Ecological Strategies for the Cowichan Estuary

Report to the Ministry of Water, Land and Air Protection

Cowichan Community Land Trust
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Executive Summary

This report is a summary of a workshop and literature review undertaken by the Cowichan Community Land Trust Society (CCLT) on the ecological health of the Cowichan Estuary. The CCLT is a non-profit organization whose purposes are to conserve, protect and enhance the quality of the human and natural environment in the Cowichan Valley. The purpose of the workshop and literature review was to gather as much in information as possible on the current ecological state of the estuary and to consult with local residents, business, agencies and organizations on the restoration and monitoring strategies they felt would ensure the environmental health of the estuary.

The Cowichan Estuary is located on the east coast of Vancouver Island within the Cowichan Valley. It is the estuary of the Cowichan and Koksilah Rivers that provide the major source of fresh water for Cowichan Bay. This area has historically provided the Cowichan First Nations with many essential resources and was developed through European settlement to accommodate logging, agriculture and fishing industries. To address these human impacts on the sensitive ecology of the estuary, the *Cowichan Estuary Management Plan* was developed through the 1970s and early 1980s and was completed in 1987. This project has focused on the Management Plan Area delineated in the *Cowichan Estuary Management Plan*.

The literature review was undertaken to determine the volume and extent of biological information on the Cowichan Estuary in order to assess the current priorities for restoration and monitoring programs. Biological studies were identified through contacts and referrals from individuals and organizations and through a posting on the CCLT website. An annotated bibliography was developed and provided to workshop participants to inform group discussion.

The workshop, entitled 'Ecological Restoration Strategies for the Cowichan Estuary', focused on community and stakeholder participation by bringing together members of the local and scientific community. Representatives from a number of interest groups associated with the estuary as well as members of the general public were invited to attend the one-day workshop.

Participants identified water quality and habitat loss as the primary issues facing the Cowichan Estuary. The importance of these two issues is also reflected in research findings that identify water quality issues and habitat loss as having the most influence on the future health of the Cowichan Estuary.

Water quality restoration and monitoring programs recommended by participants focus on identifying and ameliorating PCP contamination and their residual effects as well as reducing pollution from sewage and ballast dumping. Suggested strategies include replacing the current sewage treatment facility that serves the village of Cowichan Bay and providing facilities for ballast dumping, as well as enforcing legislation.

Recommendations to address habitat loss include eelgrass restoration and monitoring programs that inventory, augment and monitor potential and existing eelgrass beds and define limiting factors. Wood waste surveying and reduction was also suggested as a means to monitor impacted substrate habitat for potential restoration. Invasive species were also identified as an increasing threat to productive habitat. Restoration and monitoring programs developed by participants included inventory and removal of targeted invasive species, as well as ongoing monitoring. These suggested programs would be well suited to a stewardship approach in which volunteers from the local community could implement restoration programs and carry out monitoring activities with appropriate training, support and guidance. Public awareness and education programs were also identified as a necessary strategy to reduce undesirable human impacts on this sensitive habitat.

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1. Introduction

1.1 The Cowichan Estuary

The Cowichan Estuary is located at the west end of Cowichan Bay on the east coast of Vancouver Island. It is the common estuary of the Koksilah and Cowichan Rivers. The Koksilah River begins at Waterloo Mountain, south of the Cowichan Valley and the Cowichan River originates at Cowichan Lake. These two rivers provide most of the fresh water inflow to Cowichan Bay.

The Cowichan Estuary is the traditional land of the Cowichan people, with European settlement beginning in the late 1800s. Before the Esquimalt and Nanaimo Railway was built in 1886, Cowichan Bay (then Harrisville) was the area's first port. Fishing, agriculture and logging have been the primary land uses within the estuarine intertidal and backshore areas. As well, the shallow water, marshes and tidal flats of the Cowichan Estuary provide some of the most biologically productive habitat essential to migrating waterfowl, anadromous fish and other species.

This area has changed greatly over the years as a result of human activities in the marine environment, the surrounding shores and intertidal flats, and in the watershed. In response to these changes, the *Cowichan Estuary Environmental Management Plan* (CEEMP) was developed through the late 1970s and was completed in 1987 to provide a framework for future management of the estuary. The management plan area encompasses multiple jurisdictions and land-uses (Map 1), including the village of Cowichan Bay, First Nations traditional lands, industrial leases of Crown lands and parcels under the management of the municipality of North Cowichan, the Cowichan Valley Regional District, national and international conservation organizations and private landholders. This multiplicity of tenure, jurisdictions and interests means that community and stakeholder participation is essential for sound environmental management.

1.2 The Cowichan Community Land Trust Society

The Cowichan Community Land Trust (CCLT) is a registered non-profit organization whose purposes are to conserve, protect and enhance natural values on land in the Cowichan Valley Regional District and surrounding area. CCLT works with landowners and the community in:

- *Helping landowners develop and achieve objectives for conservation, through providing biological, legal and land-use planning information and referral;*
- *Providing public education to increase awareness of the importance of protecting private lands and ways this can be achieved; and*
- *Developing and maintaining co-operative relationships with government and non-government agencies, to work together toward encouraging stewardship of private lands.*

Cowichan Community Land Trust Society was incorporated under the *B.C. Societies Act* (Reg. S33252) in February 1995. The Society holds registered charity status with Revenue Canada and is approved by the Surveyor General to hold conservation covenants. CCLT has a growing membership and volunteers from the community who are working to support its activities in many ways, contributing their time, expertise and knowledge, professional services, and materials.

2. Project Purpose

In 2003, the Cowichan Community Land Trust was asked by the Ministry of Water, Land and Air Protection (Vancouver Island Region) to assist in identifying priorities for future restoration and monitoring projects in the Estuary area.

The project objectives were:

1. To provide a detailed review of biological studies that have taken place in the Cowichan Bay Estuary (Management Plan Area) since the early 1980s, to summarize the findings and to gauge the positive or negative trends.
2. To identify restoration projects that can be initiated that would provide a net benefit to the estuary's ecosystems.
3. To develop an environmental monitoring program that would be used to gauge the estuary's health over time.
4. To organize and host a workshop concerning the environmental health of the Cowichan Estuary.

This project was achieved in two related parts: a literature review, and a workshop.

3. Literature Review

3.1 Purpose

The Cowichan Estuary has been the focus of considerable scientific study over the years, including published papers and a large amount of 'grey' literature. The purposes of the literature review were:

1. To assess current priorities for restoration and monitoring through a review of biological studies that have taken place in the estuary since the early 1980s; and
2. To inform the workshop, at which participants would identify possible restoration projects and an environmental monitoring program to be used to gauge the estuary's environmental health over time.

3.2 Methodology

Biological studies were identified through contact with individuals known to have undertaken research in the Cowichan Estuary as well as referrals through Canadian Wildlife Service, Ministry of Water, Land and Air Protection, University of Victoria Environmental Studies faculty and databases, and local organizations such as the Cowichan Bay Improvement Association (CBIA), the Cowichan Estuary Preservation Society (CEPS), Dr. Bill Austin of Khoyatan Marine Laboratory. Referrals were often given for additional contacts or studies. An annotated bibliography was created and posted on the CCLT website with an open invitation to add to, or comment on the information gathered to date.

Where possible, original abstracts were used to annotate the bibliography but on occasion abstract and/or papers were unavailable. References were sorted under three headings: "research," "restoration" and "planning." Planning documents were not included as part of a literature review as the biological information contained in these documents is not significant, however, they are included in the bibliography as additional information.

This literature review is by no means an exhaustive review but represents known papers and studies conducted on the Cowichan Estuary from the early 1980s to the present. While some additions have

been made to the bibliography since the workshop date and some papers deal with studies on the Cowichan River or the watershed in total rather than the Cowichan Estuary specifically, these papers are included as their findings may be significant to further discussions on the health of the Cowichan Estuary.

3.3 Results

A copy of the annotated bibliography is provided in Appendix A. Appendix B shows the chronological table of references.

Research conducted on the Cowichan Estuary can be broken down into five main categories: intertidal and marine, fish, water quality, waterfowl, and habitat.

3.3.1 Intertidal and Marine

Studies on the intertidal and marine environment include eelgrass distribution, density and benthic habitat (Burns & Tutty, 1982), a checklist of marine invertebrates (Austin, 1985) and two studies on dredging and dredgate dumping (New Pacific Ventures, 1997 and Austin 1998). More recent inventories of eelgrass distribution have been conducted by Bill Austin but have not been compiled to date.

Burns and Tutty's 1982 study of eelgrass habitat found eelgrass distribution discontinuous and of low density due to exposure to wave attack, specifically on the northern part of the delta, and abrasion from log and debris grounding. The environmental impact of dredging and dredgate dumping has been well documented in the New Pacific Ventures 1997 environmental assessment which recommends decreasing dredging frequency and discontinuation of sidecast dumping with ongoing evaluation by independent environmental monitors. Austin's 1998 study concludes that dredgate dumping eradicates fish habitat through the loss of productive mudflat diatoms; comparable to eelgrass as critically productive habitat. Austin recognizes this habitat loss through infilling of intertidal mudflats as a priority concern because it is typically irreversible.

The most recent research on the intertidal and marine environment is an initial impact assessment on the proposed breakwater for Cowichan Bay (Austin, 2000) which includes a video survey of the bottom, a survey of the substrate and substrate organisms, eelgrass distribution. This study showed changes in the biota toward the shore and abundant mussel shells under the pilings and floats but no evidence of attached primary producers such as eelgrass, sugar kelp and benthic diatoms. The breakwater site is removed from existing or potential eelgrass beds except at two locations. Sediment composition is uniform under the proposed breakwater with one exception where wood debris has accumulated. Changes to the substrate biota from accumulation of wood debris, and barnacle and mussel shells would likely result in more epifaunal or surface dwelling species. Austin concludes that it is not clear whether this would impact negatively on existing food webs of infaunal species.

3.3.2 Fish

Studies done on fish populations tend to concentrate on the Cowichan and Koksilah watershed such as (Burns & Tutty, 1986) and the Cowichan River (Candy, 1995, 1996, and Nagtegaal, 1996, 1998, 1999, 2000) so are outside of the Management Plan area, however, they are included as the data collected is significant for fish populations utilizing the Cowichan Estuary. An analysis of juvenile coho and chinook populations in the Cowichan Estuary can be found in the 1986 study by Argue, Hillaby and Shepard.

3.3.3 Water Quality

Water quality studies have been carried out by Doman Forest Products Ltd. and WestCan Terminals Ltd. as well as a comprehensive study in 2000 of the Cowichan and Koksilah Rivers and the Cowichan Bay by Rideout, Taekema and Deniseger, et al.

