Environmental Impact Assessment for water withdrawal from St. Mary Lake, Saltspring Island BC

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1. BACKGROUND

North Salt Spring Waterworks District (NSSWD) holds four water licenses to extract water from St. Mary Lake, Saltspring Island, British Columbia. The most recent licenses (C101050 and C101070) were obtained to meet projected demand through 2020. Based on discussions with staff from water management and provincial fisheries agencies, the water licenses have specific conditions including maximum diversion rates, flood control capability, minimum flow releases to Duck Creek (the outlet of St. Mary Lake), and upstream and downstream fish passage capability.

The cumulative effect of water withdrawals from St. Mary Lake likely have a negative influence on the ecological integrity of the lake and also influence discharge to Duck Creek. Fish production in Duck Creek is believed to be flow limited. Fisheries agencies requested a minimum flow release of 10% of mean annual discharge (MAD) as an enhancement to compensate for impacts to St. Mary Lake resulting from water withdrawal. To meet this request and to also allow for fish passage to and from St. Mary Lake requires the construction of a low head dam and channel modifications to Duck Creek.

A site visit with regulatory agency staff determined that construction of a dam and related project components may result in impacts to fish habitat, and would likely require authorization under the Fisheries Act. Under Canadian law, any project requiring a Fisheries Act authorization triggers the Canadian Environmental Assessment Act (CEAA), so a screening-level review under CEAA is also required. Fisheries and Oceans Canada (DFO) therefore instructed NSSWD to complete an impact assessment of the project as a whole, including impacts to St. Mary Lake and Duck Creek, and to submit the findings for a CEAA review. This report represents an overview impact assessment of the works and activities proposed by NSSWD. Since the environmental impacts and benefits of the project are almost entirely associated with fish and fish habitat, this report addresses these concerns.

2. DESCRIPTION OF PROJECT

2.1 Project Area

The primary project area is defined as St. Mary Lake below the current high water mark and Duck Creek from the outlet of St. Mary Lake to Tripp Road. The project is expected to have considerable benefits in Duck Creek downstream of Tripp Road, and there may also be some impacts associated with construction activities. Downstream costs and benefits are discussed in this report, but there are no construction activities planned for areas beyond Tripp Road. Duck Creek downstream of Tripp Road is therefore defined as being outside the primary project area.

2.2 Project Description

The following is an overview description of the project based on our understanding of discussions with NSSWD and their engineering consultants. This description is meant only to guide the environmental assessment of the project. Readers should consult with NSSWD to obtain complete design details.

The project is centered around the need to acquire additional water from St. Mary Lake for distribution by NSSWD. Water will be extracted from the lake and is expected to have an effect on lake levels, and flows in Duck Creek. During discussions with provincial water management and fisheries agencies it was agreed that a minimum flow release to Duck Creek would be an appropriate mechanism to compensate for environmental impacts associated with the project. A minimum flow of 10% MAD was recommended, as was provision for passage of fish to and from the lake.

Several project components are required to meet the demands of the minimum flow release and passage of salmonids to and from the lake:

1. construction of a low-head dam with a low-level output for the minimum flows,
2. construction of a service road from Vesuvius Bay Road to the proposed dam site,
3. construction of a fishway to accommodate adult and juvenile movements, and
4. channel modifications to accommodate hydraulic requirements of fisheries and flood control.

These components are shown in detail in the project design drawings, and in annotated photos in Appendix A.

The low head dam is proposed as a 6m wide concrete structure. The spillway will have a 14:1 slope as measured from crest of dam to 19m downstream. Overcrest spills will be uncontrolled and provide upstream and downstream passage for adult and juvenile salmonids.

At one side of the dam will be a low level outlet that provides the minimum flow release for Duck Creek. The minimum flow will pass through a structure engineered to provide passage conditions for juvenile salmonids.

Construction and maintenance of the dam and fishway requires a service road. The road will extend from Vesuvius Bay Road along the south side of Duck Creek to the proposed the dam site. The road will cross a small tributary of Duck Creek adjacent to Vesuvius Bay Road. The service road is to be built outside the existing riparian area of Duck Creek.

Modifications to Duck Creek are required both upstream and downstream of the dam to ensure proper hydraulic conditions for flood routing and minimum flows. Specifically, the inlet channel upstream of the dam must be widened and deepened to ensure sufficient flow from St. Mary Lake to the dam. Downstream of the dam some sections of the channel must be lowered slightly to accommodate flow from the dam (flows from overcrest and low level outlet).

It is important to understand the constraints placed upon the potential design of this project. First, NSSWD has been given a legal opinion that they must undertake due diligence to ensure that lake levels do not rise above 41.0m elevation due to concerns with private property around St. Mary Lake. Second, to protect fisheries values within St. Mary Lake, lake levels should not be allowed to fluctuate lower than 40.0m. Third, to meet the required minimum flow release using gravity feed through a low level outlet, the outlet must by constructed at an elevation of 39.7m. Fourth, in order to have continuous discharge through a structure that would allow juvenile passage, there must be discharge through an open channel accessible and attractive to fish (i.e., a pump or siphon technology to provide the minimum flows is not acceptable). The project has been designed with these constraints and objectives in mind.

2.3 Impact Types

Footprint.— The footprint of this project (permanent changes to fish habitat) is restricted to the low-head dam and the excavated portion of the Duck Creek channel upstream of the dam. The footprint of the dam and fishway is approximately 23m in length by 12m wide. Modifications to the channel downstream of the dam will not permanently alienate habitat. The service road is being built outside the existing riparian area of Duck Creek.

Construction.— Potential construction impacts are typical for this kind of project and are primarily related to sedimentation, erosion, and disruptions in flow. All construction impacts are mitigable with standard best management practices (BMPs).

Operation.— Substantial downstream benefits for fish and fish habitat are expected from operation of the dam; no negative environmental impacts are expected. Extraction of water from St. Mary Lake is expected to have an impact on fish and aquatic resources in the lake.

3. EXISTING WATER USES

A query of the Land and Water BC Inc database indicates that a considerable number of water licenses have been issued for St. Mary Lake and Duck Creek and have been maintained as current (Appendix B). Demand for water is clearly high for residential and irrigation uses. The true extent and temporal patterns of water use are not known, since only NSSWD water use is gauged. It seems likely however, that if most active licences are being used, the cumulative effect will influence the water budget of St. Mary Lake and Duck Creek. It should be stressed that this impact assessment and regulatory review applies only to water licence C101050 for water extraction, and water licence C101070 for water storage.

4. ST. MARY LAKE

In 1997 NSSWD contracted Westland Resource Group to conduct an environmental impact assessment of proposed water level drawdowns. The impact assessment focused on potential impacts to smallmouth bass, rainbow trout, and cutthroat trout from a proposed permanent reduction in water level. It should be noted that the Westland report was based on a water budget developed by Bullock Baur (1996) assuming a spillway elevation of 40.5m, which is slightly lower than that currently being proposed. Hamilton (1998) subsequently conducted more detailed hydrologic modeling for lake levels and outlet streamflow, and NSSWD uses this more rigorous hydrologic assessment for planning purposes. Hamilton's study indicates a considerably lesser effect on lake drawdown than that indicated in the Bullock Baur water budget. The Westland report therefore assesses a predicted hydrologic change that is more drastic than that predicted by Hamilton. We expect that the results are nevertheless sufficiently applicable to understand the kinds of impact that may occur from this project as it is currently proposed, though the magnitude of impacts may be overstated. This issue is discussed in greater detail in Section 6.

The Westland report is available as a stand alone document. This section summarizes findings from that report.

4.1 Existing Conditions and Likely Changes to Existing Conditions

St. Mary Lake is a small, shallow lake located on the north end of Saltspring Island, British Columbia. Situated near the communities of Ganges and Vesuvius, St. Mary Lake acts as the predominant supply of drinking and domestic water for the area, as well as for local irrigation. The lake supports a recreational smallmouth bass and salmonid fishery, which has been enhanced over the last two decades through stocking and habitat enhancement programs. In addition to fishing, residents and tourists utilize the lake for activities such as camping, boating, and swimming.

St. Mary Lake supports populations of coastal cutthroat trout (*Oncorhynchus clarki*), rainbow and steelhead trout (*Oncorhynchus mykiss*), smallmouth bass (*Micropterus dolomieui*), prickly sculpin (*Cottus asper*), and threespine stickleback (*Gasterosteus aculeatus*). Rainbow, cutthroat, and steelhead trout have been regularly stocked in the lake by MELP Fish Culture Branch (now the Freshwater Fisheries Society of BC). Smallmouth bass were first introduced into the lake in 1920 (McMynn, 1952), and have become established as a self-sustaining population.

McMynn (1952) reported that anadromous cutthroat migrated up Duck Creek into the lake historically. At present St. Mary Lake appears to offer less than ideal salmonid habitat due to high water temperatures and low dissolved oxygen levels.

Existing water level fluctuations and projected levels (based on Bullock Baur 1996) are shown in Figure 1. The water level versus surface area relationship indicates that the lake basin is fairly straight-sided, without an exaggerated bowl-like shape except at very low elevation (Figure 2). Table 1 indicates the magnitude of projected water level reductions for both dry year and average conditions. On average, lake levels are projected to decline roughly 30 to 70 cm, but in dry years the decline may exceed 1m.

Table 1. Projected reduction in water level relative to current conditions. Projections are based on a water budget developed by Bullock Baur (1996).

Month	Depth reduction (m) average year	Depth reduction (m) dry year
Jan	0.31	0.31
Feb	0.39	0.39
Mar	0.31	0.31
Apr	0.48	0.53
May	0.50	0.60
Jun	0.58	0.73
Jul	0.61	0.81
Aug	0.68	0.88
Sep	0.60	0.95
Oct	0.56	1.01
Nov	0.50	1.05
Dec	0.60	1.15

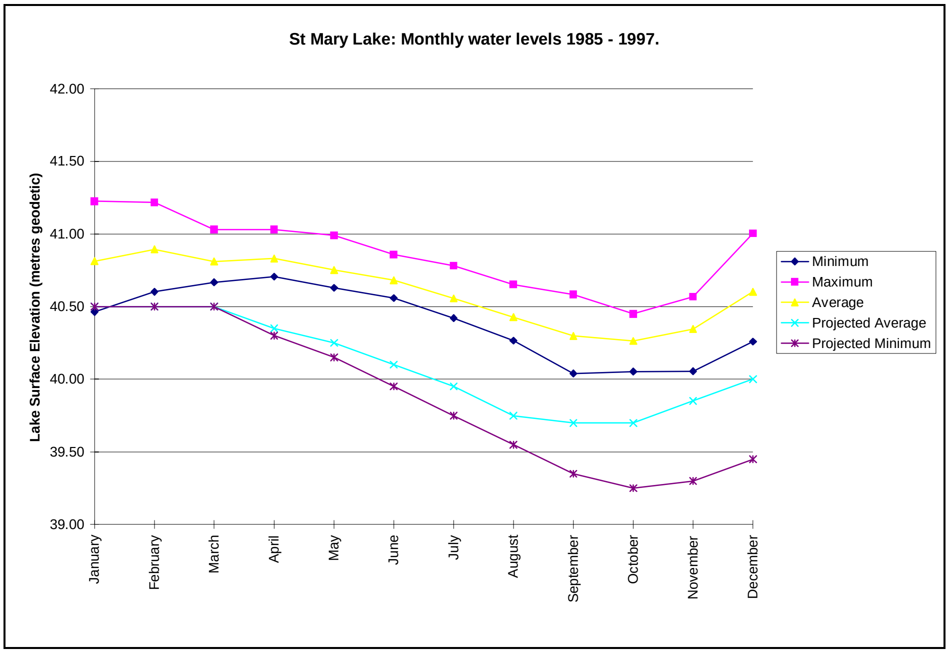

Figure 1. Current and post-drawdown projected monthly water levels.

