	15		80	1.3	168	22.5		2.43	2.4	1-22.5	average > max ?????		
02-Mar-99	-4			M10	55	grv,cb,fns	66	73.66		80	-2	154	20.1					7.42		
02-Mar-99	-4	RA,BM	12:42	M10	55	grv,cb,fns	66	29		137	-2	154	20.2					7.42	side channel	

MORICE RIVER
OVERWINTERING HABITAT 1998/99

Date	Air temp. C	Crew	Time	Site	Location	Substrate	Snow pack (cm	Ice (cm)	Ice cover c	H_2O (cm)	H_2O temp C^0	% sat.	O_2 mg/l	Velocit	Avg	Max	Frame #	pH
02-Dec-98	-4	RA,BM		MB1	McB 2	smgv,fns	124	17		27	0.07							
10-Mar-99	-2	GB,WN	15:15	MB1	McB 2	smgv,fns												

MORICE RIVER
OVERWINTERING HABITAT 1998/99

Date	Air temp. C^0	Crew	Time	Site	Locatio	Substrate	Snow pack (cm	Ice (cm)	Ice cover cm	H_2O (cm)	H_2O temp C^0	% sat.	O_2 mg/l	Velocity	Avg	Max	Frame #	pH
30-Nov-98	-5	BM,RA		MB2	McB 1	lg grv, fns		free flow	o	94								
14-Nov-98		RA,EC		MB2	McB 1	lg grv, fns	14	free flow	o	64	1	9.7	76		.5 km	.6 km		
14-Dec-98	-6	RA,BM		MB2	McB 1		14			64	1	9.7	76		0.5	0.6		
16-Dec-98	-7	RA,BM,EC	14:24	MB2	McB 1	lg grv, fns	74		o	64	1	80						
25-Feb-99	-1	GB,WN	11:45	MB2	McB 1	lg grv, fns	103	free flow	o	61	0.7	135	18.8				19, video	
03-Oct-98	0	GB,WN	12:20	MB2	McB 1	lg grv, fns	119	free flow	o	58	0.7	182	24.8				14-Nov	
11-Mar-99	1	GB,WN	12:00	MB2	McB 1	lg grv, fns	101	free flow	o	94	0.6	217	30				17	
10-Mar-99	0	GB,WN	12:20	MB2	McB 1	lg grv, cb	110		0	58	0.7	182	24.8				14-12	

MORICE RIVER
OVERWINTERING HABITAT 1998/99

Date	Air temp. C^0	Crew	Time	Site	Locatio	Substrate	Snow pack (cm)	Ice (cm)	Ice cover c	H_2O (cm)	H_2O temp C^0	% sat.	O_2 mg/	Velocity	Avg	Max	Frame #	pH
02-Mar-99	-1	WN,GB		MB3	nan/kid	gvl,fns	66.04	20.32		129	-3							
03-Mar-99	2	WN,GB	13:18	MB3	nan/kid	gvl,fns	68.58	68.58	1.27	129	-0.3	need calib	21.8					
10-Mar-99	0	WN,GB	13:50	MB3	nan/kid	gvl,fns	88.9	68.58		129.54	-0.1	78	10.3				15-17	
11-Mar-99	1	WN,GB	12:37	MB3	nan/kid	gvl,fns	78.74	68.58	1.9	127	0	*33	*4.1				18-20	
*=malf																		

MORICE RIVER
OVERWINTERING HABITAT 1998/99

Date	Air temp. C0	Crew	Time	Site	Locatio	Substrate	Snow pack (cm)	Ice (cm)	Ice cover (cm	H2O (cm)	H2O temp C	% sat.	O2 mg/l	Velocity	Avg	Max	Frame #
24-Nov-98	-2	RA,EC,BM		ME1	HEB	fines,grv		8	iced over	107	3.2	47	4.4	pool	pool		video
26-Nov-98		BM,EC		ME1	HEB	fines,grv	4			107	4.2	59	4.9				
22-Mar-99	3	SS,GB	14:27	ME1	HEB	fines,grv					3.8	88	10	pool			