One study of the Doman Forest Products site surveyed the biota, water and effluent discharge and sediments and found abundant signs of polychaete worms and crab molting shells, traces of chlorophenols in the water and effluent sampling and only one sediment sampling point containing chlorinated phenolics. The presence of chlorophenol traces and tetra- and pentachlorophenol in clam and crab Hepatopancreas indicate that historical chlorophenate releases and pulpmill effluent are influencing the biological quality of the Cowichan Bay (Envirochem Special Projects Inc., 1990).

A second study found that, of eight test areas within the Doman site, only one sediment sample contained a detectible chlorophenol concentration, just above detection at 0.12 mg/kg (ppm) (Envirochem Special Projects Inc., 1990). The site assessment done at WestCan Terminals Ltd. found no detectable concentrations of chlorophenols in surface soils, subsurface soils or catch basin sediments suggesting that long-term presence of pavement minimized subsurface contamination (Envirochem Special Projects, 1990).

The water quality assessment (Rideout, 2000) of the Cowichan and Koksilah Rivers and Cowichan Bay was undertaken to identify sources of coliforms and nutrients with an emphasis on non-point sources. Samples were analysed for fecal coliforms, nutrients, total and dissolved metals and toxic substances. The Cowichan River frequently exceeded desired levels of fecal coliform bacteria and the Koksilah River regularly contained excessive fecal coliform bacteria attributed to non-point sources in both river systems. Discharge from the sewage treatment plant, serving the village of Cowichan Bay, was found to be a primary contributor to fecal coliform bacteria pollution in the bay. One of the most recent papers proposes a remote sensing approach to water quality monitoring (Costa, 2003).

3.3.4 Waterfowl

Research on waterfowl has primarily consisted of waterfowl counts (Stoner, 1983 and Vermeer, et al., 1994) and comparisons of composition and density of populations (Vermeer, et al., 1994). A waterbird survey on bird use of the Blackley farm and Koksilah marsh enhancement areas (Campbell Prentice, 1988) was conducted between 1983 and 1987 and found that more birds were observed in intertidal than backshore areas within the Koksilah marsh area, with the exception of eagles. Waterfowl use of the Blackley farm enhancement area was most commonly in the intertidal, marsh and tidal channels as well as agricultural and marsh backshore habitat.

3.3.5 Habitat

Habitat studies have been conducted in the Cowichan Estuary with two habitat inventories delineating habitat types as a function of substrate, vegetation, salinity and anthropogenic influences (Hunter, et al., 1982 and Wayne, 1983). Soil and vegetation surveys have also been conducted in the Blackley farm and Koksilah marsh enhancement areas (Dawe, et al., 1986, Quesnel, et al., 1986 and Campbell Prentice, 1988, 1989) primarily to monitor the ecological change caused by dyke breaching in these areas. Other habitat studies include an arborist report for potential restoration of the maple grove located at the south end of the Management Plan Area (Chaster, 1994) and the Sensitive Ecosystem Inventory of 1997 which includes the Cowichan Estuary.

3.3.6 Comprehensive Studies

Two comprehensive studies of the Cowichan Estuary were undertaken by Ferguson, Holman and Kistriz in 1989 and by Frith, Humphrey, Wainwright and English in 1993. Ferguson's study is an application of three wetland evaluation methods that describe the characteristics and distribution of wetland habitat types within the estuary and explores the impact of two hypothetical development projects. Frith's study evaluates the state of the marine environment in Cowichan Bay which includes the intertidal areas and estuary marsh. Four main areas of concern are identified; habitat loss, discharge of antisapstains, presence of dioxins and furans and the presence of coliform bacteria. This study found that problems associated with antisapstains, dioxins and furans are a lesser concern as measures have been taken to reduce or eliminate these pollutants and concludes that the greatest threat to the health of the estuary are habitat loss and contamination from sewage.

4. Workshop

4.1 Purpose

The purposes of this workshop were:

- To share information on the state of knowledge of the biological health of the Cowichan Estuary;
- To identify restoration projects that would benefit the estuary ecosystem, and determine priority projects; and
- To identify elements of an environmental monitoring program that could be used to gauge the estuary's health over time.

4.2 Participation

In developing this workshop, the CCLT was keen to ensure that participants included people who were knowledgeable about the area, and/or involved in the management or use of the land or water, as well as interested members of the public. Representatives from a number of interest groups associated with the estuary as well as members of the general public were invited to attend the one-day workshop.

Stakeholders were initially contacted through a formal network of governmental agencies and local organizations including the Ministry of Water, Land and Air Protection (WLAP), the Cowichan Estuary Preservation Society (CEPS), Directors of the Cowichan Community Land Trust (CCLT), Cowichan Tribes, the Cowichan Valley Naturalists Society (CVNS), the Department of Fisheries and Oceans (DFO) and the Cowichan Bay Improvement Association (CBIA). Referrals from these organizations formed an informal network of interested groups or individuals. Every contact was informed of the goals and objectives of the workshop and referrals were requested.

The CCLT website was updated to include information on the upcoming workshop and a copy of the annotated bibliography as a work in progress. Contacts were directed to our website to view the bibliography prior to the workshop. Notices were emailed to all contacts who had an interest in the upcoming workshop or who were potential participants due to their organizational association with the Cowichan Estuary (Appendix C). Advertisements were submitted to both local papers prior to the workshop indicating the goals and objectives of the workshop and including a contact number for any interested participants (Appendix D).

As a result, over 40 people from various local community groups, agencies and organizations attended this workshop. Participants included individuals from the local community as well as representatives from the Department of Fisheries and Oceans (DFO), Ministry of Water, Land and Air Protection (MWLAP), Cowichan Tribes, Cowichan Valley Regional District (CVRD), Nature Trust, Cowichan

Estuary Preservation Society (CEPS), Cowichan Bay Improvement Association (CBIA), Cowichan Watershed Council (CWC), WestCan, Cowichan Valley Naturalists Society (CVNS), Cowichan Community Land Trust (CCLT), Norske Canada, Cowichan Bay Maritime Centre, Hul'qumi'num Treaty Group, Municipality of North Cowichan, Nature Conservancy of Canada (NCC), and Ducks Unlimited (DU).

4.3 Agenda

The agenda was designed to provide participants with background information on the estuary and watershed, but also to allow as much time as possible for contributions from individuals through small group sessions. The morning session included presentations from Arvid Charlie of Cowichan Tribes, because of the estuary's importance to the Cowichan Tribes as traditional lands, and Cheri Ayers, presenting Bill Austin's studies and community-based research in the Cowichan Estuary. Participants then selected from four field trips for a first-hand look at some of the issues and possibilities around the Estuary. The afternoon sessions focused on the participants' priorities for restoration and monitoring.

A copy of the agenda is provided in Appendix E.

4.4 Presentations

4.4.1 Arvid Charlie, Cowichan Tribes

The numbers of good fish habitats are decreasing. We are all responsible for restoring the habitats. Some things that are a concern are the low water level now, but I can remember that the riverbed has been dry a few times in past years. We have worked to improve the river and over 80,000 cubic metres of accumulated gravel has been removed from the riverbed over several years. Now there are deep pools were there used to be one long riffle. Dykes are built to stop flooding of land. We have had years in the past that the river floods and floods around our homes. Pollution is a problem in our rivers, especially non point sources and in the Koksilah. Sewage lagoons by the Cowichan River were built in 1958, with a promise that the treatment process would end up with drinking quality water. More than forty years later we still are not seeing wastewater processed to drinking water. Changes are needed.

When planning restoration or enhancement projects, we have to keep the entire watershed in mind. What is happening upstream will affect the lower parts of the rivers and the estuary. Salmon need larger catch basins in the mountains. In small creeks, such as Tzouhalem or Kelvin, salmon were caught until the late 1940's. To bring the salmon back we must look after *all* creeks.

We need to work together to improve quality of fish habitats in all watersheds.

Question/Answer

Q. Are you for or against dykes?
A. Some dykes are too close to the river, and should be set back. Any changes, such as gravel removal or dyke building must be carefully planned

Q. What is your priority?
A. Priority is to work effectively together. There are problems with how decisions are made. Again, together is better.

4.4.2 Cheri Ayers,

Cheri Ayers spoke on behalf of Dr. Bill Austin and presented a historical perspective on the estuary and highlighted three main areas; impacts, monitoring projects and restoration projects.

Cheri began her presentation with a map of the estuary pre1800 where there were no English names. There was extensive river habitat and a very different composition of river channelling with the Koksilah and the Cowichan rivers connected much further inland. These rivers would swing wildly because of a high level of deposition that would often alter their course significantly. Over the past 100 years several activities have impacted the Cowichan Estuary. Logging activity would erode the bank of the river and the river would jump its banks or a log jam would change the course of the river.

A later map from the late 1800's shows some channelling of the river and some English names. In 1936 the railway was built out into the estuary at the WestCan dyke location. One photo shows a sailing regatta on the Cowichan Bay and shows the Cowichan canoes. These canoes were made of large trees, demonstrating that there were significant numbers of large trees in the vicinity for the Cowichan to use for canoes.

During the 1940's there was more development in Cowichan Bay. As homes began to be built around the shoreline the shoreline became shaded and hardened, affecting plant and fish life.

In 1978 a dyke was built around Blackley farm to increase agricultural lands. Log booming in the estuary was extensive at this time and woody debris accumulated and logs from the booms often became loose and sank. Log booming was still significant in the 1980s and have created swales as logs dig into the mudflats. Doman's site and log haul channel became an issue due to toxic leachate from wood waste piles and wood preservatives used at that time. There were no catch basins so this leachate went straight into the estuary. This wood preservative product has since changed decreasing its significant impact on the estuary. Doman's have done more work now to ensure they don't lose logs but there are still a large number of logs in the estuary from previous years which over time have become habitat. Some of the effects of log booming and waste accumulation are habitat loss, smothering, compaction, scouring, shading and channel modification.

Further inland the hog fuel pile on Cowichan Tribes land is gradually being removed by Doman's as it is a concern because of the fire hazard and leachate. Some testing has been done for leachate impacts. Log jams also occur at the railway bridge and are accumulating but are difficult to remove as the site is sensitive and loosened log jam materials will simply accumulate downstream. Leaving the jams causes flooding while removing them could cause water quality, turbidity and erosion problems. Ships may also be to blame for several issues in the estuary. Invasive species have been turning up (such as the Japanese varnished clam) that are most likely coming from discharged ballast.