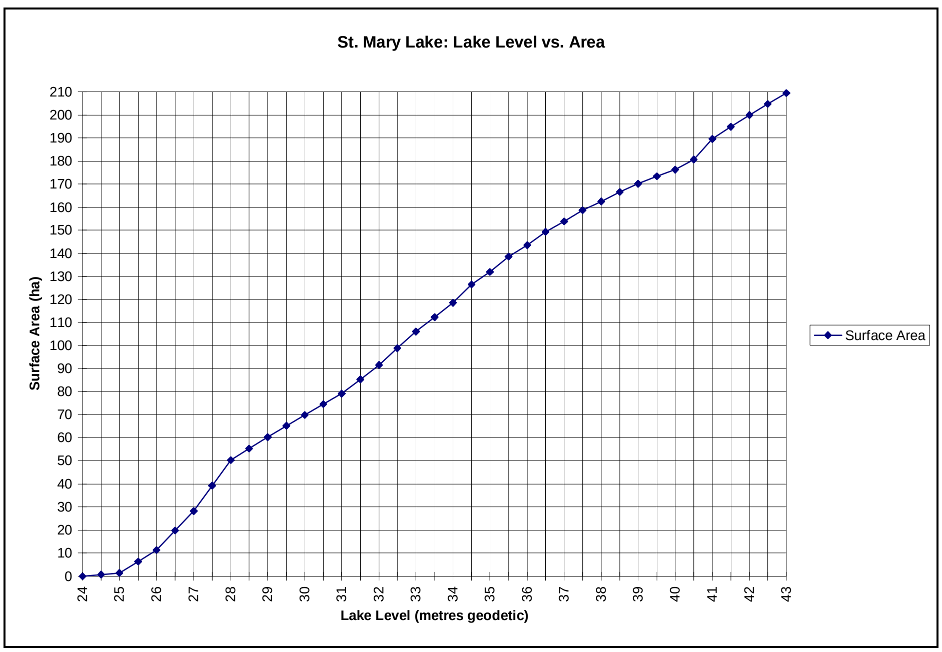

Figure 2. Lake elevation versus surface area.

Lake surface area, littoral area and shoal area are also expected to decline as a result of lower lake levels. Currently, surface area of the lake fluctuates between 185 and 187 hectares from February through April, then declines to an average of 178.6 hectares in October. Levels then rise again through February. Figure 3 outlines the reduction in lake surface area projected for average and dry years post-drawdown, with a magnitude of reduction ranging from 3.7 hectares to 8.1 hectares based on season, rainfall, and water usage. Similar patterns are indicated for both average and dry years through August, when dry year area reduction increases through December. Average year area reduction diminishes from August through November, then increases in December.

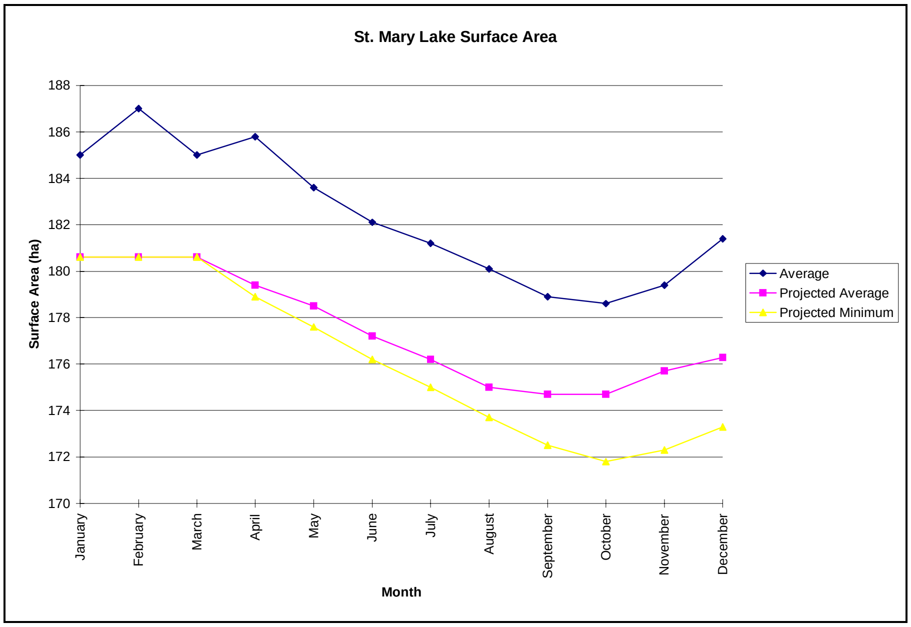

Figure 3. Current average, projected average, and projected minimum surface area.

Dynamics of the established littoral area (defined as the area 6.0 m below current average seasonal water levels) are presented in Figure 4, which displays average littoral area for current, post-drawdown average, and post-drawdown dry years. The magnitude of reduction in established littoral area for projected average and dry year conditions, ranges from a minimum of 3.7 hectares in November for an average year, to 8.1 hectares in December for the dry year projection. As a percentage, reduction of littoral area varies between 6.5% and 12.5% for average year projections, and between 8.0% and 15.0% for the dry year condition.

Shoal area is defined as ≤ 6.0 m depth. Figure 5 shows the changes in shoal area associated with lake level drawdown, and demonstrates a trend to increasing shoal area with declining depth. The current average shoal area fluctuates between 54.1 and 55.9 ha from January through April, declines slightly to 53.0 in June, then increases again, reaching a plateau of 54.7 ha September through November. Projections for average and dry year conditions indicate that shoal area would remain constant at 54.1 ha from January through June, which corresponds with the proposed spillway elevation of 40.5 m geodetic. Both projections then show an increase in shoal area, peaking at 59 hectares in September for the average year projection and 62.7 hectares in October for the dry year projection.

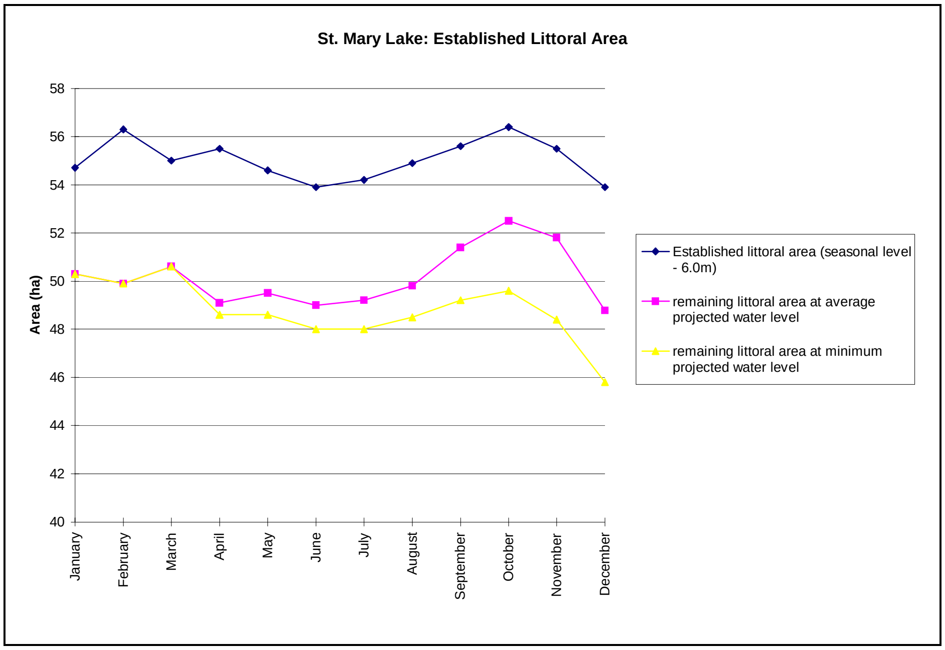

Figure 4. Monthly established littoral area for current, post-drawdown average, and post-drawdown dry conditions.

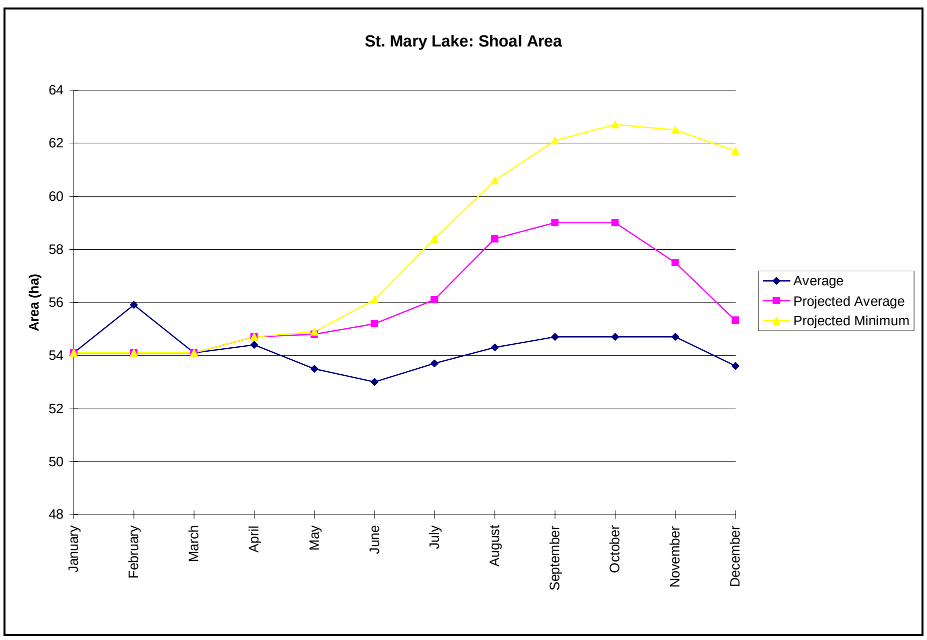

Figure 5. Lake shoal area for current average and projected post-drawdown conditions.

4.1.1 Spawning Habitat

Areas of preferred, adequate, marginal, and unsuitable smallmouth bass spawning habitat were surveyed by snorkelling and are indicated on Map 2, Appendix A, in Westland (1997). Individual spawning areas and the rating criteria applied to them are also described in detail in Westland (1997).

Preferred habitat is distributed mainly in the northern section of the lake, north of the NSSWD pumphouse. Adequate and marginal habitat is evenly distributed throughout the lake, and only three areas were identified as being not suitable for spawning. It is worth noting in the context of this project that one of the three is the area around the lake outlet (i.e., Duck Creek). Approximately 300 m in length, this area is at the extreme southern end of the lake extending out to the 1.5 m depth contour. Depths here are very shallow and substrate is composed of silt up to 1.5 m deep. No adequate nesting sites were observed.

4.1.2 Juvenile Rearing Habitat

Smallmouth Bass.— Distribution of smallmouth bass rearing habitat was determined by daylight swims, seining, and trapping during August and September 1997, and is displayed in maps 3 to 7, Appendix A of Westland (1997). These observations indicate that juvenile bass were primarily found outside the *Juncus* zone during this period, in water between approximately 1.5 m and 3.0 m depth, above areas of submerged macrophytes (predominantly *Potamogeton* and *Elodia* sp.). Bass moved slowly towards this submerged vegetation when disturbed, or towards large woody debris such as submerged or floating logs. Juvenile bass were observed to be using a section of the steep shore on the east side of the lake, south of the CRD pumphouse, in significant numbers, although less than areas above submerged macrophyte growth. Fish in this area were found 1 m to 3 m from shore, in water of approximately 2 to 4 m depth, and moved close inshore toward masses of large and small woody debris when approached. These fish were far less abundant than in the preferred areas, moving in smaller schools of 10 to 20 fish. These individuals also appeared to be more wary of us moving sooner and more rapidly into areas of cover. This area of the littoral zone was classified as adequate rearing habitat. Bass were observed to make very little use of shallower water and areas of emergent growth, and in very low densities when they do so, and hence these areas were classified as not preferred.

Night observations of juvenile bass rearing habitat were conducted on August 20, September 4 and 10, and November 5 1997. Juvenile bass appear to be almost exclusively restricted to shallow water of less than 1.0 m deep, and show a strong preference for areas clear of macrophyte growth such as rock ledges or sand or gravel beach areas. Large masses (>50 m^{-2}) of small bass were observed crowding onto rocky ledges in water as shallow as 5 cm along the west side steep shore and in the north east bay near the CRD pumphouse. Large aggregations were also observed in the sandy/gravely beach areas near Island Gardens Resort, the CRD pumphouse, Cottage Beach Resort, and an embayment in the northern portion of the west side steep shore. Within these types of habitat, fish showed a strong association with various types of cover, utilizing rock crevices, boulders and small woody debris. Juvenile bass were not observed to make use of areas covered by *Juncus*, *Vassineria*, or *Potamogeton* during dark hours in August and September, being almost exclusively limited to the habitats outlined above. No juvenile bass were observed in the south end of the lake, south of Cottage Beach Resort during night surveys.