MORICE RIVER
OVERWINTERING HABITAT 1998/99

Date	Air temp. C	Crew	Time	Site	Location	Substrate	Snow pack (cm	Ice (cm)	Ice cover c	H_2O (cm	H_2O temp C	% sat	O_2 mg/l	Velocity	Avg	Max	Frame #	pH
24-Nov-98	-2	RA,BM,EC		ME2	heb connect		4	7.5		66	1			pool			3+4	
25-Nov-98				ME2				7.5	1	66	1							
24-Nov-98	-2	RA,BM,EC		ME2	x heb	fns	4	7.5		66	1	47	4.4	pool			1*2	
25-Nov-98		RA,BM,EC		ME2	x heb	fns			1									
26-Nov-98		RA,BM,EC		ME2	x heb	fns					2.8	53	3.9	pool				

MORICE RIVER
OVERWINTERING HABITAT 1998/99

Date	Air temp.	Crew	Time	Site	Location	Substrate	Snow pack (cm	Ice (cm)	Ice cover c	H_2O (cm)	H_2O temp C^0	% sat.	O_2 mg/	Velocit	Avg	Max	Frame #	pH	
26-Mar-99		WN, GB		MF1	Fenton	cb,smgr,lggr	81.28				0.5	104	13.2						
24-Mar-99		WN, GB	13:00	MF1	Fenton	cb,smgr,lggr	66.04			36.83	-0.1	88	11.6					turbid water	
16-Dec-98		RA,BM,EC	15:25	MF1	Fenton	cb,smgr,lggr	21				-0.2	91	11.9						
15-Dec-98		GB,BM	13:47	MF1	Fenton	cb,smgr,lggr	16	5			0.2	140	16.5						

MORICE RIVER
OVERWINTERING HABITAT 1998/99

Date	Air temp. C	Crew	Time	Site	Location	Substrate	Snow pack (cm)	Ice (cm)	Ice cover cm	H_2O (cm)	H_2O temp C	% sat.	O_2 mg	Velocity:	Avg	Max	Frame #	pH
07-Dec-98	sun/clouds	RA,EC,BM		MG1	69 mwest	cb,grv,fns		6.5		91	-0.4	87	11.5		2.4	3.2	18	
09-Mar-99	3	RA,BM		MG1	69 mwest	cb,grv,fns												
10-Mar-99		RA,BM	12:30	MG1	69 mwest	gv,smcb,fns	87											

MORICE RIVER
OVERWINTERING HABITAT 1998/99

Date	Air temp. C	Crew	Time	Site	Locatio	Substrate	Snow pack (c	Ice (cm	Ice cover c	H_2O (cm)	H_2O temp C^0	% sat.	O_2 mg/l	Velocit	Avg	Max	Frame #	pH			
10-Nov-98		BM,RA,EC	13:02	ML1	44	smgv,fns	0			272	1	199	27.5		0.44	1.5		7.43	see debris measurements below		
16-Mar-99	0	BM,DT	10:00	ML1	44	lggr, cb	81			40.6	0.5	97	12.8					7.44			
17-Mar-99	0	WN,GB	13:18	ML1	44	smgv,fns	81		1.27	40.6	-0.3	90	11.7		0.44	1.5		7.5			
19-Mar-99	-6	DT,BM		ML1	44	smgv,fns	70				0.5				0.63	0.8	2000/01/17	7.5			
15-Mar-99	-2	SS,GB	13:19	ML1	44	smgv,fns	67		5	30	-0.3	71	9.3		0.53	0.9	19-24	7.5			
24-Mar-99			12:33	ML1	44	smgv,fns	68			48.26	0.1	88	11.7								
03-Apr-99	-1	WN,GB		ML1	*44	smgv,fns	68.6		1.3	26	-0.4				0.36	2.3		7.5			
04-Mar-99	-1	WN,GB	12:55	ML1	44	smgv,fns	68.6		1.27		-0.4	269*	37*		0.64	1.3		7.5			
26-Feb-99	3	RA,BM	12:09	ML1	44	smgv,fns	68			73	-0.4	195	25.7		0.47	0.7		7.5			
26-Feb-99	3	RA,BM	12:26	ML1	44	smgv,fns	52	14		66	-0.4	92	12.3		2.2	2.58		7.5			
25-Feb-99	3	RA,GG	13:17	ML1	44	smgv,fns	52	14		26	-0.4	194	25		0	0.2	1--4	7.5			
25-Feb-99	0	RA,GG	13:29	ML1	44	smgv,fns	54	18		78	-0.4				0.64	1.3		7.5			
07-Dec-98	-5	GB,GG	12:44	ML1	44	smgv,fns	7.62	23*		61	0.4	78	10.6					7.5			
11-Dec-98	-5		13:02	ML1	44	smgv,fns			anchor		2.2	179	22.6					7.5			
01-Dec-98	-4	RA,BM		ML1	44	smgv,fns				46	0				0.63	0.8	1--4	7.5			
18-Feb-99	-6			ML1							-4	119	15.7								
12-Mar-99		GB	13:06	ML1	44	smgv,fns	63.5		6.35	33	-0.3	106	13.9								
03-Mar-99	2	GB,WN	13:18	ML1	44	smgv,fns	68.58		1.27	30.48	-0.3		21.8								
01-Apr-99				ML1							0.1	105	13.8								
10-Nov-98	debris																				
	width	height	length																		
	8 m	3 m	16 m																		