Monitoring Projects:

The following are several monitoring projects have taken place/are occurring in the Estuary:

- Hydrographic surveys testing the salinity have been done but vary with the tides and the amount of rainwater
- Kids are doing surveys to determine distribution and density of eelgrass
- Camps are being held to do clam density surveys

- Food surveys for intertidal juvenile salmon are being completed

- A barnacle study was completed by using a quadrant formula. All the barnacles on a certain amount of rip rap were counted, then the length of the rip rap was determined. The barnacles are then multiplied by the length of the rip rap to determine the density of the barnacles

- Remotely Operated Vehicle (ROV) surveys have shown that benthic levels are up in Cowichan Bay

- A study was completed by a University of Victoria student adjacent to the Masthead Rentals and Marina. Two sites were analyzed for their benthic levels

Restoration Projects:

Low tide days occur once a year where the community works together to collect garbage and other debris from the water. Divers are also used to ensure a complete collection. A derelict vessel has been removed and was sold to Harper's Recycling. The Cowichan Bay Improvement Association (CBIA) have been cleaning and planting an area along the shoreline prior to a change in ownership. Volunteers from the Royal British Columbia Museum (RBCM) have been coming to help clean up which shows an interest in the estuary from outside of this community.

Cheri's closing remarks recognized the importance to remember to share the responsibility for the health of the estuary.

4.5 Results

4.5.1 Priorities

Workshop participants identified their priorities for restoration and monitoring by completing a questionnaire form (Appendix F) that was distributed at the beginning of the workshop. These questionnaires were also made available to interested individuals who could not attend the workshop but wished to contribute. Participants were asked to refer to the annotated bibliography (Appendix A) and chronological table of references (Appendix B) to help identify their two top priorities for restoration and monitoring for the Cowichan Estuary.

The following priorities were identified by workshop participants:

Water quality
Eelgrass health, location and quantity
Wood waste from log booming activities
Whole watershed focus
Reduction of industrial uses
Biophysical inventory and monitoring

It is important here to note that while the participants recognized that restoration and monitoring strategies for the estuary were to be limited to the Cowichan Estuary Management Plan Area, an overriding concern expressed during this workshop was the necessity of seeing the ecological health of the estuary in broader terms. The entire watershed of the Cowichan and Koksilah Rivers and other smaller creeks were consistently recognized as being of major importance to the continuing health of the estuary.

Priorities were classified under the following categories for discussion in small groups.

Marine environment – species and habitat
Water Quality
Land based and intertidal – species and habitat
Human Activities – water based
Human Activities – land based

4.5.2 Restoration and Monitoring

Workshop participants worked in five small groups, each focused on restoration and monitoring priorities for one category. Aerial maps of the Cowichan Estuary Management Plan area were distributed to each group along with markers to give a contextual reference to the discussion (Map 2), and participants were encouraged to draw on the map to indicate the location of suggested restoration and monitoring projects. The recommendations of each group are provided below.

Marine Environment Issues and Priorities

Issue # 1: Loss of eelgrass habitat on the north side of the estuary.

RESTORATION
Identify potential eelgrass habitat
Transplant eelgrass
Restore damaged habitat
Resolve barriers, e.g. toxins

MONITORING
Monitoring of the extent of eelgrass beds
Stewardship group to gather data in a consistent manner
Core samples of substrate wood waste
Monitor success of rehabilitated eelgrass beds to determine limiting factors.

Issue # 2: Protection of salmon habitat in the Cowichan River system.

RESTORATION
Raise the weir
Storm water management
Manage the hydrology of the watershed

Water Quality Issues and Priorities

Issue: 30% of sewage treatment plant flow bypasses treatment during the winter months

RESTORATION
Close sewage treatment plant.
Redirect to the Duncan lagoons which have been upgraded.
Compile information on non-point sources.
Inventory of water licenses and amount of water removed under these licenses.
Develop watershed management plan.

MONITORING
Compile results of all monitoring and all federal studies of marine water quality
Develop a multi-matrix index for the watershed (Index of Biotic Integrity)
Monitor rivers, estuary, bay and point sources of contaminants.

Undertake consistent sediment sampling

Land-based and Intertidal Issues and Priorities

See Map 3.
Issue: Loss of biodiversity through invasive species– specifically Japanese knotweed, yellow flag iris, bullfrogs, Canada geese, white clematis.

RESTORATION
- Increase public education and resources on a watershed basis
- Map and identify areas of infestation
- Prioritize areas or zones
- Determine best method of control
- Gather resources for invasive species removal

MONITORING
- Build on existing ecosystem maps
- Utilize bird studies done in 1974 and 1989
- Utilize vegetation study done in 1986
- Utilize 'Intertidal and Adjacent Upland Habitat Assessment', 1988.
- Undertake consistent baseline inventories

Human Activities – Water-based

See Map 4
Issue # 1: Ballast dumping affecting water quality.

RESTORATION
- Stop sewage and ballast dumping by having sites for unloading
- Increase public awareness of legislation

MONITORING
- Monitor impacts on fish
- Monitor shipping line
- Enforce legislation
- Identify how many small boats 'flush out' into the water.

Issue # 2: Log booms/wood waste creating significant deposition of waste which negatively affects the estuary.

RESTORATION
- Determine if PCPs are being used
- Determine extent of contamination
- Map 'hot spots'
- Reduce number of log booms
- Determine size and extent of wood waste materials on substrate

MONITORING
- Inspect log pond for accumulation of wood waste
- Check for compliance

Human Activities – Land-based

Issue: Lack of awareness of the importance of estuary values (ecological, economic and cultural).

RESTORATION

Develop options to improve eco-tourism opportunities
Involve all user groups in identifying need and aid for future restoration

MONITORING

Need environmental, economic and social data
Monitor, research initiatives, and publish on a regular basis
Identify key indicator species
Use biological/ecological indicators
Monitor health of young Coho
Develop inventory of native plants/ecosystems and invasive species
Determine role of agricultural land as habitat for waterfowl.

5. Analysis and Recommendations

Marine Environment

The two main issues identified for the marine environment are loss of eelgrass habitat on the north side of the estuary and protection of salmon habitat in the Cowichan River system. Research on eelgrass in the Cowichan Estuary has not been undertaken since Burns and Tutty, 1982. Some research has been done by school groups through the Marine Ecology Station under the direction of Dr. Bill Austin. However, this data has yet to be compiled. Surveys on the distribution and density of eelgrass beds in the Cowichan Estuary would provide the necessary information for maintaining and enhancing this productive habitat.

Eelgrass bed restoration and monitoring could easily be undertaken by volunteer work crews with the appropriate training and supervision. An eelgrass restoration project could include a comparative study of the distribution and density of eelgrass in Burns and Tutty with current eelgrass populations. This would identify potential eelgrass sites as well as indicating limiting factors. Habitat restoration would involve transplanting eelgrass and monitoring test sites to determine these limiting factors.

Stewardship groups of trained and supervised volunteers to help delineate, transplant and monitor eelgrass beds would be an appropriate community strategy to enhance and restore this valuable habitat.

Workshop participants also identified the protection of salmon habitat in the Cowichan River. Fish population studies have been undertaken in the Cowichan River system on a regular and consistent manner. Strategies suggested by workshop participants included raising the weir, managing storm water and the hydrology of the watershed. These suggestions could be addressed through community development of a watershed approach to future management of the Cowichan Estuary. As the Cowichan River system falls outside of the current Cowichan Estuary management plan area, restoration and monitoring of these essential river systems were not thoroughly examined during this workshop.

Human Activities – Marine Environment

The main issue identified by participants while discussing human activities in the marine environment was the effect of log booming and associated contamination and wood waste accumulations that negatively affects the estuary water quality and substrate. Three studies done on levels of contamination on industrial sites in the Cowichan estuary done by Envirochem Special Projects , 1990 found minimum chlorophenol concentrations although historical chlorophenate releases and pulpmill effluent are influencing the biological quality of the Cowichan Bay.

Restoration activities designed to address human activity impacts on water quality could include determining the current usage and extent of PCP's (sodium pentachlorophenol) and monitoring for compliance with existing regulations regarding water quality. More information on the amount and extent of wood waste could be gathered to determine the best option for ameliorating the loss of substrate habitat due to this accumulation. Reducing the number of log booms was suggested by participants as a way to reduce the ongoing accumulation of wood waste.

Water Quality

The main water quality issue identified by the workshop participants was non-point pollution sources and the percentage of effluent that bypasses the sewage treatment plant during the winter months.

The most current information available on water quality in the Cowichan Estuary is found in Rideout's assessment of the Cowichan and Koksilah Rivers and Cowichan Bay published in 2000. This study identified sources of coliforms and nutrients with an emphasis on non-point sources. While contaminants in both river systems were found to be primarily from non-point sources, discharge from the sewage treatment plant serving the village of Cowichan Bay was identified as the primary contributor to fecal coliform bacteria pollution in the bay.

In response to this issue participants suggested that the sewage treatment plant be closed and non-point sources and water licenses be inventoried towards developing a watershed management plan. Further steps would include compiling the results of monitoring to date and developing a multi-matrix index for the watershed, incorporating ongoing monitoring of rivers, estuary and bay waters and sediments with a focus on identifying point sources of contaminants.

Water quality problems arising from the Cowichan Bay sewage treatment plant are close to being resolved. The Cowichan Regional District is currently in the process of confirming Federal funding, pending an environmental assessment, to replace the existing wastewater treatment plant at Cowichan Bay. This project has been undertaken to improve system reliability and protect the environment.

The effects of ballast dumping on water quality and the spread of harmful invasive species was also identified by participants. It was suggested that this issue could be addressed by providing a site for unloading ballast and sewage coupled with a public awareness program and enforcement of existing legislation.

Land-based and Intertidal Areas

A priority identified for restoration and monitoring projects in the land based and intertidal areas of the Cowichan Estuary is the loss of biodiversity through the spread of invasive species. The literature gathered to date on habitat loss in the Cowichan Estuary includes Frith, *et. al.,* 1993 and Cowichan

Estuary Habitat Inventories done by Hunter, *et al*.,1982 and Wayne, 1983. Frith clearly identified habitat loss as one of the greatest influences on the ecological health of the Cowichan Bay. Other vegetation studies such as Dawe, *et al*., 1986, Quesnel, *et al*., 1986 and Campbell Prentice, 1988 and 1989 focused on ecological changes caused by dyke breaching in the Blackley farm and Koksilah marsh areas.