Salmonid Species.— Lacustrine habitat for juvenile salmonids is described in Tabor and Wurtsbaugh (1991), Trotter (1989), Nilsson and Northcote (1981), Beauchamp *et al.* (1994), Beauchamp (1990), Trotter (1989), Wurtsbaugh and Brocksen (1975), Gresswell *et al.* (1994), Nilsson (1971), Raleigh *et al.* (1984), EPA (1993), and Scott and Crossman (1973). These studies describe salmonid habitat in a range of geographic locations including coastal British Columbia.

Like bass, juvenile salmonids make extensive use of littoral habitat for cover and food. Typically, wild populations of lacustrine rainbow and cutthroat spawn in inlet or outlet streams of their resident lakes. Juveniles remain in the natal streams for up to three years after emergence, then emigrate to the lakes. As a result, these juveniles are larger and less vulnerable to predation when entering lentic habitat, and less dependent on littoral rearing habitat for the provision of cover and forage. However, juvenile trout stocked into St. Mary Lake lack the benefit of natal streams as rearing habitat, and hence require adequate littoral space and cover to reduce predation and provide adequate forage for growth and development.

The eutrophic conditions observed within St. Mary Lake are well suited to fish such as smallmouth bass, which are tolerant of warm water and low dissolved oxygen. However, salmonid species require low temperatures and well-oxygenated water. As surface waters warm, these cold water fish are forced to occupy deeper, cooler lake strata. Unfortunately, these favourable thermal conditions occur below the thermocline, where oxygen levels are often reduced. Additionally, as juvenile salmonids are driven from the upper strata of the lake they are prevented from exploiting the upper littoral zone for cover and food, where both are plentiful.

Our observations indicate that this dynamic occurs within St. Mary Lake. Juvenile salmonids were not observed or sampled from the lake until our final field visit in November. Water temperatures remained between 19°C and 24°C from June through September. These temperatures are above the thermal optima for salmonid species, and close to the thermal maxima reported for rainbow and cutthroat, (22°C and 24°C, respectively). Given these temperatures, it appears that juveniles are prevented from exploiting the upper littoral zone during this period.

No juvenile salmonids were observed, trapped or seined during the June to September component of this study. Observations recorded during the November field visit failed to locate these fish in daylight hours, however, many juvenile rainbow trout were observed during night snorkel observations, and one 106mm individual was caught in a night time beach seine set at Island Gardens Beach (Site North East Bay 4).

Rainbow trout of approximately 100 mm to 150 mm in length were observed holding on the substrate in the upper 0.5 m of the littoral zone in North East Bay near the CRD pumphouse (approximately 10 individuals), and in West Side Steep Shore along a series of shallow bedrock ledges (approximately 25 individuals). These fish showed a strong preference for rock, sand, or gravel substrate. Trout were observed using rock crevices as cover and were not observed among the stems of aquatic macrophytes. These fish did not bolt when approached, but when touched would swim away rapidly. Fish would not move into water greater than 1.0 m depth, and were observed holding in water as shallow as 0.05 m.

The distribution of preferred, adequate, and marginal night holding habitat for juvenile salmonids is outlined on Map 8, Appendix A, of Westland (1997).

4.1.3 Aquatic Macrophyte Community

The majority of the lake shore is colonized by dense growth of *Juncus* sp., which extends to an elevation of 39.3m, well below the proposed drawdown limit. Where bathymetry is steep the shoreline is devoid of emergent growth. Other emergents include naturalized yellow iris. Floating leafed macrophyte growth is limited almost exclusively to *Nuphar* sp., occurring predominantly in North East Bay, North West Bay, and the extreme southern tip of the lake. The submerged macrophyte community appears to be dominated by *Potamogeton crispus*, with *Elodia canadiensis* and *Potamogeton amplifolius* occurring in association with this. The *Potamogeton/Elodia* type of submerged growth dominates most areas of the littoral between 1.5 m and 3.0 m depth, with the exception of the south end of the lake, where a dense growth of *Vallisneria americana* dominates. The gently sloping bottom between 2 m and 1 m on the northern shore of North East Bay is carpeted in a dense growth of *Isoetes* sp**.**

4.1.4 Riparian Vegetation

Dominant members of the overstory vegetation in the riparian zone are western red cedar (*Thuja plicata*), Douglas fir (*Pseudotsuga menziesii*), big leaf maple (*Acer macrophyllum*), willow (*Salix* sp.) and alder (*Alnus* sp.). Riparian understory is composed predominantly of shrubs such as small willow (*Salix* sp.), hardhack (*Spirea* sp.), wild rose (*Rosa* sp.), oceanspray, snowberry and additional herbacious plants such as nightshade, potentilla, equisitum, and various grasses.

4.1.5 Water Quality and Limnology

St. Mary Lake has been the subject of four reviews of water quality and limnology (Holms, 1996; Nordin *et al.*, 1983; Goddard, 1975; McMynn, 1952). The lake occupies a relatively small drainage basin for its size (7.07 km^2), and as a result of this and overall low precipitation the water residence time of the lake is long for coastal BC, calculated at a mean value of 5.4 years (Nordin *et al.*, 1983). Maximum depth of the lake is 17 m, with a mean depth of 8.7 m and a volume of 16,522 dam^3 at 41.0 m geodetic. Littoral zone area has been estimated at 28% (McMynn, 1952, Goddard, 1975) and 30% (Nordin, 1983).

Reported water temperatures range from a winter low of 1-2°C, to a summer high of 23-24°C. Thermal stratification usually begins mid April to mid May, and continues through until mid September to mid October, with thermocline depths ranging from approximately 5 m in May, to approximately 11 m prior to fall overturn. St. Mary Lake is a monomictic lake, with only one thermal stratification period per year.

Additional review of water quality parameters are presented and discussed in Westland (1997).

4.2 Impacts

The ecological conditions of St. Mary Lake are similar to other small, warm water eutrophic lakes in nearby coastal areas. Productivity is high, as indicated by macrophyte growth, fish community composition and production, dissolved oxygen dynamics, nutrient concentration, spring overturn chlorophyll *a* concentration, and other indicators of trophic state. Evaluation of the effects of the proposed drawdown of the lake on the fish communities of St. Mary Lake must be conducted with reference to these pre-existing conditions.

Observations indicate that the smallmouth bass population of St. Mary Lake is extremely productive. Recruitment of juveniles appears to be very high, with young of year bass observed in very high numbers during field work in June through September. Adult bass were very numerous as well, with individuals observed ranging in size from 100 to 500 mm in length. These conditions indicate a healthy population, with all age classes represented. It is our opinion that at present, St. Mary Lake is at or near its carrying capacity for smallmouth bass. Given the large numbers of individuals observed, it is probable that bass use all available spawning habitat, including areas of marginal habitat. Productive littoral, planktonic and benthic invertebrate communities provide abundant forage, and extensive aquatic macrophyte growth provides adequate cover for juveniles. It is likely that smallmouth bass production is presently limited by factors such as predation by adults and fall and winter mortality, as opposed to spawning or rearing habitat availability. Analysis of specific limiting factors within this population would require detailed modeling, and is beyond the scope of this study.

St. Mary Lake provides much less favourable habitat for salmonid species, which prefer cool, clear, well-oxygenated water. These conditions do not exist within St. Mary Lake during the period of thermal stratification.

Smallmouth Bass Spawning Habitat.— The effect of the proposed reduction in water level on spawning habitat is directly related to the timing and degree of change in water levels compared to current conditions. Table 1 indicates that during the smallmouth bass spawning activity window of mid May to mid June, post-drawdown water levels are approximately 0.5 m and 0.6 m below the current average water level for projected average and dry years respectively. Based on smallmouth bass spawning depth criteria and St. Mary Lake water level data supplied by NSSWD, the current probable upper limit of nest construction is 40.45 m GSC, (using May water levels). Post drawdown, this upper limit of nest construction would decline to 39.95 and 39.85 m GSC for projected average and dry years. This reduction in water level represents a corresponding reduction in established spawning area of 7.4 and 7.9 hectares respectively. Given the distribution of nesting habitat, the majority of this reduction will occur in areas of the littoral classified as adequate or marginal spawning habitat, with a smaller portion of preferred and not suitable nesting habitat reduced.

The impact of the proposed water level reduction within individual spawning areas is summarized below. Please see Westland (1997) for more details.

The magnitude of impact resulting from the proposed reduction in water level is deemed to be **NEGLIGIBLE** in all areas of adequate and marginal spawning habitat. Habitat within these areas will return to pre-drawdown conditions without mitigation activities. Loss of areas of preferred cover, substrate, and depth would result in impacts of **MODERATE** magnitude in areas of preferred spawning habitat, and would require mitigation to return to pre-drawdown conditions.

Duration of the impacts within marginal and adequate spawning habitat areas would be **SHORT-TERM**. The displacement of nesting areas would not exceed the range of nest site fidelity displayed by returning spawners, and thus spawning activity should continue uninterrupted in these areas. Duration of impacts within preferred spawning habitat would be **LONG-TERM**, with spawning activity interrupted indefinitely.

Smallmouth Bass Rearing Habitat.— The impact to smallmouth bass rearing habitat from the proposed water level reduction is summarized below. Please see Westland (1997) for more details.

The magnitude of impact to juvenile smallmouth rearing habitat resulting from the proposed changes in water level is predicted to be **HIGH** in the **SHORT-TERM** (< 2 years). Negative effects include a reduction in established *Juncus* beds, as well as other areas of emergent macrophytes critical both as cover and a source of invertebrate prey for juvenile bass. Additional effects include the reduction in cover availability from overhanging riparian vegetation, areas of small and large woody debris cover, and areas clear of aquatic macrophytes that are preferred night holding habitat for fish observed August through November.

The magnitude of **LONG TERM** (> 4 years) changes in juvenile rearing habitat as a result of the proposed drawdown is predicted to be **NEGLIGIBLE**. Aquatic macrophytes should re-establish at the adjusted water levels, and fast growing species such as alder, hawthorn, and maple will have continued to encroach upon the new shoreline. The bathymetric profile of St. Mary Lake is such that a decline in water level would in fact result in an increase in shoal area (see Figure 5). This increase in shoal area would offer a greater area of lake bottom suitable for macrophyte and invertebrate colonization. Thus, after an initial period of reduction in cover and forage provided by aquatic macrophytes, this community may occupy a larger area of the lake post drawdown, providing some increase in cover and food.

Juvenile Salmonid Rearing Habitat.— The impact to salmonid rearing habitat from the proposed water level reduction is summarized below. Please see Westland (1997) for more details.

No juvenile salmonids were observed during fieldwork from June through September. In the course of night snorkel surveys during November we observed juvenile rainbow trout of approximately 100 to 150 mm in size holding in the upper 0.5 m of the littoral zone.

Projected water level reductions from current average values for the October - November period are 0.56 to 0.50 m and 1.01 to 1.05 m for average and dry years respectively (Table 1). Average year projections will result in a reduction of lake surface area between 3.9 and 3.7 hectares through this period, with this range increasing to 6.8 to 7.1 hectares for a dry year projection. This reduction in established littoral area will reduce the availability of preferred nocturnal holding habitat for juvenile rainbow and cutthroat trout. Areas of preferred substrate will be exposed in West Side Steep Shore and the shoal in the mouth of North East Bay and thus juvenile salmonid rearing habitat will be degraded.

A review of the benthic macroinvertebrate data (see Appendix C in Westland [1997]) indicates that there would be no significant changes within this community as a result of the proposed reduction in water levels, and hence would not impact upon the quality of juvenile salmonid rearing habitat.

The magnitude and duration of impact to juvenile salmonid nocturnal holding habitat are predicted to be **MODERATE** and **MEDIUM-TERM** respectively. Areas of preferred holding habitat will be exposed without habitat of similar quality becoming available at lower bathymetric strata in the short-term.

Water Quality in Relation Fish Populations.— The magnitude and duration of impacts noted for temperature, pH, dissolved oxygen, turbidity, phosphorus, and nitrogen suggest that the proposed reduction in water levels would be **NOT SIGNIFICANT** to the smallmouth bass population within St. Mary Lake.

Temperature, phosphorus, and dissolved oxygen are noted as areas of concern for cutthroat and rainbow trout. The degree of impact as a result of an increase in temperature cannot be predicted without the calculation of a pre- and post-drawdown heat budget for the lake, hence the significance of this impact is **UNKNOWN**. Similarly, the overall significance of changes in phosphorus dynamics are difficult to assess without the calculation of a phosphorus budget for post-drawdown conditions, and hence the significance of this impact is also **UNKNOWN**. Finally, declines in dissolved oxygen levels would have a significant detrimental effect upon salmonid species within the lake given that current, pre-drawdown hypolimnion DO levels are at or near the lower tolerance limit for these species. However, based on existing information the magnitude and duration of this potential shift is unclear, and hence this impact is assessed as **UNKNOWN**.