MORICE RIVER
OVERWINTERING HABITAT
1998/99

Date	Air temp. C	Crew	Time	Site	Location	Substrate	Snow pack (c	Ice (cm)	Ice cover cm	H_2O (cm)	H_2O temp	% sat.	O_2 mg/l	Velocity:	Avg	Max	Frame #	pH
				ML2	250m 44 brdg													

MORICE RIVER
OVERWINTERING HABITAT 1998/99

Date	Air temp. C	Crew	Time	Site	Location	Substrate	Snow pack (cm	Ice (cm	Ice cover cm	H_2O (cm	H_2O temp C	% sat.	O_2 mg/l	Velocity:	Avg	Max	Frame #	pH
01-Dec-98	-5	RA,BM		ML3	1 kmBN	smgv,fns		14	sheet		0				0.63	0.8	#17	
02-Dec-98				ML3		smgv,fns												
16-Feb-99	-4	RA,BM	12:10	ML3	1 kmBN	smgv,fns	53	18	1	32	-4	113	14.9		1.65	2.4		7.64
17-Feb-99	-4	RA,BM	13:20	ML3	1 kmBN	smgv,fns	53		0.5	32	-4	119	15.7		1.65	2.4		7.64
18-Feb-99	-6	RA,BM		ML3	1 kmBN	smgv,fns					-0.4							
15-Mar-99		SS,GB	13:19	ML3	1 kmBN	smgv,fns	70		7	36	-0.4	73	9.4		0.7	1.3		
17-Mar-99	0	WN,GB		ML3	1 kmBN	smgv,fns	78.7		7.6	40.6	-0.3	77	10					
19-Mar-99	-1	SS,GB	11:59	ML3	1 kmBN	smgv,fns	76.2		2	40.6	-0.2	73	9.6		0.7	1.3		
22-Mar-99	3	SS,GB	11:50	ML3	1 kmBN	smgv,fns	61			40.6	0.2	79	10.2		0.7	1.3		
24-Mar-99	2	RA,BM	12:33	ML3	1 kmBN	smgv,fns	76.2			48	0.1	96	12.6		0.7	1.3		
01-Apr-99			12:58	ML3	1 kmBN	smgv,fns					0	106	14					