Rapid and increasing populations of Japanese knotweed, yellow flag iris, bullfrogs, Canada geese and white clematis was identified by workshop participants as the major contributors to the loss of biodiversity in the Cowichan Estuary. These concerns could be addressed through restoration and monitoring programs that identify, inventory and prioritize areas or zones of infestation and offer resources to remove the invasive species. By building on existing ecosystem maps such as the Cowichan Estuary Habitat Inventory and utilizing previous bird and vegetation studies an inventory could be created. Inventories could be undertaken by volunteer stewardship groups incorporating local knowledge and the many local groups and organizations that have an interest in the ecology of the Cowichan estuary.

Monitoring invasive species outbreaks could also be provided through local stewardship programs with appropriate training to provide consistent reporting and response to new or recurring outbreaks. A stewardship approach also allows for a large amount of public involvement which in turn increases public awareness and education.

Human Activities – Land-based

Workshop participants identified the importance of public awareness of the ecological, economic and cultural values inherent in the Cowichan Estuary. Opportunities to improve eco-tourism and community involvement in identifying future restoration needs and monitoring programs would benefit from readily available environmental, economic and social data and stewardship programs associated with monitoring and research initiatives. This public awareness and involvement in the stewardship of the Cowichan Estuary would provide opportunities to utilize local knowledge in gathering information on eelgrass, invasive species, waterfowl and fish, as well as other significant indicators of habitat change.

6. Conclusion

Two main issues identified as priorities for restoration and monitoring through workshop discussions and research findings are water quality and habitat loss.

Suggested strategies for water quality restoration and monitoring to ameliorate potential PCP contamination and sewage problems include, replacing the current sewage treatment facility that serves the village of Cowichan Bay and providing facilities for ballast dumping as well as enforcing legislation.

Habitat loss was identified by research findings indicating uneven density and distribution of eelgrass, wood waste accumulations that impact on substrate habitat and harmful invasive species. Restoration and monitoring strategies for eelgrass habitat includes eelgrass surveys, transplanting, and a monitoring program that identifies limiting factors. Surveys of substrate wood waste accumulations were also suggested as a way to determine potential areas for restoration through wood waste removal and monitoring removal methods.

Specific invasive plant species were identified as an increasing threat to estuarine habitat. Restoration and monitoring programs to deal with these species were developed by participants and include the

inventory and removal of targeted invasive species as well as ongoing monitoring of potential re-growth.

Public education and awareness was also identified as an important aspect of any restoration and monitoring program. As well, a strong recommendation echoed by all discussion groups was the importance of a community-driven and inclusive watershed approach to restoration and monitoring of the Cowichan Estuary. For this reason, an appropriate format for implementing the suggested strategies for restoration and monitoring within the Cowichan Estuary would be through stewardship programs where volunteers from the local community could implement restoration programs and carry out monitoring activities with appropriate training, support and guidance.

Appendices

Appendix A: Annotated bibliography

RESEARCH

Argue, A.W., Bruce Hillaby, and C.D. Shepard. Distribution, timing, change in size, and stomach contents of juvenile chinook and coho salmon caught in Cowichan Estuary and Bay, 1973, 1975, 1976. Canadian technical report of fisheries and aquatic sciences; No. 1431. Department of Fisheries and Oceans, Field Services Branch. Nanaimo, BC. 1986.

Abstract: This report presents analyses of distribution, abundance, duration of residence, growth and feeding for marked and unmarked juvenile chinook and coho found on the Cowichan estuary and in Cowichan Bay. Results are also presented for Chinook and coho juveniles caught at stations Cowichan Bay. Past estimates of juvenile population size are reviewed.

Armstrong, R.W. and A.W. Argue. Trapping and coded wire tagging of wild coho and chinook juveniles from the Cowichan River system, 1975. Fisheries and Marine Service, Field Operations Directorate, Pacific Region. Vancouver BC. 1977.

Abstract: Between April 7 and July 2, 1975, coho salmon (Oncorhynchus kisutch) and chinook salmon (O. tshawytscha) smolts from the Cowichan River system were captured and tagged with binary coded-wire-tags. This was a pilot study to assess logistics and field methods of tagging sufficient numbers of juveniles from a wild stock, at a reasonable cost, for assessment of ocean migration patterns and fishery contributions.
The total number of coho smolts tagged over a two month period was 26,135; made up of 18,928 captured using plywood fence traps on outlet streams from Rotary Park pools near Duncan; 4,110 captured using fence traps on Pastuch Creek, a small tributary of the Robertson Ricer which enter Cowichan Lake; and 3,097 captured using minnow traps on an isolated side channel of the main Cowichan River. A total of 18, 332 90-day chinook smolts were captured with beach seine gear and tagged over a nine day period (June 23 to July 2) on the north side of the Cowichan estuary. All tagging equipment performed without any important mechanical problems.
This study demonstrated that tagging of wild coho and Chinook juveniles, particularly coho, is highly feasible under field conditions (cost exclusive of capital items less than $20, 000). Further work is required on delayed tagging mortality of juvenile coho and chinook in fresh and estuarine waters.

Austin, William C. An annotated checklist of marine invertebrates in the cold temperate northeast Pacific. Khoyatan Marine Laboratory, Cowichan Bay, BC. 1985.

Austin, William C. Aspects of Land Use and Ownership in the Cowichan-Koksilah Estuary. Khoyatan Marine Laboratory, Cowichan Bay, BC. 1978.

Abstract: In British Columbia the high water mark is a natural boundary visable as a mark on both vegetation and soil left by water. Opinions differ on where this lies and how it may be recognized; and in situations where it is regarded that no mark is visible, the mean high tide may be employed as an alternative boundary.
It is argued here that biological criteria should be used to define the high water mark and that a mark so defined is realistic, at least generally visible, practical, and best fits the historic reasons for having such a boundary.
This boundary should demarcate a change from a maritime terrestrial to a littoral biota (littoral here considered as ecologically distinct from either purely terrestrial or purely marine). Species of animals or plants are considered as belonging to one or the other of these realms based on the vertical distribution of local populations of the species NOT on the basis of where their relativeslive or where they can live under artificial conditions. A high water mark occurs at the line of best fit for the lower boundary of species with clear terrestrial populations (i.e. extending well above this mark), and the upper boundary of species with clear littoral populations (i.e. extending well below this mark), and with a minimum of transgressive species (i.e. populations both well above and well below this mark).
The absolute level of this biological boundary will clearly change with variations over and above change in tidal amplitude. In Cowichan Bay (under defined conditions), initial observations place this boundary at the most likely level of 3.41m (11.2ft) (less likely at 3.69m or 12.1ft) above Canadian Hydrographic 0 datum. Initial ground and

aerial surveys show that broad areas considered above the high water mark in various maps and plans are covered by water at the 3.4m level and a number are also covered at 3.3m (10.2ft) the mean high water level of tide tables.
A variety of documents were examined (maps, photos, plans, grants, deeds, federal and provincial regulations) in an attempt to assess the degree to which these differences were due to natural changes, historical errors or differences of opinions. In adition, an assessment was made of the conditions and basis for a Crown grant or most the intertidal land in Cowichan Bay. In the latter case it is suggested that some present uses contravene the terms of the Crown grant. The author's opinion (here) is that of a layman and only modest legal opinion has been sought to date.
A brief proposal on land use compatible with the findings here is included at the end of this report.

Austin, William C. Dredgate dumped on Intertidal Estuary in Cowichan Bay. Marine Ecology Station. Cowichan Bay, BC. 1998.

Abstract: This paper looks at dredgate dumped on the intertidal area just east of the Cowichan River branch opposite the log pond adjacent to Doman Industries saw mill 48 degrees 45.7' N, 123 degrees 37.9' W. The dredgate covers an area about 650 ft. long by up to 150 ft. wide amounting to at least several acres, the height is 8.0 ft. above the natural level of the adjacent estuary. In addition eroded portions of the dredgate extend seaward over the mudflats for several 100 ft. The general composition of the natural flat is mud and sandy mud with varying small amounts of gravel. The high standing crop of animal and plant life on the flats indicates that this is a highly productive region. The productivity of mudflat diatoms is comparable to that of eelgrass in estuaries where it has been assessed. Corophium species, the tube building amphopod, is a mainstay food source for some species of fish (e.g., Chinook fry) and shorebirds. Sampling was restricted to those species which stay in place during lowtide. Fish, crabs, shrimp, birds were not assessed although numbers of Canada Geese were observed in the area. Infilling of the estuary flats essentially eradicates this fish habitat. The British Columbia/Washington Marine Science Panel recommended in 1994 that no further loss of nearshore estuarine habitat should be allowed in embayments that already have lost a significant fraction of their historic habitat area. They further regarded habitat loss through infilling as a priority concern since it is typically irreversible.

Austin, William C. Mapping Marine Life and Habitats on the Seafloor of Cowichan Bay. Marine Ecology Station, Cowichan Bay, BC. 1998.

Abstract: This project involved introducing the public to underwater remote vehicle technology, fostering awareness of an estuary environment and our impacts on the environment, and surveying portions of Cowichan Bay for key species, characteristic habitats, debris and impacts. The report includes a list of species, their abundance, and their distribution (all found using SEAMOR).

Austin, William C. Proposed Breakwater in Cowichan Bay, BC: Initial Environmental Impact Assessment. Khoyatan Marine Laboratory, Cowichan Bay, BC. 2000.

Abstract: This assessment includes the following studies in and around the proposed breakwater area: tidal current flows at the surface, a video survey of the bottom, a survey of eelgrass distribution, survey of the substrate and organisms in the substrate. The drogue movement patterns in the present study show that surface water can be flushed out of the marina area in an hour or two under moderately fast falling tides. Further questions regarding the breakwater's effect on this flushing action must be addressed by a qualified engineer. The sea floor under and adjacent to the proposed breakwater has a low slope and consists of soft mud. Populations of the plumose sea anemone would be expected to increase with the addition of concrete anchors along the bottom. This species of sea anemone feeds primarily on small zooplankton (Haderlie et al 1980), and it is unlikely that this species would have a direct impact on juvenile fish such as salmonids although it might impact on crab larval populations. Dungeness crabs *(Cancer magister*) were seen, but not in any particular abundance. Flatfish were commonly seen and, at least, some were English sole *(Parophrys vetulus)*. Surveys occurred during periods of phytoplankton blooms which would be a food source for clams such as horse clams and geoducks. There was no evidence of geoduck feeding, suggesting that populations of this clam are small or absent in the survey areas. The transects under the potential shore connectors did show changes in the biota toward the shore. Mussel shells were abundant under the pilings at the Maritime Centre and under the floats of the government wharf. To some degree this fall-out may restructure the associated community of animals; however, the impact of such restructuring is not known and may well not be significant to the resource species in the Bay. There is no

evidence of attached primary producers such as eelgrass, sugar kelp and benthic diatoms. Some unattached sugar kelp was seen; however, it is below the depth where it can grow.
Eelgrass is notably absent over much of the shallow bottom within the marina areas. A few small patches occur. Eelgrass is abundant at similar depths and on comparable substrate both east and west of the marinas. This distribution pattern suggests that shading and scouring within the marina have impacted on eelgrass distribution. The breakwater and shore connection sites are far removed from existing or potential eelgrass beds except at two locations: the western end and the southeast end.
The sediment composition is rather uniform along the footprint under the proposed breakwater with the exception of station 51/00 where there was lots of wood debris. On the other hand, stations adjacent to pilings, and particularly under floats, had high percentage of mussel and barnacle shells. It would be expected that the breakwater would also act as a source for shell build up on the bottom. This would likely result in some changes in the biota with more epifaunal or surface dwelling species. It is not clear whether or not this would impact negatively on existing food webs of infaunal species. No rare or endangered species were identified.