5. DUCK CREEK

5.1 Existing Conditions

Duck Creek is the outlet stream of St. Mary Lake. The creek flows for approximately 3km from St. Mary Lake to the ocean at Duck Bay on the western shore of Saltspring Island. Duck Creek has characteristics typical of inhabited parts of this portion of British Columbia in that it flows through agricultural, urban, as well as relatively wild parkland sections.

5.1.1 Streamflow

Streamflow patterns in Duck Creek are typical of this climatic region with a “U-shaped” rainfall-driven hydrograph: high flows occur in fall and winter, with low flows in late spring through early fall (Figure 6). Flows fluctuations are attenuated somewhat by St. Mary Lake, particularly as the lake recharges in the fall. Flows may nevertheless be quite variable in response to seasonal rainstorms (Figure 6). Duck Creek flows are also influenced by beaver dams on the stream, and ongoing human attempts to modify these to release flow.

Flows in Duck Creek have been monitored consistently on a seasonal basis since 1990. These data indicate severe low flows in Duck Creek, with long periods each year of zero or near zero flow (Figure 6). Based on hydrology studies by Hamilton (1998, 1999), MAD for Duck Creek is estimated to be approximately 89 L sec^{-1}. Low flows at present fall below 10% MAD for extended periods each year.

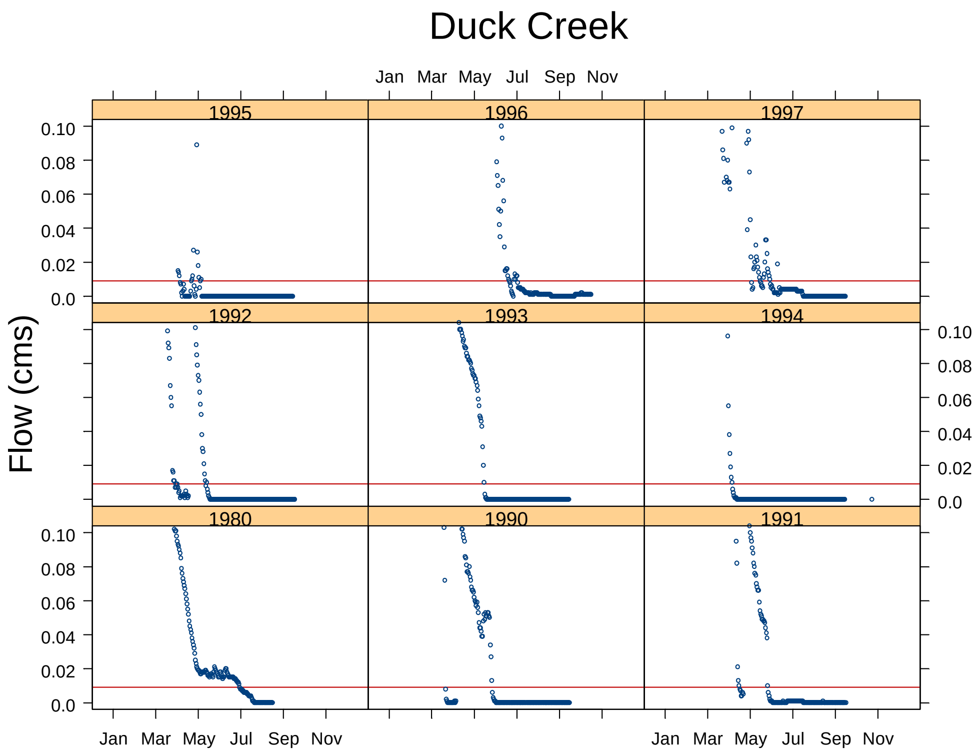

Figure 6. Streamflow in Duck Creek in 1980 and 1990-1997 as measured at gauge 08HA046 near the outlet of St. Mary Lake. Flows have been monitored only seasonally. The horizontal red line indicates 10% mad (approximately 8.9 L sec^{-1}); flows are indicated to only 0.1 cms to highlight detail at low flow.

5.1.2 Fish and Fish Habitat

Fish and fish habitat in Duck Creek were surveyed for this report on September 1, 2004. A detailed survey was completed for all areas from the outlet of the lake to the culvert crossing at Tripp Road. Fish presence – absence sampling was conducted using a Smith-Root electrofisher, and habitat was surveyed by completing site cards at three representative locations. Photographs and notes were taken to supplement this information (see Appendix A).

Visual observations of Duck Creek were made at numerous accessible locations downstream of the Tripp Road crossing. The main areas examined include the stream and ponds on Duck Creek Farm (immediately downstream of Tripp Road) and accessible portions of the stream from Broadwell Road to Sunset Drive.

Electrofishing of Duck Creek resulted in capture of four juvenile coho salmon and numerous threespine stickleback (Appendix A). Coho were captured in small pools within that portion of stream with good riparian cover. Stickleback were captured throughout the stream, in ponds and slough-like habitats.

During visual observations of Duck Creek downstream of Tripp Road we noted numerous juvenile salmonids. Since these fish were not captured they could not be identified to species. Based on size, the fish appeared to be from more than one age class, though the majority were young of the year. Fish were seen rising to feed in the two large ponds on Duck Creek Farm, and the owner of the farm noted he had occasionally observed mature cutthroat in the system. Numerous juvenile salmonids were present in pools within Duck Creek park.

Fish habitat within and downstream of the project area is shown in a series of photographs (Appendix A). Locations of the three sites at which habitat was measured are indicated in Appendix A. A summary of site card data is presented in Appendix C. Within the project area there are essentially two portions: the lake outlet consisting of ~130 m of ditch with minimal riparian cover, and ~270 m of mostly natural stream with good riparian cover. These portions are discussed separately below.

In the section of Duck Creek that is the outlet from St. Mary Lake, the stream is essentially an agricultural ditch. Riparian vegetation has been cleared to accommodate agricultural use — hay fields border the stream on both sides (Appendix A). The channel has been heavily modified to improve land drainage and a small pond has been constructed to facilitate water withdrawal for irrigation. The site has poor rearing and spawning capability for salmonids, though threespine sticklebacks were fairly abundant. Substrates in this section of the stream are dominated by fines; no gravels or cobbles are apparent.

Fish habitat within Duck Creek improves considerably downstream of the existing bridge where it becomes protected by mature riparian vegetation comprised of large deciduous and conifers and abundant undergrowth. Throughout this section, which is approximately 270 m in length, the overhead canopy is extensive, providing good cover. Although some sections of the channel are affected by previous ditching there are also small pools that provide fish habitat and in some locations the channel is slightly meandering. There is evidence of previous habitat enhancement activities such as cobble and gravel placement and a large constructed pool. Sedimentation appears to be an ongoing problem: at the time of this site visit the pool was mostly filled by fines and the gravels were moderately embedded. At the time of this assessment we estimated streamflow to be less than 1 L sec^{-1} and this low flow severely restricted habitat availability for fish. At higher flows there appears to be moderate potential for rearing, but only limited potential for spawning.

Duck Creek downstream of Tripp Road appears to offer considerably better habitat. On Duck Creek Farm immediately downstream of Tripp Road two large constructed ponds offer abundant rearing habitat. We observed numerous fish rising to feed in the ponds. The ponds were apparently constructed as part of a fish and wildlife habitat enhancement project. The owner of the farm noted the presence of large cutthroat, as well as frequent otter.

Further downstream, below Broadwell Road, Duck Creek has a meandering morphology as it runs through mature woodlands within Duck Creek Park. There is evidence of considerable habitat enhancement effort here (Appendix A). Salmonids were observed in pools throughout this section of the stream. Rearing and spawning habitat is abundant and of high quality. Habitat availability is considerably greater than higher in the watershed, but still appears to be flow limited.

Conditions for juvenile and adult passage were poor throughout all sections of Duck Creek at the time of this assessment. Even in the lower watershed, where flows were considerably greater than in the project area, flow was insufficient for all but local movements. Although we have not observed conditions during higher flows, we assume that conditions for passage improve considerably during these periods.

In summary, Duck Creek within the project area has instream habitat that is used for rearing by stickleback and salmonids. However, the quality of habitat is generally poor and appears to be limited in part by flow. Substrates are dominated by fines and sedimentation is high. Quality and abundance of fish habitat increase substantially downstream of Tripp Road. Rearing habitat is abundant in some locations such as the ponds in Duck Creek Farm, and spawning gravels are abundant within other locations such as within Duck Creek Park. Although flows are greater with distance downstream from St. Mary Lake, habitat availability nevertheless appears to be limited by flow. Conditions for juvenile and adult fish passage appear to be very flow-limited; during periods of low flow movement is likely restricted and localized.

5.1.3 Fish Life Histories

Long term records of fish presence and migration patterns were not available for this review. However, earlier correspondence with agencies, enquiries to provincial and federal databases, and results from this study indicate that Duck Creek has coho salmon, cutthroat and rainbow trout, and threespine stickleback. The general biology of these species is discussed in Appendix D.

Life history information is summarized in a periodicity table (Table 2). Since life history data specific to Duck Creek were not available we have relied on data from Water Use Plans and professional experience. Fish life histories are remarkably plastic and may vary considerably among watersheds. Minor adjustments to this information may be possible with help from biologists with long-term experience with this system. However, we expect the information to be sufficiently accurate for assessment and planning purposes.

There is no defined inlet stream to St. Mary Lake and Duck Creek is the only outlet stream. We therefore assume that Duck Creek is the primary spawning stream for cutthroat and rainbow trout in the lake. (Littoral spawning has been recorded in some populations of salmonids, but this is generally rare and therefore unlikely to account for a significant portion of spawning habitat for St. Mary Lake salmonids.)

Table 2. Species periodicity table for fish species in Duck Creek. (P = peak, E = emergence)

		Jan				Feb				Mar				Apr				May				Jun				Jul				Aug				Sep				Oct				Nov				Dec			
Species	**Life Stage**	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Cutthroat	Adult migration					x	x	x	x	x	x	x	x	x	x	x	x																																
	Spawning							x	x	x	x	x	x	x	x	x	x																																
	Incubation					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	E	E	E																						
	Rearing	x	x	x	x	x	x	x	x	x	x	x	x	x	x	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	x	x	x	x	x	x	x	x
Rainbow	Adult migration					x	x	x	x	x	x	x	x	x	x	x	x																																
	Spawning							x	x	x	x	x	x	x	x	x	x																																
	Incubation					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	E	E	E																						
	Rearing	x	x	x	x	x	x	x	x	x	x	x	x	x	x	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	x	x	x	x	x	x	x	x
Coho	Adult migration																																			x	x	x	x	P	P	P	x	x	x	x	x	x	x
	Spawning	x	x																																					x	x	P	P	P	x	x	x	x	x
	Incubation	x	x	x	x	x	x	x	x	x	x	E	E	E	E	E																								x	x	x	x	x	x	x	x	x	x
	Rearing	x	x	x	x	x	x	x	x	x	x	x	x	x	x	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	x	x	x	x	x	x	x	x
	Juvenile migration											x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x																						
Threespine stickleback	Spawning														x	x	x	x	x	x	x	x																											
	Incubation															x	x	x	x	x	x	x	x																										
	Juvenile rearing	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	x	x	x	x	x	x	x	x	x	x	x	x
	Adult rearing	x	x	x	x	x	x	x	x	x	x	x	x	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	x	x	x	x	x	x	x	x	x	x	x	x
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
		Jan				Feb				Mar				Apr				May				Jun				Jul				Aug				Sep				Oct				Nov				Dec			

5.2 Changes Likely to Occur and Their Impacts to Fish Habitat

5.2.1 Low-head Dam

Construction of a low-head dam with a low-level outlet for the minimum flows and a fishway to accommodate adult and juvenile movements, will displace some wetted habitat and some riparian habitat. The present habitat values for fisheries resources are minimal at the proposed site of construction for the dam. In effect, an agricultural drainage ditch and beaver dam will be replaced by a concrete structure that provides passage conditions for both juvenile and adult salmonids. Passage conditions will therefore be substantially improved, leading to a net benefit from the proposed project.

Some short-term construction impacts are possible, in the form of sedimentation and erosion. These impacts are mitigable with standard BMPs. Recommendations for mitigation are outlined in Section 6.