MORICE RIVER
OVERWINTERING HABITAT 1998/99

ddmmyy	Air temp. C0	crew	time	location	substrate	snow pack (cm)	ice (cm)	ice cover c	ddmmyy	H2O (cm)	H2O temp C0	% sat.	O2 mg/l	velocity:	avg	max	frame #	pH
5-Nov-98		RA,BM,EC	13:57	28	smgv,fns				5-Nov-98	51	6.4	162	19.1		0.65	7.6		see debris measurements below
19-Nov-98		RA,BM,EC	13:02	28	smgv,fns				19-Nov-98	51	0.4	290	40.7		0.56	0.6		
20-Nov-98		GB,		28	smgv,fns				20-Nov-98								2001/01/02	
14-Dec-98	-6	GB,BM	13:41:00	28	smgv,fns	8	19		14-Dec-98	50	0.2	144	16					
15-Dec-98	-2	GB,BM	14:30	28	smgv,fns	8	19		15-Dec-98		0.1	136	15.8					
15-Feb-99	-4	RA,BM	13:35	28		45.5	37		15-Feb-99	32	-0.3	120	15.8		2.29	2.8	#3	
16-Feb-99	-1	BM, RA		28	smgv,fns	45.5	20		16-Feb-99	50	0.1							
16-Feb-99	-4	RA,BM	12:10	28	smgv,fines				16-Feb-99	32								
22-Feb-99	0	RA,BM		confl 28	smcb,sg,f	57	7		22-Feb-99	61	0.2	220	30		0.53	1		7.47
24-Feb-99						61			24-Feb-99	42							video*****	
25-Feb-99	-1	GB,WN		28	smgv,fns	60.96	38.1		25-Feb-99	63.5	-0.4	98	12.9					
26-Feb-99	0	BM,GB	11:33	28	smgv,fns	24	38.1		26-Feb-99	66.04	-0.4	92	12.3					
12-Mar-99	4	GB, BM	14:00				1		12-Mar-99			65	8.4					
05-Nov-98	debris																	
	width	height	length	site														
	10 m	2 m	40 m	1														

Appendix 2. Individual Fish Data For Fish Captured Locations In The Preliminary Morice River Overwintering Habitat Study.

Morice River
Overwintering Study
Fish Data 1998/99

DATE	Site	LOCATIO	SPECIES	LENGTH (cm)
15-Dec-98	M3	35 km	CO	9
15-Dec-98	M3	35 km	CO	8
15-Dec-98	M3	35 km	CO	9
15-Dec-98	M3	35 km	CO	7.5
15-Dec-98	M3	35 km	Dv	17.5
15-Dec-98	M3	35 km	Rb	8
15-Dec-98	M3	35 km	Rb	11.2
15-Dec-98	M3	35 km	Rb	10.5
15-Dec-98	M3	35 km	Rb	7.5
15-Dec-98	M3	35 km	Rb	8.5
15-Dec-98	M3	35 km	Rb	8
15-Dec-98	M3	35 km	Rb	15
24-Feb-99	M3	35 km	Co	7.5
24-Feb-99	M3	35 km	Co	10.5
24-Feb-99	M3	35 km	Rb	7.5
24-Feb-99	M3	35 km	Rb	17
10-Nov-98	M3	35 km	Co	7.5
10-Nov-98	M3	35 km	Co	12.5
10-Nov-98	M3	35 km	Rb	7.5
10-Nov-98	M3	35 km	Rb	17

Morice River
Overwintering Study
Fish Data 1998/99

DATE	Site	LOCATION	SPECIES	LENGTH (cm)
Mar. 4, 99	M4	37.5	CC	14

Morice River
Overwintering Study
Fish Data 1998/99

DATE	Site	LOCATIO	SPECIES	LENGTH (cm)
26-Feb-99	M5	38	CO	7.6
26-Feb-99	M5	38	CO	7.6
26-Feb-99	M5	38	CO	7.6
26-Feb-99	M5	38	RB	8.9
26-Feb-99	M5	38	RB	8.9
26-Feb-99	M5	38	RB	14
26-Feb-99	M5	38	RB	14
26-Feb-99	M5	38	RB	7.6

Morice River
Overwintering Study
Fish data 1998/99

DATE	Site	OCATIO	SPECIES	LENGTH (cm)	
03-Mar-99	M6	45	RB	14.5	
03-Mar-99	M6	45	DV	20	
03-Mar-99	M6	45	CC	9.5	