Austin, William. Survey of habitats, potential food, and remediation requirements in juvenile Chinook nursery areas of the Cowichan Estuary.

Abstract: The Cowichan Estuary, while not a salmon-spawning habitat, is a critical and important environment for the rearing and feeding of juvenile Chinook and chum, and perhaps Coho salmon. The Chinook project worked broadly to survey the edges of the estuary and some areas of the mudflats to assess habitat suitability for Chinook juveniles, determine what if any rehabilitation is needed to improve habitat suitability and develop an awareness program.
Interim results: The proponent surveyed approximately 95% of the estuary edges including reclaimed marshes and shorelines as well as impacted shorelines and mudflats at 32 stations. Data sheets and photo records characterize each of 2-3 transects/station. Biotas have been sampled at 7 subtidal sites and about 95 intertidal sites.

Baseline Contamination Study: Nearshore area of Cowichan Bay Doman Forest Products Ltd. Cowichan Bay Division. Envirochem Special Projects Inc. N. Vancouver, BC. 1990.

Abstract: Surveys of biota, water and effluent discharge and sediments were conducted. Biota surveys found abundant signs of polychaete worms and shells from crab molting. Water and effluent sampling indicate that traces of chlorophenols still occur in the storm runoff waters. Sediment samples adjacent to and within the log pond found chlorinated phenolics only at the sampling point directly adjacent to the west drain. The north branch of the Cowichan River showed detectable concentrations of chlorophenols as well as the south fork of the Koksilah River. This indicates that traces of chlorophenols can be found in stormwaters even 2 years after ceasing the use of chlorophenols. The presence of tetra- and pentachlorophenol in clams and crab hepatopancreas indicate that residues from sawmill operations are also present. The hepatopancreas also contained 2,3,7,8 tetrachlorodibenzo-p-dioxin, hence suggesting that pulpmill effluent is indeed a factor in influencing the biological quality of Cowichan Bay in addition to historical chlorophenate releases.

Bell, Leonard M., Ronald J. Kallman. The Cowichan-Chemainus River Estuaries Status of Environmental Knowledge to 1975. Environment Canada. 1976.

Abstract: This paper goes into detail about all of the data and reasearch done/collected prior to 1975 in the Cowichan and Chemainus river estuaries. Topics included are geology, climatology, hydrology and water quality, oceanography, invertebrate biology, fish, flora, wildlife, land and water use, pollution and effects of development. It was concluded that the Cowichan River estuary is a vital recreational area, highly dependent of the coho and chinook resources of both the Cowichan and Koksilah rivers. They serve as a vital nursery ground for the juvenile salmonids and contribute to several commercial, recreational and Indian food fisheries. It was also concluded that there is need for detailed examination of the environmental impacts of alternative river and estuarine development. To increase biological productivity of the estuaries, log storage and handling should be phased out and land-filling of intertidal areas should be more effectively controlled, and if possible, eliminated. Better sewage treatment and control of contaminated runnoff is necessary for reinstatement of unrestricted oyster production and cleanup of bathing areas.

Bigg, M. A., G. M. Ellis, P. Cottrell, and L. Milette. Predation by harbour seals and sea lions

on adult salmon in Comox Harbour and Cowichan Bay, British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 1769. Department of Fisheries and Oceans, Biological Sciences Branch, Pacific Biological Station, Nanaimo, BC. 1990.

Abstract: The movements, feeding behaviour and predation rate on prespawning salmon by harbour seals (*Phoca vitulina)* at Comox Harbour and Cowichan Bay and by sea lions (*Zalophus californiaus, Eumetopias jubatus*) at Cowichan Bay were examined during 1989-90. Tidal variation largely governs the daily movement of harbour seals over the estuaries. Sea lions tended to remain in slightly deeper water than harbour seals and their movements were affected less by tides. Peak harbour seal abundances of 750 and 175 were recorded in Comox Harbour and Cowichan Bay respectively. A maximum of 30 sea lions were counted at Cowichan Bay. The seasonal movement of these pinnipeds into the estuaries coincided with the migration of prespawning salmon into nearby rivers. Harbour seals and sea lions fed on salmon mainly along the outer edge of the estuaries, although harbour seals also commonly fed in the lower reaches of the Puntledge River which drains into Comox Harbour. Two to four harbour seals usually preyed together upon a single salmon. A combination of cooperation and opportunism seems involved in group predation. Sea lions tended to feed individually. Based on the number of salmon seen eaten hr^{-1} in 1989, an estimated 46% of the fall run of chinook, 4% of pinks, 8% coho and 7% chum salmon were taken by harbour seals at Comox Harbour. In Cowichan Bay an estimated 1% of coho and 1% of chum were eaten by harbour seals and 3% of coho salmon at Comox Harbour were particularly vulnerable to predation by harbour seals due to the low number of fish and their availability for predation in both the Comox Harbour estuary and the slow moving Puntledge River.

Blood, D.A. J. Comer and J. Polson. Migratory Bird use of the Duncan-Cowichan Bay Area in 1975. Environment Canada, Canadian Wildlife Service. Delta, BC. 1976.

Abstract: This report describes the local distribution, species composition, and seasonal abundance of aquatic, wetland and raptorial birds of the Duncan-Cowichan Bay area during 1975. One count per week was carried out in 11 survey areas within the total study area. A cumulative total of 273,576 birds was counted during the year. Counts on single days varied from 12,827 (Nov. 13) to 1,314 (May 15). The ten most abundant species in descending order were: American wigeon, western grebe, mallard, European starling, common merganser, northwestern crow. American coot, northern pintail, mew gull and glaucous-winged gull. Maximum counts for waterfowl, coots, herons, grebes, loons and cormorants indicate that over 16,000 such birds are dependent on the area for habitat at some time during the year. Seasonal trends in abundance are described for each species group. The most significant groups in terms of numbers - diving ducks, dabbling ducks, and western grebes - were 20 to 100 times more abundant in winter than summer. Species composition within each group is also analysed. American wigeons were the dominant dabbling ducks, followed by mallards, northern pintails, green-winged teal and northern shovelers; and common mergansers were the most abundant divers, followed by bufflehead, surf scoters, scaup, white-winged scoters, and common goldeneye. Species composition of ducks in the estuary area in winter is compared for 1973, 1974, and 1975. Three hundred fifty four individuals of eleven species of falconiform birds were identified, of which more than half were bald eagles. Observations on brood production are presented for great blue herons, mute swans, Canada geese, mallards, blue-winged teal, wood duck, common merganser and red-breasted merganser. Cinnamon teal, green-winged teal, northern shovelers, and American coots are also thought to have nested in the area. Survey areas were grouped into 5 broad habitat types: flooded fields and swamps; lakes; estuary; small deep marine bays; and open coastline and the distributions of dominant species groups in those types were analysed. Dabbling ducks were the dominant group in 3 types (flooded fields, lakes, estuary), and grebes dominated the two marine types. Diving ducks came second in lakes, small bays and open coastline, while gulls were second in flooded fields and the estuary. American coots were only abundant in the lake and estuary habitats, and Canada geese only on the lakes. A map is included which rates habitats on an importance scale of 1 to 4, indicates dominant species groups in each, and whether the area is important for production or wintering. Past and potential impacts on waterfowl habitat in the study area are briefly discussed.

Burns, T. & B.D. Tutty. Coho colonization potential of the Cowichan-Koksilah watershed: a habitat evaluation. Canadian manuscript report of fisheries and aquatic sciences; no. 1865. Canada Dept. of Fisheries and Oceans. Pacific Region. Habitat Management Unit Vancouver, B.C. Dept. of Fisheries and Oceans, South Coast Division, Habitat Management Operations. 1986.

Abstract: Reaches of the Cowichan-Koksilah system situated above barriers were assessed for their suitability as

coho rearing habitat in the arid late summer of 1985. Discharge and temperature were recorded, along with structural characteristics of specified stream sections.

Burns, Ted. Observations on the Lower Intertidal and Upper Subtidal Zones of the Cowichan Estuary. Cowichan Estuary Plan Implementation. 1982.

Abstract: This survey was carried out on May 25, 1982 on the lower intertidal and upper subtidal zones of the Cowichan Estuary to assess eelgrass distribution and density as well as to observe benthic habitat conditions and faunal utilization. Eelgrass distribution along the delta front is discontinuous, and overall density is low. Two factors appear to be limiting expansion: exposure and log handling. Wave attack potential is realatively high on the northern part of the delta and substrate rippling was evident in several places. River erosion accretion in this area may limit eelgrass expansion. Propellor wash and log and debris grounding is also evident and inhibits development. These two factors work together to impose a strong limit on full development of the north delta eelgrass community. Deepwater log storage just off the delta foreslope would aid eelgrass development by protecting eelgrass habitat from wave attack and the abrasive impacts of intertidal and upper subtidal log movement.

Campbell, Alison Prentice. The effects of dyke breaching on the vegetation, bird use and soil salinity at the Blackley farm and Koksilah marsh habitat enhancement areas of the Cowichan River estuary: a preliminary report. BC Ministry of Environment and Parks, Fish and Wildlife Branch. Victoria, BC. 1988.