5.2.2 Service Road for Dam

Construction and maintenance of the dam requires a service road. The road will extend from Vesuvius Bay Road along the south side of Duck Creek to the dam site. The road will cross a small tributary of Duck Creek adjacent to Vesuvius Bay Road. This tributary functions as agricultural and roadway drainage, and was assessed as fishless on the September 1 field visit. It is possible that fish may periodically use a small portion of the tributary at its confluence with Duck Creek, but this is downstream of the proposed crossing. Since wildlife may utilize the stream as a corridor we have recommended the use of an oversize or open-bottom culvert for the crossing. The rest of the service road is to be built outside the existing riparian area of Duck Creek. We therefore deem there to be no impact to fish habitat associated with the service road.

Some short-term construction impacts are possible, in the form of sedimentation and erosion. These impacts are mitigable with standard BMPs. Proposed mitigation activities are outlined in Section 6.

5.2.3 Upstream Channel Modifications

Some channel modifications are required upstream of the proposed dam to accommodate hydraulic requirements of fisheries and flood control. The channel will need to be widened to ensure sufficient flow from St. Mary Lake to the dam. The present habitat values for fisheries resources are minimal upstream of the proposed dam site. In effect, an agricultural drainage ditch will be widened from its current width of ~3.5m to a width of 4 to 8m. This habitat currently offers very limited rearing potential for salmonids; this is unlikely to change considerably post construction. Passage conditions will likely be improved since this section of stream will remain permanently wetted and have depths sufficient for passage of adult and juvenile salmonids. This change is deemed to provide a net benefit to fisheries habitat from the proposed project.

Some short-term construction impacts are possible, in the form of sedimentation and erosion. Destruction of riparian shrubs is also possible. These impacts will be short-term and are mitigable with standard BMPs. Proposed mitigation activities are outlined in Section 6.

5.2.4 *Downstream Channel Modifications*

Downstream of the dam some sections of the channel must be lowered slightly to accommodate flow from the dam (flows from overcrest and low level outlet). Immediately downstream of the dam the channel must be lowered by up to 0.5m. Construction is limited to ~92m of stream channel downstream of the proposed dam. No excavation is planned beyond this point and any disturbances are expected to be of minor magnitude at most.

The stream channel in this section of Duck Creek currently offers limited rearing and spawning potential for salmonids. Riparian conditions are good, particularly for a stream in an agricultural setting. Some sections of the channel are affected by previous ditching, but there are also small pools that provide fish habitat. A total of four juvenile coho were found between Tripp Road and the proposed dam site. Under current conditions habitat availability for fish is severely restricted by low flows for extended periods during the summer and fall.

Channel modifications will likely improve passage conditions since this section of stream will remain permanently wetted and have depths sufficient for passage of adult and juvenile salmonids, as a result of the minimum flow release. Some minor habitat improvement is planned, including construction of a 7m pool. These changes are deemed to provide a net benefit to fisheries habitat from the proposed project.

Some short-term construction impacts are possible, in the form of sedimentation and erosion. Impacts to riparian shrubs are also possible. These impacts will be short-term and are mitigable with standard BMPs. Proposed mitigation activities are outlined in Section 6.

5.2.5 *Downstream Flows*

The project includes a minimum release of 10% MAD (~8.9 L sec^{-1}) from the dam. This flow release is expected to provide substantial benefits to downstream fish habitat, from the dam site to the outlet of the stream at Duck Bay. We have not attempted to quantify the flow-related changes to fish habitat as this would require a substantial effort that we believe is unnecessary for a project of this scale. Our opinion that the changes will result in a substantial net benefit is shared by all agency and project biologists who have assessed this component of the project. These benefits would extend over a stream length of approximately 3 km.

Currently at the proposed dam site there are extended periods when flow ceases altogether (Figure 6). A minimum flow release will ensure connectivity among habitats, improve rearing and spawning habitat conditions, and improve passage conditions for juvenile and adult salmonids. These changes are deemed to provide a substantial net benefit to fisheries habitat from the proposed project. Negative impacts from the proposed changes in minimum flow are unlikely. The minimum flows are substantially below peak flows so they are unlikely to cause sedimentation or erosion.

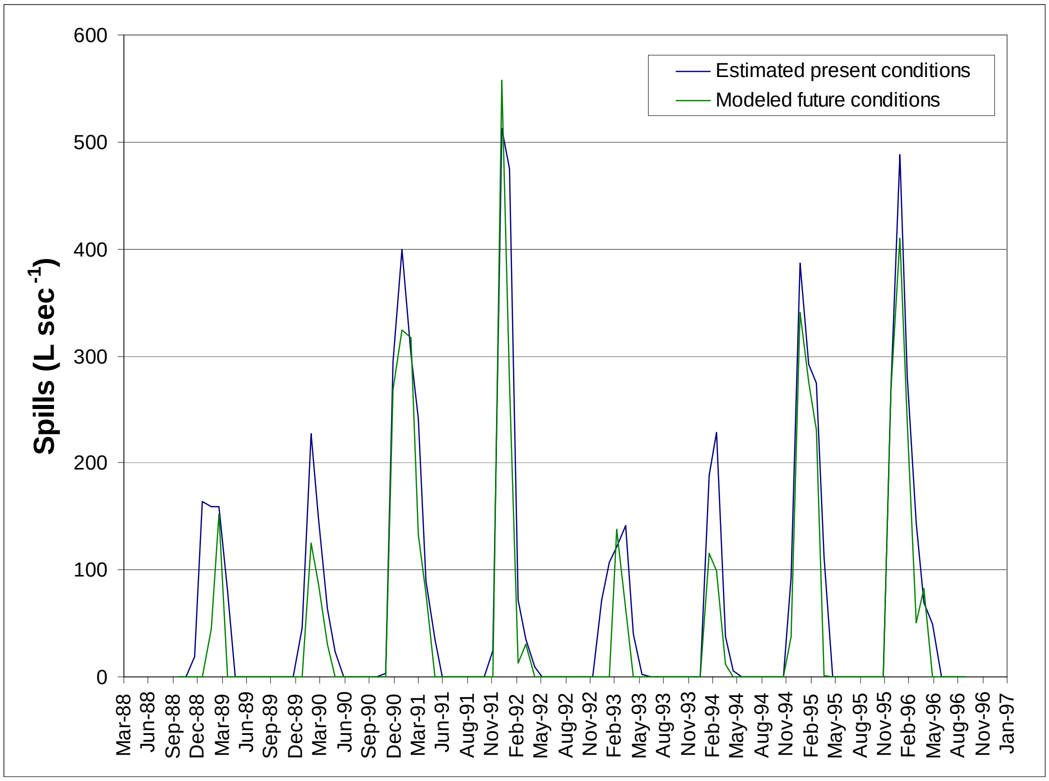

Figure 7. Overcrest spills provide passage conditions for adult and juvenile salmonids. The frequency of these flows has been modeled for present conditions and those anticipated with future water demands. Data provided by Denis Russell, based on data in Hamilton (1998).

Passage to and from the lake is currently regulated by the height of existing beaver dams; passage is only possible when water spills over the beaver dam or humans modify the dam in some way (e.g., destroy a section). As water demands increase in the future, overcrest spills will decline in frequency (i.e., number of days per year), so the question arises whether conditions will be sufficient to provide adequate passage. Figure 7 shows conditions at present and those anticipated under future demands. Under present conditions passage flows are available in late fall through spring. Future demands on water indicate a shrinking in the availability of these flows, particularly in dry years. The change during wet years is minimal.

Fish are often opportunistic in their utilization of streamflow and will take advantage of passage conditions as they arise, provided the flows are within the timing window of their life history needs. For example, rainbow and cutthroat may undertake spawning migrations anytime between February 1 and April 30, but passage conditions may not be required throughout this time. The timing of overcrest spills will likely vary among years, but provided the spills are frequent enough during the migration window the fish will take advantage of the flows and migrate. This likely occurs in the system at present. The pattern of spills in Figure 7 indicates that passage conditions will be retained during the most important time of the adult life stage. Since a dedicated passage structure is planned for juveniles, this life stage will be able to undertake passage during a considerably wider period than at present, which is a net benefit from the project.

NSSWD have have engaged the services of Barry Chilibeck (Northwest Hydraulic Consultants) to review fishway design and provide input as required to ensure that that the fishway will provide the expected benefits for fish passage. Mr. Chilibeck has reviewed the initial design of the fishway and made suggestions for minor modifications that will improve its efficacy. Suggestions include addition of a notch in the weir to concentrate flows, selection of appropriate surfacing for the fishway, and use of alternate construction materials for the fishway baffle. NSSWD will incorporate Mr. Chilibecks suggestions to the extent feasible.

In summary, the proposed project is deemed to result in substantial net benefits to fish and fish habitat in Duck Creek.

6. MITIGATION

NSSWD has agreed to a series of actions to manage and mitigate potential impacts from this project. These actions are standard BMPs for work in and around streams during construction of projects such as that proposed by NSSWD. DFO and MWLAP may have specific comments or BMPs in addition to those suggested below. Additional BMPs specific to the Vancouver Island region are discussed in Ministry of Environment, Lands and Parks (2001) and

1. All environmental approvals must be in place prior to initiating construction.
2. Instream construction should take place within work windows specified by the regulatory agencies. For rainbow and cutthroat trout this is currently August 1 to September 30. Work outside these windows should be approved by DFO or MWLAP.
3. Instream work areas should be isolated to the extent feasible.
4. Flows should be maintained around any instream work sites.
5. Fish should be salvaged from work areas and released downstream.
6. Disturbance to riparian vegetation should be minimized, and replanted with native vegetation where temporary removal is required.
7. All machinery working in or near aquatic habitat must be clean and free of grease, oil, and fuel residues.
8. Refuelling of machinery and washing of buckets and hand tools is not permitted within 20m of aquatic habitat.
9. The contractor will maintain a hydrocarbon spill kit on-site, consisting of absorbent materials and a spill containment boom. A site specific sediment and erosion control plan is to be developed. Sediment and erosion control supplies are to be stored on-site, including polyethylene sheeting, straw bales, stakes, and silt fencing.
10. In the event of a fuel, hydraulic oil, or other spill of construction materials occurs, DFO Habitat staff is to be notified and briefed as to the cause and extent of the spill, and the clean-up efforts undertaken.
11. Filling, dredging, or blasting is not to be conducted within wetted habitat without prior approval or permits. Spoil removed from the footprint of the structure is not to be piled within wetted aquatic habitat. Any spoil piles must be placed in such a manner as to prevent sediment laden water from reaching the aquatic environment.
12. Cement is to be mixed off-site, or if mixed on-site is to be mixed and handled such that no residue or cement laden water reaches aquatic habitat. Cement trucks are not to wash their hoses or delivery chutes on-site.

13. Construction equipment is not permitted within wetted aquatic habitat without prior approval or permit.
14. No water is to be withdrawn from the environment for construction purposes without prior approval.
15. All areas of exposed loose fill are to be covered with geotextile fabric and capped with clean, angular riprap to prevent erosion, as directed by the project engineer.
16. An environmental monitor (EM) is to be provided during construction. The EM will brief the contractor and crew regarding environmental best management practices prior to the start of construction. The EM need not be on site at all times, but should visit with sufficient frequency to direct mitigation activities as required. The EM (or another appropriately qualified person) should supervise all intensive instream and riparian enhancement or rehabilitation.

7. CONCLUSIONS

Our assessment concludes that additional water withdrawal from St. Mary Lake has the capacity to negatively effect fish habitat in the lake. There may be impacts to spawning habitat for smallmouth bass, and to rearing habitat for juvenile bass and salmonids. These impacts are likely to decline substantially through time as macrophytes respond to lower lake levels.

There are three caveats that should also be taken into account when considering whether impacts to fish habitat in St. Mary Lake are within acceptable bounds. The first is that the Westland (1997) impact assessment was based on a water budget and change in lake levels that is now considered to be exaggerated. Hydrologic analysis conducted by Hamilton (1998, 1999) indicates considerably less effect on lake level than that indicated in the Bullock Baur study. For example, even in dry year conditions under future demands Hamilton concludes that lake level will decline less than 0.5m below that observed under current demands. This is considerably less than the decline of >1m indicated in the Bullock Baur water budget (see Table 1). Under normal conditions the change in lake levels will be much less than this (see Hamilton 1998).