Morice River
Overwintering Study
Fish Data 1998/99

DATE	Site	LOCATION	SPECIES	LENGTH (cm)
23-Mar-99	M9	52 km	CH	9
23-Mar-99	M9	52 km	CH	9
23-Mar-99	M9	52 km	CH	9
23-Mar-99	M9	52 km	CO	6.5
23-Mar-99	M9	52 km	BB	12.5
24-Mar-99	M9	52 km	RB	13

Morice River
Overwintering Study
Fish Data 1998/99

DATE	Site	OCATIO	SPECIES	LENGTH (cm)
19-Nov-98	M10	55 KM	CC	12
19-Nov-98	M10	55 KM	CC	10
19-Nov-98	M10	55 KM	CC	13
19-Nov-98	M10	55 KM	CC	15
19-Nov-98	M10	55 KM	CC	12
19-Nov-98	M10	55 KM	CC	11
19-Nov-98	M10	55 KM	CC	12
19-Nov-98	M10	55 KM	CC	10
19-Nov-98	M10	55 KM	CC	15
19-Nov-98	M10	55 KM	CC	12
19-Nov-98	M10	55 KM	CC	11
19-Nov-98	M10	55 KM	CC	11
19-Nov-98	M10	55 KM	CH	13
19-Nov-98	M10	55 KM	CO	8
19-Nov-98	M10	55 KM	CO	10
19-Nov-98	M10	55 KM	CO	9
19-Nov-98	M10	55 KM	RB	8
03-Mar-99	M10	55.5	CO	9.5
03-Mar-99	M10	55.5	CO	6

Morice River
Overwinter Study
Fish Data 1998/99

DATE	Site	OCATIO	SPECIES	LENGTH (cm)	
30-Nov-98	MB2	Mc1	CT	15	
30-Nov-98	MB2	Mc1	CT	14	

Morice River
Overwintering Study
Fish Data 1998/99

DATE	Site	LOCATIO	SPECIES	LENGTH (cm)
30-Nov-98	MB3	.5 Nan fsr	Ct	15
30-Nov-98	MB3	.5 Nan fsr	Ct	14
25-Feb-99	MB3	.5 Nan fsr	Bb	7

Morice River
Overtwintering Study
Fish Data 1998/99

DATE	Site	LOCATION	SPECIES	LENGTH (cm)
10-Nov-98	ML1	44 lamp	CO	8.5
10-Nov-98	ML1	44 lamp	CO	9
10-Nov-98	ML1	44 lamp	CO	9
10-Nov-98	ML1	44 lamp	Rb	12
10-Nov-98	ML1	44 lamp	Rb	13
10-Nov-98	ML1	44 lamp	CH	13
01-Dec-98	ML1	lamp	Rb	10
01-Dec-98	ML1	lamp	Rb	13.5
01-Dec-98	ML1	lamp	Rb	13
01-Dec-98	ML1	lamp	Rb	13
01-Dec-98	ML1	lamp	Rb	12
01-Dec-98	ML1	lamp	Rb	13
01-Dec-98	ML1	lamp	Rb	12
01-Dec-98	ML1	lamp	Rb	13
01-Dec-98	ML1	lamp	Rb	9
01-Dec-98	ML1	lamp	Rb	7
01-Dec-98	ML1	lamp	Rb	7.5
01-Dec-98	ML1	lamp	Rb	8
01-Dec-98	ML1	lamp	Rb	7.5
DATE	Site	LOCATION	SPECIES	LENGTH (cm)
18-Feb-99	ML3	1 km B.Nye	Rb	13
18-Feb-99	ML3	1 km B.Nye	Rb	10
18-Feb-99	ML3	1 km B.Nye	Rb	9

Morice River
Overwintering Study
Fish Data 1998/99

DATE	Site	LOCATIO	SPECIES	LENGTH (cm)	caudal mark	
15-Dec-98	MO1	28	Rb	6.5		
20-Nov-98	MO1	28	Rb	13.5		
20-Nov-98	MO1	28	Rb	15	Yes	
20-Nov-98	MO1	28	Rb	10.5		
20-Nov-98	MO1	28	Rb	16	Yes	
20-Nov-98	MO1	28	Rb	12.5		
20-Nov-98	MO1	28	Rb	13		