Abstract: This report summarizes the information collected at the Blackley farm and Koksilah marsh enhancement areas on the Cowichan River estuary between 1983 and 1987. Vegetation surveys and Waterbird surveys were completed for the two areas and a comparison of soil salinity and pH at the Blackley farm enhancement area before and after dyke breaching was completed. Vegetation surveys found that after dyke breaching, vegetation changes included the disappearance of several salt intolerant upland species and increases in a number of salt tolerant colonizing species important for fish and waterfowl. The complexity of the vegetation increased in response to the increased variety of habitats but remained different from the natural marsh outside the dykes which contained a number of species not found in the enhancement area. Waterbird surveys of the Blackley farm enhancement area found the intertidal areas, marsh and tidal channels were the most commonly used habitat types while agricultural and marsh habitat backshore areas were most commonly used. Waterbird surveys within the Koksilah marsh area found more birds were observed in intertidal than backshore areas with the exception of eagles which were only observed in backshore habitats. After dyke breaching, a larger percent of species were observed in intertidal than backshore habitats. Soil salinity testing found that field tests showed no correspondence to lab tested samples and pH comparisons before and after breaching showed and increase in pH following dyke breaching and with the mean value increased from 4.9 to 5.6.

Campbell, Alison Prentice. The effects of dyke breaching on the bird use of the Blackley farm and Koksilah marsh habitat enhancement areas of the Cowichan River estuary. Fish and Wildlife Branch, BC Ministry of Environment, Nanaimo, BC. 1990.

Abstract: The effects of dyke breaching on the bird use of the Blackley farm and Koksilah marsh enhancement areas of the Cowichan River estuary were studied by investigating species numbers and habitat use. Many species groups (e.g. shorebirds) showed an increase in average number and frequency of occurrence after dyke breaching and those species groups were often observed using th enew intertidal habitat types created by dyke breaching. At the Koksilah marsh, shorebirds, dabbleing ducks, geese, gulls, killdeer and herons and allies showed an increase in numbers and a preference for the newly created habitats. At the Blackley farm area, shorebirds and herons and allies were affected the most by dyke breaching. Changes in vegetation of the areas that were subject to tidal flooding after dyke breching may have contributed to the changes in bird use. On days when snow and ice cowvered the upland habitats at the Blackley farm and Koksilah marsh, more birds used the enhanced intertidal areas created by dyke breaching after the dykes were breached than before. This could be due to the fact that those areas became intertidal following dyke breaching and therefore did not freeze in winter. However, the birds also used the areas more after dyke breaching on days without snow and ice so other factors such as the changes in vegetation following breaching of the dykes are probably involved.

Campbell, Alison Prentice and W. Sean Boyd. Intertidal and Adjacent Upland Habitat in

Estuaries Located on the East Coast of Vancouver Island - A pilot assessment of their Historical Changes. Technical Report Series No. 38, Environment Canada, Canadian Wildlife Service, Pacific and Yukon Region. Delta, BC. 1988.

Abstract: This pilot study investigated historical change to estuaries on the east coast of Vancouver Island. Within the estuary intertidal boundary, the most serious habitat loss was a 32% decrease in marsh habitat which occured at the turn of the 20th century when early settlers dyked upper marshes for agricultural purposes. During the last 40 to 50 years, loss of marsh habitat has slowed and has been offset by dyke breaching and vegetation transplanting. Intertidal substrate and subtidal water habitats have experienced relatively high losses in recent years, however those losses represent only 2% of their original areas. The major threats to estuarine intertidal habitats were log handling, log storage, pulpmill construction, and marina expansion. In upland areas adjacent to estuaries, forest, meadow, and agriculturual land have been increasingly replaced by log handling industries, logged areas, and residential development. Aerial photographs were useful in determining habitat change even though some problems with time period coverage and scale were experienced.

Campbell, Alison Prentice. Vegetation change on to three years following dyke breaching at the Blackley farm enhancement area, Cowichan River estuary. Fish and Wildlife Branch, BC Ministry of Environment, Nanaimo, BC. 1989.

Abstract: Vegetation and salinity changes one, two and three years following dyke breaching were examined at the Blackley farm enhancement area. Vegetation changes included the disappearance of upland species and the increase of species important from a fish and waterfowl perspective e.g. *Carex, Scirpus*, and *Triglochin*. Two desirable species – *Ruppia* and *Eleocharis* were new to the study area one year after dyke breaching. The newly created channels and areas that became devoid of vegetation due to heavy machinery gaining access to the dykes both supported new communities containing desirable species such as *Ruppia* and *Scirpus*. Those changes were most likely related to the increased tidal flooding of the area since the salinity and pH did not show much change following dyke breaching.

Candy, J.R. D.A. Nagtegaal, B. Riddell, B. A Preliminary report on juvenile chinook production in the Cowichan River during 1993 and 1994. Canadian manuscript report of fisheries and aquatic sciences/ Canada. Dept. of Fisheries & Oceans ; no. 2354 Nanaimo, BC Dept. of Fisheries & Oceans, Pacific Biological Station.1996.

Abstract: As part on an ongoing study to assess the productivity of chinook salmon in the Cowichan river, the Dept. of Fisheries and Oceans, Pacific Biological Station, began monitoring the downstream migration of chinook juveniles in 1991. This report presents the results of the study, which includes migration timing, growth, interaction, and abundance estimates of naturally-spawned and hatchery chinook juveniles in the Cowichan river over a two-year period.

Candy, J.R., D.A. Nagtegaal & B. Riddell. A Preliminary report on juvenile chinook production in the Cowichan River during 1991 and 1992. Nanaimo, BC Dept. of Fisheries & Oceans, Biological Sciences Branch, Pacific Biological Station. 1995.

Abstract: Presents the findings of part of an ongoing study to assess the productivity of chinook salmon in the Cowichan River, in which researchers began monitoring the downstream migration of Chinook juveniles in 1991. They also monitored the interaction between hatchery and naturally-spawned chinook juveniles. Various techniques
and equipment such as minnow traps and purse seines were used on the river in 1991 and 1992 to collect information on growth, abundance, and migration timing of juvenile chinook salmon. Results presented include estimates of naturally-spawned chinook juveniles and hatchery releases.

Costa, Maycira. Four-scale remote sensing approach for investigating water quality of Cowichan estuary, BC, Canada. AMRS Conference 2003: Hyperspectral Issues for Coastal Zone Environments. Alliance for Marine Remote Sensing Association. Halifax, NS. 2003.

Abstract: Co-authors: Telmer, K.; Piller, C.; Gallagher, L. The main goal of this project is to provide baseline information and models to effectively use optical remotely sensed imagery to evaluate changes in water quality of fresh and coastal waters, and contribute to our ability to separate natural versus anthropogenic inputs and impacts on water and ecology. The research area is Cowichan lake and estuary, located in the Southeast of Vancouver Island, British Columbia, Canada. The Cowichan watershed represents a large range in land-use and land cover. The research method encompasses a hierarchical four-step approach in terms of data acquisition: (i) field samples
of water quality variables, (ii) field spectro-radiometry, (iii) air-borne hyperspectral image acquisition, and (iv) satellite image acquisition. In this hierarchical approach, field data are acquired in natural conditions, which will then be upscaled to airborne and finally to satellite-borne imagery. Further, the land-use and land cover of the watershed will be associated to the water properties. We expect to define the optimal wavelengths and width of spectral bands for the determination of water quality parameters of coastal waters under the influence of land use.

Cottrell, Paul Edward. Diet, activity budgets, and movement patterns of harbour seals (*Phoca vitulina*) in Cowichan Bay and adjacent areas. University of Victoria, Biology M. Sc. Thesis. 1995

Abstract: This project investigated harbour seals using Cowichan Bay and adjacent areas, and the interaction of seasonal changes in diet with movement patterns, population fluctuations, and activity budgets. Seasonal and diel variation in prey distribution, abundance, and behavior also were examined in relation to harbour seal diet, movement patterns, and diel haul-out and swimming patterns.
Captive harbour seals feeding studies were conducted to evaluate and improve techniques for prey identification. Teleost otoliths in faeces have been used to characterize pinniped diet. A total of 471 prey occurrences (x = 1/5 per scat) representing 19 species in 16 families were identified. Teleost fish represented 93% of all prey identified. Prey diversity was greatest during September and October. Seasonal variation in the diet was pronounced for most prey species. This variation appeared to be a result of annual changes in prey abundance, distribution, or behavior. Nineteen harbour seals were captured and fitted with radio-tags. Seals were monitored every 3-5 minutes for 20 seconds from May 1991 to June 1992 from a remote monitoring station located in Cowichan Bay. The diel and seasonal haul-out and swimming patterns of radio-tagged seals were determined. In addition, the movement patterns and foraging areas of radio-tagged seals outside the study area were located by finding animals from land or boat with a hand held radio-receiver. Harbour seal haul-out patterns on log-booms were closely correlated with tidal height and, to a lesser extent, time of day. Sixteen of 18 seals had significant, positive linear relationships of time that seals spent hauled out to tidal height. The proportion of time that seals spent hauled out was low at dawn and dusk during the summer and at dusk during the winter. The two main prey items of harbour seals in this area were herring and hake (>65%), which are diel vertical migrators. Crepuscular movements of these prey types closer to the surface combined with changes in their schooling behaviour may increase harbour seal foraging success. Seals spent more time hauled out in August to February than the rest of the year. This corresponds to the moulting period and growth of new pelage of harbour seals in the area.

Dawe, Neil K., Lindsay E. Jones. Vegetation of the Koksilah marsh, Cowichan estuary: a pre-restoration study, July 1985. Technical report series no. 9. Environment Canada, Canadian Wildlife Service, Pacific and Yukon Region. Delta, BC. 1986.

Abstract: To determine the effect of returning a former agricultural field (Koksilah Marsh) and adjacent disturbed wetland (CN March) on the Cowichan River estuary to intertidal habitat, baseline vegetation and soil-water salinity data were gathered in July and September 1985. Three permanent transects were established across the areas of proposed impact and 21 species of vascular plants were recorded. Seven additional species from the family Graminese were also noted. Four plant communities were identified and are described along with elevation and soil water salinity
data. Broad predictions of the resulting vegetation, following a return of the study area to tidal inundation, are made.

Doman Forest Products Ltd. Cowichan Bay Division Subsurface Environmental Assessment. Envirochem Special Projects Inc. North Vancouver, BC. 1990.

Abstract: This assessment was conducted to evaluate the presence and potential for offsite migration of chlorophenol residuals at the site which may have resulted from the historical use of chlorophenols as

antisapstain chemicals. Eight boreholes were drilled within the site boundaries and monitor wells were installed at all eight locations. Based on this drilling program and previous drilling efforts in the area, the Doman site is underlain by up to 30 meters of interbedded sands and gravels with some silt. Groundwater flow is relatively fast due to the permeability of the coarse subsurface sediments. The analytical results indicated that of 8 test areas, only one sediment sample contained a detectible chlorophenol concentration, just above detection at 0.12 mg/kg (ppm). This sample was collected near the surface in the vacinity of the dredgate storage pile and was well within acceptable limits for all land uses. All groundwater analyses, including those near the dredgate pile, were less than the detection limit of 1 ug/L (ppb), indicating no detectible migration of chlorophenols in the subsurface at the Doman site.