The second consideration is that the Westland assessment assumed an immediate change to water levels. If water consumption rates are increased only gradually from current conditions then abrupt alteration of fish habitat is less likely. Lake levels would decline gradually relative to current conditions, which should lessen overall impacts relative to those assumed in the Westland report. Demand is not expected to increase all at once.

The third consideration centers around whether impacts will result in a decline in adult populations. Although the Westland (1997) assessment describes impacts to fish habitat, it is not at all certain that these would translate into a lower productivity fishery. The supply of juvenile bass for recruitment to adult stages appears to be vast, and it is possible that a smaller supply of juveniles will not result in less recruitment to mature life stages. Clearly, the population dynamics (and the mechanisms limiting recruitment to various life stages) of the St. Mary Lake bass population are not known, but it is certainly possible that the population is not limited by juvenile rearing habitat or spawning habitat.

Our assessment concludes that impacts to Duck Creek will be of substantial net benefit to instream fish and fish habitat in the stream. There may be short-term impacts associated with construction of the project, but these are readily mitigable. The net benefit to instream fish habitats is a result of improved flows in the stream, and improved passage conditions. At present, productive capacity throughout the stream appears to be severely flow-limited: there are extended periods in the summer and fall when flow in the stream ceases altogether. Our opinion, that a minimum flow release of ~9 L sec^{-1} will result in a substantial net benefit, is shared by all agency and project biologists who have assessed this project.

How the potential fish habitat gains and losses trade-off against each other is to a large extent a value judgement and ultimately must be decided by regulators. However, we believe that the trade-off is a reasonable one, and one that is justifiable solely within the context of environmental values[1]. St. Mary Lake is dominated by an introduced species, smallmouth bass, whereas Duck Creek represents habitat for indigenous species, rainbow and cutthroat trout, coho salmon, and threespine stickleback. Society and resource managers typically place substantially greater value on native species than introduced species. Since impacts are greatest for smallmouth bass and benefits are greatest for native species, this places greater weight on the habitat gains within Duck Creek. It is our opinion that improvements to fish habitat in Duck Creek are adequate compensation for impacts to lake level changes in St. Mary Lake. This opinion appears to have been shared by agency staff, who in the past have suggested that the project was acceptable provided fish passage was maintained (or improved) and a minimum flow release to Duck Creek was implemented.

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[1] Social and economic values are the motivation for the water withdrawal, but are not considered in the trade-offs here.

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Appendix A
Annotated photographs of habitats in the project area

Appendix B
Summary of water licences on
St. Mary Lake and Duck Creek

Licence No	Stream Name	Purpose	Quantity	Units	Licensee	Licence Status	Priority Date	Issue Date
C028860	St. Mary Lake	Waterworks Local Auth	18250000	GY	CAPITAL REGIONAL DISTRICT ATTN: ENVIRONMENTAL SERV 625 FISGARD ST PO BOX 1000 VICTORIA BC V8W2S6	Current	19631010	0
C030778	St. Mary Lake	Irrigation	50	AF	HUGHES BARBARA 192 VESUVIUS BAY RD SALT SPRING ISLAND BC V8K1K3	Current	19650921	0
C032525	St. Mary Lake	Waterworks Local Auth	45625000	GY	NORTH SALTSPRING WATERWORKS DIST 761 UPPER GANGES RD SALT SPRING ISLAND BC V8K1S1	Current	19670626	0
C035715	St. Mary Lake	Waterworks Local Auth	2007500	GY	NORTH SALTSPRING WATERWORKS DIST 761 UPPER GANGES RD SALT SPRING ISLAND BC V8K1S1	Current	19690421	0
C039721	St. Mary Lake	Enterprise	5500	GD	CEDAR BEACH RESORT 1685 CHANDLER AVE VICTORIA BC V8S1N7	Current	19720131	0
C040376	St. Mary Lake	Domestic	1000	GD	DELMONICO WILLIAM E & BETTY P 1236 NORTH END RD SALT SPRING ISLAND BC V8K1M2	Current	19720413	0
C041670	St. Mary Lake	Enterprise	2500	GD	BLACKBERRY INVESTMENTS LTD. 357 OLD SCOTT RD SALT SPRING ISLAND BC V8K2L9	Current	19730508	0
C041671	St. Mary Lake	Irrigation	5	AF	DELMONICO WILLIAM E & BETTY P 1236 NORTH END RD SALT SPRING ISLAND BC V8K1M2	Current	19730426	0
C043830	St. Mary Lake	Domestic	500	GD	CAROL HOLDINGS LTD (INC 469847) 4344 JERICHO CIRCLE VANCOUVER BC V6R1E9	Current	19730612	0
C047548	St. Mary Lake	Waterworks Local Auth	136875000	GY	NORTH SALTSPRING WATERWORKS DIST 761 UPPER GANGES RD SALT SPRING ISLAND BC V8K1S1	Current	19751008	0
C052527	St. Mary Lake	Domestic	750	GD	MARSHALL MICHAEL K & ANNE 343 LANGS RD SALT SPRING ISLAND BC V8K1N3	Current	19780406	0
C052695	St. Mary Lake	Enterprise	2500	GD	824397 ALBERTA INC 241 LANGS RD SALT SPRING IS BC V8K1N3	Current	19790115	0
C063954	St. Mary Lake	Domestic	500	GD	ANTONIK FRANCES A 171 LANGS RD SALT SPRING ISLAND BC V8K1N2	Current	19850718	0
C065711	St. Mary Lake	Waterworks Local Auth	21169000	GY	CAPITAL REGIONAL DISTRICT ATTN: ENVIRONMENTAL SERV 625 FISGARD ST PO BOX 1000 VICTORIA BC V8W2S6	Current	19680306	0
C065712	St. Mary Lake	Waterworks Local Auth	4867000	GY	CAPITAL REGIONAL DISTRICT ATTN: ENVIRONMENTAL SERV 625 FISGARD ST PO BOX 1000 VICTORIA BC V8W2S6	Current	19700331	0
C065713	St. Mary Lake	Waterworks Local Auth	1703000	GY	CAPITAL REGIONAL DISTRICT ATTN: ENVIRONMENTAL SERV 625 FISGARD ST PO BOX 1000 VICTORIA BC V8W2S6	Current	19731211	0
C065806	St. Mary Lake	Domestic	500	GD	DOVE FRAN 2368 ESPLANADE VICTORIA BC V8R2W2	Current	19880927	0
C065807	St. Mary Lake	Domestic	500	GD	QUICK VERNON R & JENNIFER A 1160 NORTH END RD SALT SPRING ISLAND BC V8K1M1	Current	19880908	0

Licence No	Stream Name	Purpose	Quantity	Units	Licensee	Licence Status	Priority Date	Issue Date
C065827	St. Mary Lake	Domestic	500	GD	BAUMGARTNER OLAF 355 LANG RD SALTSPRING ISLAND BC V8K1N3	Current	19881117	0
C065830	St. Mary Lake	Domestic	500	GD	MITCHELL ANGUS C 375 LANGS ROAD SALT SPRING ISLAND BC V8K1N3	Current	19881121	0
C070379	St. Mary Lake	Domestic	500	GD	TAYLOR WAYNE A 1186 NORTH END RD SALT SPRING ISLAND BC V8K1M1	Current	19890511	0
C101050	St. Mary Lake	Waterworks Local Auth	80000000	GY	NORTH SALTSPRING WATERWORKS DIST 761 UPPER GANGES RD SALT SPRING ISLAND BC V8K1S1	Current	19880304	20011101
"	St. Mary Lake	Storage	300	AF	NORTH SALTSPRING WATERWORKS DIST 761 UPPER GANGES RD SALT SPRING ISLAND BC V8K1S1	Current	19880304	20011101
C101052	St. Mary Lake	Storage	15	AF	BYRON KENNETH I PO BOX 584 GANGES SALT SPRING ISLAND BC V8K2W2	Current	19871201	20011101
"	St. Mary Lake	Irrigation	15	AF	BYRON KENNETH I PO BOX 584 GANGES SALT SPRING ISLAND BC V8K2W2	Current	19871201	20011101
C101056	St. Mary Lake	Domestic	500	GD	BURROWS ALAN & JOYCE M 1120 NORTH END RD SALT SPRING ISLAND BC V8K1M1	Current	19890224	19940119
C101075	St. Mary Lake	Irrigation	2.75	AF	EAGLE CHARLES J 176 TRIPP RD SALT SPRING ISLAND BC V8K1K5	Current	19900329	19941018
"	St. Mary Lake	Storage	2.75	AF	EAGLE CHARLES J 176 TRIPP RD SALT SPRING ISLAND BC V8K1K5	Current	19900329	19941018
C103160	St. Mary Lake	Domestic	500	GD	STEPANIUK JOHN & MARY 820 MAXWELL RD COMP 1 SALTSPRING ISLAND BC V8K2H7	Current	19910906	19940825
"	St. Mary Lake	Stockwatering	100	GD	STEPANIUK JOHN & MARY 820 MAXWELL RD COMP 1 SALTSPRING ISLAND BC V8K2H7	Current	19910906	19940825
C104325	St. Mary Lake	Storage	25	AF	CAPITAL REGIONAL DISTRICT ATTN: ENVIRONMENTAL SERV 625 FISGARD ST PO BOX 1000 VICTORIA BC V8W2S6	Current	19920214	20011101
"	St. Mary Lake	Waterworks Local Auth	4563000	GY	CAPITAL REGIONAL DISTRICT ATTN: ENVIRONMENTAL SERV 625 FISGARD ST PO BOX 1000 VICTORIA BC V8W2S6	Current	19920214	20011101
C105603	St. Mary Lake	Domestic	500	GD	GREENBERG ESTHER F 4462 MARGUERITE ST VANCOUVER BC V6J4G6	Current	19921103	19931014
C109911	St. Mary Lake	Domestic	500	GD	LEWIS MARTIN S 135 RICHARD FLACK RD SALT SPRING ISLAND BC V8K1N4	Current	19950630	19950828
C110227	St. Mary Lake	Domestic	500	GD	HAZENBOOM HANS & ELLEN P PO BOX 374 SALTSPRING IS BC V8K2W1	Current	19950925	19951019
C110228	St. Mary Lake	Domestic	500	GD	PRENDERGAST JAMES T 131 ACHESON RD SALTSPRING IS BC V8K1M3	Current	19950925	19951019
C112527	St. Mary Lake	Domestic	500	GD	LEDERMAN JEFFREY A 322 LANGS RD SALTSPRING-IS BC V8K1N3	Current	19970725	19990128

Licence No	Stream Name	Purpose	Quantity	Units	Licensee	Licence Status	Priority Date	Issue Date
C114780	St. Mary Lake	Enterprise	2500	GD	824397 ALBERTA INC 241 LANGS RD SALT SPRING IS BC V8K1N3	Current	19990816	20000510
C114859	St. Mary Lake	Domestic	500	GD	JANZEN THEODORE D AND JANE M 333 STARK RD SALTSPRING ISLAND BC V8K1M4	Current	19991115	20000112
C116807	St. Mary Lake	Domestic	1000	GD	CUPPLES RICHARD B C/O 2521B NORTH END RD SALT SPRING ISLAND BC V8K1A9	Current	19480114	20011115
"	St. Mary Lake	Irrigation	1.4	AF	CUPPLES RICHARD B C/O 2521B NORTH END RD SALT SPRING ISLAND BC V8K1A9	Current	19480114	20011115
"	St. Mary Lake	Stockwatering	1380	GD	CUPPLES RICHARD B C/O 2521B NORTH END RD SALT SPRING ISLAND BC V8K1A9	Current	19480114	20011115
C116808	St. Mary Lake	Domestic	500	GD	STOBBE KENNETH A AND SHEILA S 37191 INDIAN RD ABBOTSFORD BC V3G2H6	Current	19480114	20011115
"	St. Mary Lake	Irrigation	0.7	AF	STOBBE KENNETH A AND SHEILA S 37191 INDIAN RD ABBOTSFORD BC V3G2H6	Current	19480114	20011115
"	St. Mary Lake	Stockwatering	240	GD	STOBBE KENNETH A AND SHEILA S 37191 INDIAN RD ABBOTSFORD BC V3G2H6	Current	19480114	20011115
C117771	St. Mary Lake	Irrigation	2	AF	LOGAN JEFFREY K 5507 STELLAR AVE NORTH VANCOUVER BC V7R4N3	Current	19720425	20021203
C117772	St. Mary Lake	Irrigation	2	AF	BRENT LESLIE J BOX 254 GANGES PO SALT SPRING ISLAND BC V8K2V9	Current	19720425	20021203
C117773	St. Mary Lake	Irrigation	2	AF	LOGAN DARYL D RR 3 MANSFIELD ON L0N1M0	Current	19720425	20021203
C117774	St. Mary Lake	Irrigation	2	AF	LOGAN JOY O 12 - 14045 NICO WYND PL SURREY BC V4P1J2	Current	19720425	20021203
C117775	St. Mary Lake	Domestic	500	GD	LOGAN JOY O 12 - 14045 NICO WYND PL SURREY BC V4P1J2	Current	19720425	20021203
C117776	St. Mary Lake	Domestic	500	GD	LOGAN JEFFREY K 5507 STELLAR PL NORTH VANCOUVER BC V7R4N3	Current	19720425	20021203
C118083	St. Mary Lake	Domestic	500	GD	PREDDY HUGH W AND KAREN B 108 LANGS RD SALT SPRING ISLAND BC V8K1N2	Current	19730816	20030226
C118084	St. Mary Lake	Domestic	500	GD	HALTRECHT ANNA J 104 LANGS RD SALT SPRING ISLAND BC V8K1N2	Current	19730816	20030226
C118560	St. Mary Lake	Domestic	500	GD	STAFFORD JANE E 142 RICHARD FLACK RD SALT SPRING ISLAND BC V8K1N4	Current	20030522	20030710
C118582	St. Mary Lake	Domestic	750	GD	STEELE DARLENE S 130 RICHARD FLACK RD SALT SPRING ISLAND BC V8K1N4	Current	20030619	20030710
F021380	St. Mary Lake	Domestic	1000	GD	ALLAN MARIANNE ET AL 150 MAYCOCK RD SALT SPRING ISLAND BC V8K1N2	Current	19670608	0
F046776	St. Mary Lake	Enterprise	1500	GD	TOOLE MARK L & DEBORAH P 1450 NORTH END RD SALT SPRING ISLAND BC V8K1M5	Current	19720412	0

Licence No	Stream Name	Purpose	Quantity	Units	Licensee	Licence Status	Priority Date	Issue Date
F047043	St. Mary Lake	Enterprise	3500	GD	EILERS HAROLD 1170 NORTH END RD SALT SPRING ISLAND BC V8K1M1	Current	19700707	0
C035157	Duck Creek	Irrigation	2	AF	CAMERON-CHAPPELLE CHERIE ANNE 10513 155A ST SURREY BC V3R4K6	Current	19690517	0
C105308	Duck Creek	Conserv.-Stored Water	0.25	AF	WILCOX JOHN D & LYNDA A 134 TRIPP RD SALT SPRING ISLAND BC V8K1K5	Current	19920909	19940517
"	Duck Creek	Conserv.-Stored Water	0.25	AF	WILCOX JOHN D & LYNDA A 134 TRIPP RD SALT SPRING ISLAND BC V8K1K5	Current	19920909	19940517
C049476	Duck Creek	Irrigation	12	AF	REIMER ALLAN & KATHLEEN 196 TRIPP RD SALT SPRING ISLAND BC V8K1K5	Current	19760824	0
"	Duck Creek	Irrigation	12	AF	REIMER ALLAN & KATHLEEN 196 TRIPP RD SALT SPRING ISLAND BC V8K1K5	Current	19760824	0
C049477	Duck Creek	Storage	12	AF	REIMER ALLAN & KATHLEEN 196 TRIPP RD SALT SPRING ISLAND BC V8K1K5	Current	19760824	0
"	Duck Creek	Storage	12	AF	REIMER ALLAN & KATHLEEN 196 TRIPP RD SALT SPRING ISLAND BC V8K1K5	Current	19760824	0
C045748	Duck Creek	Irrigation	2	AF	WILCOX JOHN D & LYNDA A 134 TRIPP RD SALT SPRING ISLAND BC V8K1K5	Current	19740822	0
C045749	Duck Creek	Storage	2	AF	WILCOX JOHN D & LYNDA A 134 TRIPP RD SALT SPRING ISLAND BC V8K1K5	Current	19740822	0

Appendix C
Summary of site card data for the project area

Site	Date	UTM	Mean Channel Width (m)	Mean Wetted Width (m)	Gradient (%)	Stage	Residual pool depth (m)	Substrate		D95 (cm)	D (cm)	Stream morph	Stream pattern
								Dominant	Subdominant				
1	1/Sep/04	10 460462N 5413897E	3.5	1.2	0	Low	0.5	fines		na	na	agricultural ditch	straight
2	1/Sep/04	10 460380N 5413825E	3.7	1.2	< 1%	Low	0.4	fines	gravel	40	60	riffle-pool	straight
3	1/Sep/04	10 460270N 5413804E	2.6	1.3	< 1%	Low	0.4	fines	gravel	20	25	riffle-pool	sinuous

Site	LWD abundance	Riparian Vegetation		Cover	Notes on fish habitat	Wildlife observations
		type	stage			
1	none	agricultural pasture	grass - shrubs	overhanging veg > instream veg > SWD	poor rearing and spawning habitat for salmonids, though migration possible at higher flows	hedgerow birds, evidence of beaver, amphibians likely
2	none	conifer-deciduous	young forest	overhanging veg > instream veg > SWD	this section of the creek is still essentially a ditch, showing signs of recent and former excavation, evidence of habitat improvements (e.g., small boulder and gravel), narrow but relatively mature riparian fringe, some rearing potential for salmonids, limited spawning potential, high sedimentation and infiltration	sharp shinned hawk, amphibians, hedgerow birds, nesting potential
3	few	deciduous	young forest	overhanging veg > instream veg = SWD = pool > boulder = LWD	moderate rearing potential (outplanted coho fry are rearing here), low spawning potential, placed gravels are patchy and moderately embedded, flow estimated at <1 L/sec	hedgerow birds, evidence of beaver, amphibians likely

Appendix D
General Biology of Fish Species in Duck Creek and St. Mary Lake

Coastal Cutthroat Trout (*Oncorhynchus clarki clarki*)

The two main subspecies of cutthroat trout in Canada are the coastal and westslope forms. The coastal cutthroat is the most abundant and most widely distributed of any of the cutthroat trout subspecies. It occurs from northern California to Prince William Sound, Alaska, and inland to the Coast and Cascade mountain ranges. Among coastal populations there are three distinct life history forms: an anadromous form, a potadromous form, and a non-migratory form that resides in small streams and headwater tributaries.

Sea-run cutthroat trout spawn in tributaries of small stream systems and in small tributaries of moderate-size low gradient rivers. The spawning period for anadromous coastal cutthroat can extend from December through May. The peak spawning period in British Columbia is February.

Spawning takes place in riffles 15–45 cm deep in areas of low gradient. The fish choose clean, pea-sized gravel to build their redds, often near deep pools. Spawning activity occurs throughout the day and night, and may extend over a period of 2–3 days. Spawning apparently takes place only in small, gravelly streams. On the spawning grounds males court the females and are aggressive toward other males. Both males and females will drive off other females that attempt to dig too close to a redd being dug or spawned in. The female prepares the redd by lying on her side and thrashing her tail to create a depression in the gravel. This is usually at least 30 cm in diameter and 12 cm deep. When the nest is complete the female settles in the nest, head and tail curved upward. The male swims to her side, the fish gape and quiver, and eggs and sperm are released. The eggs fall into the interstices between the gravel at the bottom of the redd. Other males may participate in fertilization also. After spawning the female covers the eggs with up to 15 cm of gravel. Males often spawn with more than one female.

As with all salmonids female fecundity varies with body size; reports vary from 226 eggs for a 20 cm long female to 4,420 eggs for a 43 cm fish. Few female sea-run cutthroat mature before 4 years, and first-time female spawners have been observed to be as old as 5 or 6 years old, in Washington and Alaska. In many populations some individuals return from the sea but do not mature sexually. These sexually immature fish return to the sea and migrate to freshwater a second time before spawning. The proportion of individuals with this characteristic varies among populations, but may be as high as 50% in some Alaska populations.

During spawning, anadromous coastal cutthroat experience weight loss of up to one-third their body weight, yet many of the spawned-out fish manage to migrate back to the sea and return for subsequent spawning. In Sand Creek Oregon, 39% of individuals returned to spawn a second time, 17% returned a third time, and 12% returned a fourth time. The return of adults to the sea varies with latitude, but generally occurs in late March or early April.

Eggs of sea-run cutthroat incubate about 6–7 weeks before they hatch, and the alevins remain in the gravel for about another 2 weeks. Peak emergence therefore occurs in mid-April. Fry emerge when the yolk sac is fully absorbed, and they move into low-velocity margins, backwaters, and side-channels, where they remain throughout the summer. Cutthroat trout juveniles have habitat requirements that are similar to coho juveniles, which often compete more effectively for these habitat types. Residence time before seaward migration varies considerably. Most juveniles smolt at the age of 2–4 years, although some have smolted as early as 1 year and as late as 6 years. The timing of seaward migration varies with latitude, peaking in mid-May in Washington and Oregon, but not until late May or early June in Alaska. Ocean habitats also vary. Some individuals remain in estuarine habitats while others move further offshore. In general, cutthroat are distributed in inshore waters.

Some sea-run cutthroat may overwinter in the marine environment, but most return to fresh water the same year that they migrate to sea. Two distinct migration times have been noted for sea-run cutthroat returning to freshwater. Early-entering stocks typically return to freshwater from July to November, with peak returns occurring in September and October. The return of late-entering stocks typically peaks in December and January, but continue through March. Early-entering stocks tend to be found in large streams, whereas late-entering stocks tend to occur in small streams that flow directly into the sea.

Potadromous Cutthroat in Streams.— Many of the larger rivers within the range of coastal cutthroat have resident cutthroat populations that exhibit migratory behaviours similar to the sea-run cutthroat, except that these potadromous individuals use mainstem river habitats in the same way as sea-run stocks use the sea. The life history of potadromous cutthroat in streams is very similar to that of sea-run stocks.

Potadromous Cutthroat in Lakes.— The life history of potadromous cutthroat in lake-dwelling populations is also very similar to that of sea-run stocks, although movement into spawning tributaries may occur later. First-time spawning may occur at 3 years, but is more commonly at 4 years. Fish subsequently spawn every year. Both inlet- and outlet-spawning populations are known and may co-occur in the same lake.

After emergence coastal cutthroat spend 1–3 years in the tributaries before migrating to lakes. Most of the information on this life history form has come from studies of the fish while in lake environments. When cutthroat are the only salmonid species in a lake, their habitat use may be very broad. However, when they co-occur with Dolly Varden or rainbow trout there can be segregation into distinct habitats.

Non-migratory Cutthroat.— Coastal cutthroat trout that inhabit small headwater streams seldom grow larger than 150-200 mm in total length. Resident cutthroat in headwater streams usually mature at an early age and seldom live long.

Headwater populations exhibit only limited instream movement. After emerging from the gravel, young fish reside in the margins, side channels, and backwaters within the vicinity of the redds. They may drift short distances downstream, but generally remain in these habitats through the first summer. At the end of summer fish may move into more secure overwintering habitat, but overall seasonal movements are small.

Stream-resident cutthroat are primarily drift feeders and reside at the head of pools, under overhanging rocks, or root wads.

Rainbow Trout (*Oncorhynchus mykiss*)
Rainbow trout are considered to be the form from which all other Pacific *Oncorhynchus* species evolved. Like cutthroat, rainbow trout are a highly variable species. Populations in different watersheds may look very different, and often go by different common names. Yet it is now accepted that rainbow and steelhead trout represent only a single species, not the 16 species initially accepted by ichthyologists of the early 1900s. The native range of the rainbow trout was the eastern Pacific Ocean and fresh water, mainly west of the Rocky Mountains, from northwest Mexico, to the Kuskokwim River, Alaska. The species has been very widely introduced throughout North America. Rainbow trout are distributed as natural populations in all regions of British Columbia. In B.C. there are two reasonably distinct forms of *Oncorhynchus mykiss,* the coastal rainbow trout, and an interior form called the redband rainbow trout. Steelhead are an anadromous life history form of the coastal rainbow trout. The coastal rainbow and steelhead trout are found in the coastal regions of British Columbia west of the coastal (Cascade) mountain range, as well as in coastal regions from California to Alaska.