Drinnan, R.W., B. Emmett, B. Humphrey, B. Austin, D.J. Hull. Saanich Inlet Study. Water Use Inventory & Water Quality Assessment. Ministry of Environment, Lands and Parks, BC. 1995.

Abstract: This publication constitutes a review of published and unpublished environmental information, on the current environmental status of the inlet and the range of resources and water uses which exist. Included in the conclusions is that although there are numerous streams and small rivers that discharge into the inlet, the largest contribution of freshwater is from outside, from the Cowichan and Fraser Rivers.

Environmental Assessment and Proposed Long Range Plan for the Maintenance of the Cowichan Bay Sawmill Access Channel. New Pacific Ventures and Northwest Hydraulic Consultants. 1997.

Abstract: This report addresses the problem of gravel buildup in the Doman Sawmill log haul channel located on Cowichan Bay at the mouth of the Cowichan River. Recent channel maintenance activities, which have consisted primarily of small scale dredging of the channel immediately downstream of the log sort pond, are reviewed and an environmental assessment which considers both biological and hydraulic factors is provided. Six alternative strategies for managing this problem are presented and evaluated according to their effectiveness, anticipated environmental impact, and logistics. It is recommended to continue periodic dredging near the mouth of the log pond with a few modifications to reduce the frequency of intervention required. Sidecasting of material is to be used to adjust the channel shape in the vicinity of the gravel buildup area and then discontinued. A two year permit, allowing the minimum amount of dredging to effectively reopen the channel, to a maximum of 2000 cubic metres of gravel per fishery window (February and August of each year) is proposed. This permit would be reviewed at the end of two years to allow resource managers to evaluate the results and the best future strategy. Ongoing evaluation, through surveys of the bed elevation in the vicinity and the presence of an independent environmental monitor at each excavation is proposed.

Ferguson, A., G. Holman, and R. U. Kistritz. Wetlands are not wastelands : application of wetland evaluation methods to the Cowichan Estuary, British Columbia : Pacific and Yukon Region Pilot Study, Ottawa Canadian Wildlife Service, Sustainable Development Branch, Wildlife Habitat Canada. 1989.

Abstract: This study demonstrates the application of 3 wetland evaluation methods related to willingness-to-pay, opportunity cost and cumulative assessment, using the Cowichan Estuary on Vancouver Island as a case study. The study described the characteristics and distribution of wetland habitat types within the estuary. The impact of two hypothetical development projects on the physical, biological and socio-economic functions performed by the wetlands and the related wetland products, particularly fish, birds, recreation and water quality are assessed in detail. A habitat rating system is used to ascribe the wetland products to various habitat types and areas within the estuary.

Frith, Russ H., Blair Humphrey, Peter Wainwright and Karl English. Cowichan Estuary State of the Environment Report. LGL Limited & EnviroEd Consultants Ltd. 1993.

Abstract: In this report, the state of the marine environment in Cowichan Bay is evaluated. The marine environment includes intertidal areas of the foreshore and estuary marsh but does not include rivers and streams. In addressing the present condition of the marine environment, the main sources of input of known pollutants and contaminants were evaluated. The dominant factors of concern to the condition of the marine environment in Cowichan Bay are habitat loss, discharge of antisapstains into the estuary, the presence of dioxins and furans in the marine environment, and the presence of coliform bacteria in marine waters.
Storage of logs as log booms and the transportation of log booms in shallow waters is known to cause the compaction and disturbance of sediments. The impact of this activity is the degradation of the associated benthic community and its value as a food source and as a refuge for organisms of commercial and recreational value such as crabs, shellfish and juvenile salmon. The majority of habitat loss has been due to landfilling for industrial use or dyking for creation of farmland.
Antisapstains used by the lumber industry to treat wood during processing persist in the sediments and tissues of marine organisms for a number of years after discontinuance of a product and the long-term effects of these chemicals are unknown. However, the concentrations are well below lethal concentrations, and are below levels considered a risk to the health of human consumers. Dioxins and furans result from the processing of lumber in sawmills and pulp and paper mills, antisapstain products and possibly the municipal incinerator. The most recent data available show concentrations of dioxins and furans below levels considered a risk to human health but sufficiently high to warrant a consumption advisory. An analysis of concentrations found in sediments and organism tissue should show whether the expected decline in dioxins and furans is observed. Concentrations of coliform within the Cowichan Bay marine environment were sufficiently high to cause the closure for recreational and commercial harvesting of clams in 1973. The concentrations of coliform before and after the main sewage treatment facility indicate that the Duncan-North Cowichan sewage treatment plant does not contribute to the coliform bacteria counts observed in Cowichan Bay. The non-point sources such as septic fields adjacent to the river and bay, cattle farming and wildlife are therefore indicated as the probable cause.
The review of the state of the marine environment in Cowichan Bay revealed four main areas of concern. In our opinions, the problems of greatest future influence on the bay and the health of the resources within are habitat loss and contamination from sewage. These sources of environmental degredation are apt to continue with future urban expansion. The problems associated with antisapstains and dioxins and furans are less of a concern given that measures have been taken to reduce of eliminate the sources of these pollutants.

Hunter, R.A., M. M. Wayne, A. Campbell and H. J. Quesnel. Cowichan Estuarine Habitat Inventory map. BC Ministry of Environment. Victoria, BC. 1982.

Abstract: Hunter et al. (1982) used substrate, vegetation, salinity, and anthropologic influences to describe and delineate habitat types for several estuaries in the Strait of Georgia. Information used to produce one such map, the Cowichan Estuarine Habitat Inventory (CEHI), was derived from most recent colour air photos and ground truthing and was supplemented with information from historical reports and other air photos (Hunter et al. 1982). The CEHI map was used as an example of how habitat types could be used to create a productivity map of an estuary.
Primary production data from the literature, in conjunction with the CEHI map, was used to produce a map that shows estuarine production by habitat type. For example, vegetation described for each habitat type in the estuary were used to determine the primary production for the respective habitat. Primary production values selected from the literature for the respective vegetation types was dependent on species, communities, and location where reference values were measured. As well, dominance and percent cover were used in the calculation. Only habitat types with vegetative descriptions could be used to calculate primary production.
In some descriptions of habitat type for the CEHI map, dominance and percent cover were not documented and only a list of the vegetation types observed were presented. And in some cases no primary production values were found in the literature for the vegetation observed in the Cowichan River estuary. Therefore, some subjectivity was used to decide on what values to use in the calculation of the productivity value.

Kennedy, Kathryn and Barbara Raymond Waters. Cowichan River Estuary. Fish and Wildlife Branch BC, Nanaimo, BC. 1974.

Abstract: This survey contains a plant list of species of the Cowichan River Estuary according to each area of the estuary including aquatic vegetation. A list of birds, fish and invertebrates is included as well as a description of climate, geology, soils, hydrology, hydrography, oceanography and land use.

Lill, A.F., D.E. Marshall and R.S. Hooton, Conservation of Fish and Wildlife of the Cowichan - Koksilah Flood Plain. Canada Fisheries and Marine Service Operations Branch, Fish and Wildlife Branch BC, Environment Canada and BC Department of Recreation and Conservation. 1974.

Abstract: Background information is presented on the fish and wildlife resources and recreational amenities of the Cowichan and Koksilah rivers with particular reference to the flood plain area. An appraisal is also given of their enhancement potentials. Problems associated with various flood control measures are discussed and recommendations are given for resource protection. It is recommended to retain the remaining undeveloped area of the flood plain in a natural state and to rehabilitate those areas that have been adversely affected by encroachments. Estuarine habitat is essential to the total fish and wildlife productivity of the river systems. It is limited in quantity and cannot be replaced or enhanced by known mitigative techniques. Further interference with the natural integrity of this area by dyking and/or channelization may precipitate an ecological crisis and eliminate options for enhancement of fish and wildlife resources.

Low, D. D. and T. J. Tevendale. Shellfish growing water sanitary survey of Cowichan Bay, British Columbia. Pollution Abatement Branch, Environmental Protection Service, Pacific Region. Vancouver, BC. 1974.

Marven, D. The Birds of Cowichan Bay. 2003

Abstract: This paper rates 231 birds on whether or not they are found in Cowichan Bay. The birds have been divided into the following sections: extremely rare, very rare, rare, uncommon and common.

Morrison, D., M.Wayne, A. McKenzie, and R. Hunter. Cowichan Estuary Doman Property Land Acquisition Options:
A Discussion Paper. BC Ministry of Environment. 1983.

Abstract: This paper analyzes options available for the Ministry of Environment concerning the acquisition of the Doman (Blackley Farm) parcel. The paper discusses the options in terms of lowest costs and maximum benefits to the fish and wildlife.

Nagtegaal, D.A., C.J. Hillier and E.W. Carter. A preliminary report on juvenile chinook production in the Cowichan River, 1998. Fisheries Oceans Canada, Science Branch, Pacific Region, Pacific Biology Station. Nanaimo, BC. 1999.

Abstract: In 1991, Fisheries and Oceans Canada (DFO), Pacific Biological Station began a study of juvenile chinook salmon (Oncorhynchus tshawytscha) productivity in the Cowichan River. The 1998 study is concerned primarily with the enumeration and out-migration timing of naturally-reared chinook juveniles. The estimated production of naturally-reared chinook juveniles from the 1997 brood year was 1,638,198 (95% Confidence limit 1,376,097 - 1,900,324). There were three distinct peaks in the out-migration of naturally-reared chinook. The first occurred March 15 - 17, the second and largest occurred March 19 - 21 and the final peak occurred March 23 - 28. The release of chinook
from the Cowichan River hatchery totaled 262,675. Of these, 160,924 hatchery-reared chinook were released above the trapping site. Trapping results maintain that most hatchery-reared chinook migrate to the Cowichan estuary within one week of release. Interaction between naturally-reared and hatchery-reared chinook juveniles is therefore
believed to be limited.

Nagtegaal, D.A., E.W. Carter & B.E. Riddell. A preliminary report on the adult chinook productivity study conducted on the Cowichan River during 1995. Canadian manuscript report of fisheries and aquatic sciences/ Canada. Dept. of Fisheries & Oceans ; no. 2366. Nanaimo, BC Fisheries & Oceans Canada, Science Branch, Pacific Region, Pacific Biological Station. 1996.