Rainbow trout are basically spring spawners. They spawn in smaller tributaries of their rivers, or inlet or outlet streams of their lakes, from March to August but mainly from mid-April to late June. The usual site chosen is a bed of fine gravel in a riffle above a pool. Males are aggressive on the spawning grounds and drive other males away from a nest occupied by a female. Each digging female is usually attended by more than one male but a larger one is dominant and more active in courtship. The female digs a redd in the gravel by turning on her side and beating her tail up and down. In this way she excavates a pit that is longer and deeper than her body. Nest building occurs during day and night. When ready to spawn the female rests near the bottom of the nest, the dominant male quickly moves alongside, their bodies are pressed close together, both fish gape, arch the body, vibrate, and the eggs and sperm are released over a few seconds. Often two males participate in the fertilization of eggs. Immediately the female begins digging at the upstream edge of the nest and the eggs are covered by the displaced gravel. Females dig and spawn in several nests with the same male or other males, depositing as many as 800–1000 eggs in a redd. Average fecundity in the interior of BC has been measured at more than 4000 eggs.

Eggs take approximately 4–7 weeks to hatch, and alevins take an additional 3–7 days to absorb the yolk before becoming free swimming. The timing of emergence varies considerably among regions and depends on environmental factors and when spawning occurs. Fry commence feeding about 15 days after hatching.

Sexual maturity is achieved as early as 1 year by males to as late as 6 years by females. In general, age of maturation is 3–5 years, with males often maturing a year younger than females. If food and other factors are suitable, most mature individuals spawn every year. Some individuals have been known to spawn in as many as 5 successive years. Life expectancy can be as low as 3 or 4 years in many stream and lake populations, but that of steelhead is often 6–8 years.

The habitat of stream-dwelling rainbows is usually small to moderately large, but shallow rivers with moderate flow and gravel bottoms, of the pool-riffle type. In general, rainbow trout feed on various invertebrates including plankton, larger crustaceans, insects, snails, and leeches. Depending on size, other fishes may also be important. Rainbow trout are subject to predation in western streams by other trouts, chars, and coho salmon smolts. Young rainbow trout potentially compete with all other salmonids for food.

Coho Salmon (*Oncorhynchus kisutch*)

Coho salmon are widely distributed in commercially harvestable quantities throughout their natural range, from the east coast of Asia in the Sea of Japan, around the Bering Sea to Alaska, and south along the North American coast to California. In most areas of the North Pacific, coho occur in small numbers compared to other species of Pacific salmon, and represent less than 10% of the total catch.

The basic life history pattern for this species begins as adult salmon migrate from the sea into streams to deposit their eggs in gravel. Adults die after spawning. The eggs incubate during winter in the gravel, and in the spring free-swimming fry emerge. The fry take up residency in the stream for a year or more, migrate to sea as smolts, and then begin their rapid growth phase. After eighteen months or more at sea, the now maturing adults travel hundreds of kilometres across ocean waters, up streams, and through lakes to return to their natal streams. Within this basic pattern there are a great many variations that have evolved in response to opportunity and selective pressures.

Coho begin to mature during the summer after one winter at sea and arrive at their rivers of origin during late summer and autumn. In some case the journey is a short one along coastal routes, but in many other instances the spawning run may take one to two months and cover many hundreds of kilometres of open ocean. In general, the higher the latitude, the earlier the spawning time; in British Columbia the normal timing is September through October. If conditions (flow, temperature, etc.) in the stream are unsuitable, the fish will often mill about in the vicinity of the stream mouth, sometimes waiting weeks or even months for conditions to change. Coho normally migrate when water temperature is 7.2 °C – 15.6 °C, the minimum depth is 18 cm, and the water velocity does not exceed 2.44 m/s. This pattern of migration allows coho to reach very small headwater tributaries where good spawning and rearing conditions may be found.

Coho are capable of surmounting considerable physical obstacles: vertical leaps of more than 2m are possible. If they repeatedly fail to clear an obstacle, fish drop back and spawn downstream in whatever sites are available. Coho are able to reach locations that may be inaccessible to other salmon, and then share these areas with only migrant steelhead or perhaps resident cutthroat trout. These small headwater streams generally provide cool, clear, well-oxygenated water, with stable flows that are ideal for incubation and subsequent rearing.

Throughout their normal range, the majority of coho mature in their third year of life, having spent about four to six months in incubation and up to fifteen months rearing in freshwater, followed by a sixteen-month growing period at sea. There are, however, many variations to this normal pattern. For example, in some populations fish may spend an additional year rearing in freshwater, and in many populations some males may mature precociously ("jacks") and return to spawn after only four to six months in the sea.

During the early freshwater and marine stages of their life history there is no apparent external phenotypic difference between male and female coho. However, with the onset of maturity the fish develop markedly different secondary sexual characteristics. In male coho, the upper jaw forms an elongated hooked snout and the teeth become greatly enlarged. The hook may be of sufficient size to prevent the mouth from closing. The color of the spawning male is generally brighter than that of the female. In females, the jaws also elongate, but the development is less extreme, and the color of females is more subdued. There is a tendency for males to be slightly bigger on average than females. Coho captured at sea are mostly silvery-coloured on their sides and ventral surfaces. The dorsal surface is a dark metallic blue and there are irregular black spots on the back and upper lobe of the caudal fin. As spawning time approaches, the males become darker, and the dorsal surface, head, and ventral surface turn bluish green. The sides of the males develop a broad red streak, which in some populations is very bright. Females and jacks are not nearly as brightly coloured.

The spawning season for most coho populations is between November and January, however, spawning timing is highly variable. When the fish reach the spawning grounds the female selects a nest site. Once she has chosen a site, a female will defend it against other females. This first site may not be the only one the female uses. The female digs a depression with violent flexes of the body and tail over the gravel on the selected site. Digging activity may last as long as five days. During nest construction the female may be attended by several males. Usually one becomes dominant, stays close to the female, and attempts to drive off other males. When the nest is completed the dominant male swims closely alongside the female, and with mouths agape, both bodies quiver, and the sperm and eggs are deposited simultaneously. When the spawning act is completed, the female immediately moves upstream and performs another digging movement. The eggs are buried in about a minute, at the same time that a new depression is created slightly upstream. Successive spawnings take place in a series of nests, each slightly upstream of the earlier one.

The length of time required for eggs to incubate in the gravel is largely dependent on temperature. Time from hatching, through yolk absorption, to fry emergence is also dependent on temperature. Fry emerge from the gravel when their yolk sacs are fully absorbed, and may congregate in loose schools. After emergence, the fry continue to hide in gravel and under large stones during daylight, but within a few days they progress to swimming close to the banks, taking advantage of any cover that is available. As young juveniles the most productive habitats are quiet backwaters, side channels, and small creeks, especially with overhanging vegetation. As they become older, juveniles move progressively into areas of higher velocity in midstream and on the stream margins. The majority of coho rear in streams where they set up territories. They are found in both pool and riffle habitat, although they are best adapted to holding in pools. Once territories are established, coho fry may remain in the same locality for relatively long periods.

The migration of coho downstream towards to sea begins in spring. Factors that tend to affect the time of migration include: body size, flow conditions, water temperature, dissolved oxygen levels, day length, and the availability of food.

During the warmer summer months coho are found widely distributed throughout the northern Pacific. However, many coho do not undertake long migrations and remain in inshore waters.

Threespine stickleback (*Gasterosteus aculeatus*)

Threespine sticklebacks form a large group, made up of thousands of phenotypically diverse populations. Sticklebacks are usually regarded by fishers and fishery managers as forage fish for salmonids, but their extreme diversity has been of considerable interest to scientists.

Typically sticklebacks are small (usually 35-55 mm at maturity) fish that are abundant in coastal marine and freshwater throughout the northern hemisphere. Marine sticklebacks are phenotypically similar throughout their range, whereas freshwater sticklebacks are ecologically, behaviourally and morphologically extremely variable. In general, *G. aculeatus* has a laterally compressed body and delicate pectoral and caudal fins. Individuals in most populations are well-armoured—sticklebacks get both their Latin and common names from different aspects of their armour. Sticklebacks have retractable pelvic and dorsal spines, and their bodies are covered with calcified lateral plates. Freshwater populations are highly variable in extent of armour but generally have many fewer lateral plates than the marine form. Body color also varies considerably, from silvery to mottled green and brown. Sexually mature males develop bright red throats in most populations, although in a few freshwater populations males turn completely black instead.

Sticklebacks are generally sexually mature after one year and rarely live beyond two years. There is considerable sexual dimorphism: reproducing males tend to be bigger on average than gravid females, though this can vary among populations. Large male size enables greater nest protection and territory defence. Typical fecundity is about 30-40 eggs per clutch for a small gravid female and may be greater than 300 for a large female. Females produce several clutches per season, usually in close succession if food availability is high.

Males are the sole providers of parental care. In the spring, they acquire territories in the littoral region where they build nests and mate (sometimes with many females). They often nest in less than 1 m of water on submerged logs, in shallow bays with gravel or rocky substrates, and on firm muddy substrate. Because preferred spawning habitat is not uniformly distributed in the littoral zone, nesting males are clumped in their distribution.

Following fertilization, eggs take approximately 7 - 10 days to hatch, depending on temperature. During this time males actively aerate the eggs by thrusts of their pectoral fins; embryos die if inadequately aerated. Male sticklebacks vigorously defend their nests and territories from invaders (often other sticklebacks) and continue to defend their young for about a week after they hatch. The young then disperse into the littoral vegetation where they feed under cover.

Diets consist of snails, clams, dragonfly nymphs, amphipods, chironomids, or plankton. These invertebrates are found among a variety of substrates including plants, rocks or mud. Lake and stream-dwelling sticklebacks have similar life histories, but different habitat requirements.

Smallmouth Bass (*Micropterus dolomieui*)
Smallmouth bass spawning occurs in the spring, and is initiated by an increase in water temperature. Nest construction may begin at 13°C, and egg deposition reported as occurring when water temperatures are between 16°C and 18°C.

Males provide all parental care. In the spring, they acquire territories in the littoral region where they build nests and mate (sometimes with many females). Nests are built in areas sheltered from wind and wave action. Preferred water depths range of 1m to 5m, although some nests may be constructed outside this range. The upper portion of the nest construction range is preferred over the deeper portion of the range. Spawning substrate preference is reported as gravel/cobble mixture, followed by silt or mud, boulder or rock, and finally detritus and vegetation if other substrates are unavailable. Shoal areas with large boulders and gravel are also reported as good spawning habitat. Gently sloping bathymetry is preferred over steeper areas. There is a strong tendency for males to return to within 20 m of their previous year's nest site, and over 80% of male spawners renest within 200 m of their previous nest site.

Male smallmouth bass defend juveniles within the nest area for approximately two to three weeks post-hatching, then gradually decrease their protective behaviour, finally abandoning the nest at the end of this period. At this point the young leave the nest area and seek out appropriate rearing habitat.

Exploitation of different littoral habitat components by juvenile bass varies with life history stage, season, time of day, and environmental factors such as temperature and light transmission. Cover is used for resting, escape, and feeding activities primarily to reduce predation risk from piscivorous fish, birds, amphibians, and other predators. Cover provides secure areas within which fish can rest with minimal risk of predation, and is used by juveniles as a place of refuge during feeding. Cover can take the form of submerged woody debris, interstitial spaces within areas of cobble or boulder substrate, or the stems of aquatic vegetation. The distance between the feeding fish and cover is an indication of how secure the fish are from predation during any particular time, as well as the relative abundance of food at different distances from cover. During the first few weeks after their emergence juveniles are extremely vulnerable to predation, and thus require forage at or close to their primary source of cover. Areas of aquatic macrophyte growth are heavily exploited by juvenile smallmouth bass during this period. At older stages juvenile bass will rely less upon macrophytes, and instead aggregate in schools during feeding activity to reduce predation risk. Substrate composition is reported to be predictive of juvenile habitat quality, with coarse substrates of gravel, cobble and boulders preferred over areas where silt or organics are the dominant substrate type.

Smallmouth bass utilize different types of forage as they increase in size during their first year. Larval fish are planktivorous, feeding on zooplankton during the first two to five weeks after swim up, depending on their growth rate. The diet of juveniles shifts from plankton to immature aquatic, terrestrial drift, and benthic invertebrates as the fish reach about 20mm in total length, then fish and crustacea replace invertebrates as the dominant prey type when juveniles reach approximately 50 mm in total length. Tadpoles, fish and amphibian eggs, and plant material are reported as forage items as well.

Smallmouth bass are warmwater fish and are reported to prefer a temperature range of 20°C to 26°C during the summer months. The upper lethal limit for these fish is reported as 35°C