Abstract: Presents results of the adult escapement enumeration component of a chinook productivity study conducted on the Cowichan River in fall 1995. Components of the enumeration included recording of salmon

counts at 15-minute intervals at a counting fence, estimation of the native food fishery catch, recording of hatchery broodstock removals, collection of biological data and sampling of coded-wire tag recoveries, and carcass mark-recapture studies for both adult and jack chinook. Results presented include total return of adult chinook to the river and an estimate of the total number of natural spawners. In addition, a water management plan is described which was intended to aid upstream movement of chinook.

Nagtegaal, D.A. and E.W. Carter. Adult chinook escapement assessment conducted on the Cowichan River During 1999. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2544. Fisheries and Oceans Canada, Science Branch, Pacific Region, Pacific Biology Station. Nanaimo, BC. 2000.

Abstract: In 1999 the Stock Assessment Division, Pacific Biological Station, conducted a study of chinook salmon *(Oncorhynchus tshawytscha)* productivity in the Cowichan River. This in-depth adult escapement assessment project has been in place since 1988. Major components of this ongoing study include: I) enumeration of spawners and total return, ii) estimation of Native food fish catch, iii) recording hatchery broodstock removals, iv) biological sampling and coded-wire tag (CWT) recovery data collection. A carcass mark-recapture study was conducted to augment the fence count. Total return of adult chinook to the Cowichan River was estimated to be 6,392 in 2000. The number of natural spawners was estimated to be 4,500. Carcass mark-recapture escapement estimate of upper river spawners was determined to be 3,440 (95% CL; 2,908-3,972).

Nagtegaal, D.A. & E.W. Carter. Adult chinook escapement assessment conducted on the Cowichan River During 1996. Canadian manuscript report of fisheries and aquatic sciences/ Canada. Dept. of Fisheries & Oceans ; no. 2449 Nanaimo, BC Fisheries & Oceans Canada, Science Branch, Pacific Region, Pacific Biological Station. 1998.

Abstract: Presents results of an adult chinook salmon escapement enumeration study, conducted as part of a chinook productivity study on the Cowichan River, British Columbia, during fall 1996. Components of the study included: enumeration of chinook salmon at a counting fence; estimation and biological sampling of the Native food fishery
catch; recording of hatchery broodstock removals; collection of biological data and sampling of coded wire tag recoveries; and carcass mark-recapture studies for both adult and jack chinook.

Quesnel, Harold J. and Tarje Vold. Baseline Soil Data For Blackley Farm, Cowichan River Estuary, Cowichan Bay British Columbia. Ministry of Agriculture and Food and Ministry of Environment. 1986.

Abstract: The Blackley farm on the Cowichan River estuary is an area characterized by a complex of surface and subsurface flows of saline and fresh water. The soils have been affected intermittently by flooding and flushing from the Cowichan River. These effects have been compounded by subsurface and surface fluxes of saline water along the relic tidal channels, by the influx of subsurface saline water on the northern section of the farm, and by the subsurface flow of fresh water on the southern section of the farm. Successful reclamation of the salt-impacted soil will depend on successful control of subsurface as well as surface flows of saline water.

Rideout, Paul, Bernie Taekema and John Deniseger, et.al. A Water Quality Assessment of the Cowichan and Koksilah Rivers and Cowichan Bay. Ministry of Environment Lands and Parks, Pollution Prevention, Vancouver Island Region. 2000.

Abstract: The purpose of this study is to identify sources of coliforms and nutrients with emphasis on non-point sources to meet drinking water quality objectives in the rivers and shellfish water quality objectives in Cowichan Bay. Sampling locations were identified on each river and on several tributary streams as well as sites associated with ditches and stormwater drains located in urban and industrialized areas. Samples were collected and analysed for fecal coliforms, nutrients, total and dissolved metals and toxic substances. It was found that the Cowichan River frequently exceeded desired levels of fecal coliform bacteria, however, the two sewage discharges to the river were not found to be significant contributors to this pollution. The Koksilah River regularly contained excessive fecal coliform bacteria also attributed to non-point sources. The report concluded that the discharge from the sewage treatment plant, serving the village of Cowichan Bay, is a primary contributor to fecal

coliform bacteria pollution in the bay. Excessive nutrient levels in the two rivers result in significant algae growth impacting the natural benthic community and fish in both rivers. Levels of metals and other contaminants, such as oil and grease and hydrocarbons were low in the Cowichan and Koksilah rivers while various stormwater conduits in urban and industrial areas had comparatively high but typical concentrations. On small streams, their impact would be significant but loadings were small compared to dilution in the two rivers.

Saanich Inlet Study. Synthesis Report: Technical Version. Ministry of Environment, Lands and Parks. 1996.

Abstract: This report is a diagnosis of the Saanich Inlet's present state and sensitivities. This study synthesizes available information and makes judgements to describe the sensitivity of Saanich Inlet to the best of the study team's ability. The approach taken to the Saanich Inlet Synthesis Study can be described at two levels: baseline and interpretation. This report takes the findings of approximately ten baseline investigations conducted under the Saanich Inlet Study, conducts various analyses of assimilative capacity in some key areas and then synthesizes the information into an overall interpretation of the assimilative capacity and sensitivity of Saanich Inlet.

Sensitive Ecosystems Inventory: East Vancouver Island and Gulf Islands. BC Conservation Data Center, Victoria BC. No. 92B.072. 1997.

Abstract: This map includes the Cowichan Bay area and portions of the Cowichan and Koksilah river system as part of the SEI mapping project. This project systematically identified, classified, mapped and evaluated sensitive ecosystems in the Capital, Cowichan Valley, Nanaimo and Comox-Strathcona regional districts and the Islands Trust area. Approximately 9000 sites were identified in an area of 5000 sq. kilometers to delineate remnants of rare and fragile terrestrial ecosystems. For site specific evaluations, more detailed assessments are recommended. The accuracy of the boundaries of the mapped SEI data is limited by the scale of the air photos on which the sites are delineated.

Sibert, J., T.J. Brown, B.A. Kask, and J.D. Fulton. Observations on the lower trophic levels of the Cowichan Estuary, Vancouver Island, BC Manuscr. Rep. Ser. Fish. Res. Board Can., Fisheries Resources Board Canada. Vancouver Island, BC. 1976. 1394:1-25.

Abstract: In July 1975 a study of the lower trophic levels in the Cowichan estuary was undertaken to provide basic data on the distribution of planktonic and intertidal benthic resources, in comparison with a study on the Nanaimo estuary. Highest autotrophic activity occurred in an area of open water, as did highest heterotrophic activity; salinity profiles show good mixing, so that productivity may be attributed to a good supply of nutrients. A sandy
environment with low chlorophyll and low heterotrophic activity appears to be most suitable for harpacticoid copepods. Zooplankton was found in patches and is typical for a protected estuarine habitat in midsummer.

Site Assessment at Westcan Terminals Ltd. Cowichan Bay. Envirochem Special Projects Inc. North Vancouver, BC. 1990.

Abstract: The Westcan Terminals Ltd. Study site is located in Cowichan Bay at the mouth of the Cowichan River estuary. Since construction the site has been primarily used as a lumber ship loading facility for deep-sea vessels with additional access to the site via road and rail. The run-off water at this site collects in 5 catch basins and is discharged by gravity via two outfall. Two paved areas and one gravel area were sampled. Detectable concentrations of chlorophenols were not found in surface soils, subsurface soils or catch basin sediments from the Westcan Terminal Site. The detection level was 0.1 mg/kg. Soils with chlorophenols at less than 0.1 mg/kg are considered by the BC Ministry of Environment to be 'uncontaminated'. The long-term presence of pavement at the main storage area, further suggests that subsurface contamination was effectively minimized.

Stoner, J. Cowichan Estuary nesting waterfowl count. Fish and Wildlife Branch, Nanaimo, BC. 1983.

Vermeer, K., M. Bentley and K.H. Morgan. Comparison of the waterbird populations

of the Chemainus, Cowichan, and Nanaimo River estuaries. Occas. Pap. Can. Wildl. Serv., Environment Canada, Canadian Wildlife Service. Ottawa, ON. 1994. 83:44-56.

Abstract: Comparison of the compositions and densities of waterbird populations were made for the Chemainus, Cowichan, and Nanaimo river estuaries, censused in 1989. In all three estuaries, highest densities occurred from October through April. The Nanaimo River estuary had low densities of swans and diving ducks but high densities of glaucous-winged gulls *Larus glaucescens*. The Cowichan River estuary had higher densities of piscivorous birds, ducks in the genus *Bucephala*, and new *Larus canus* and ring-billed *L. delawarensis* gulls. It was also the only estuary used extensively by mute swans *Cygnus olor*. The Chemainus River estuary had relatively high densities of greater scaups *Aythya marila*, surf scoters *Melanitta perspicillata*, white-winged scoters *M. fusca*, and Bonaparte's *Larus philadelphia* and California *L. californicus* gulls. Differences in bird composition between estuaries are thought to be related to food availability, nearness of human refuse, effects of log storage, and adjacent nesting habitat. Waterbird densities were compared between these three Vancouver Island estuaries and the Fraser River estuary, the largest estuary in British Columbia. The Fraser River estuary had much higher densities of geese and ducks, probably because of the presence of extensive brackish water marshes, eelgrass beds, and nearby farmlands on which waterfowl feed.

Vermeer, K., K.H. Morgan, G.E.J. Smith and A.N. Wisely. Habitat use by waterbirds in the Cowichan River estuary. Occas. Pap. Can. Wildl. Serv. Environment Canada, Canadian Wildlife Service. Ottawa, ON. 1994. 83:63-69.

Abstract: Many Vancouver Island estuaries have been considerably reduced in size by human development. Campbell Prentice and Boyd (1988) reported that extensive human development, including log handling and storage, pulp
mills, and marinas, had led to more than a 30% decline in area of estuarine habitats along the east coast of Vancouver Island over the last 100 years. Because of the threats to Vancouver Island estuaries, the Canadian Wildlife
Service initiated a year-long census to determine the size and composition of waterbird populations in five estuaries on the east coast of Vancouver Island (Courtenay, Chemainus, Cowichan, Gorge, and Nanaimo estuaries). In this paper, we describe the influence of tide level and season on habitat use by waterbirds in the Cowichan River estuary. Use of habitats (subtidal zone, intertidal zone, river mouths, fields, and log booms and pilings) by waterbirds was investigated in the Cowichan River estuary, Vancouver Island, British Columbia. Habitat was the main factor that correlated
significantly with the distribution waterbirds. Most fish-eating birds other than double-crested cormorants, *Phalacrocorax auritus* occurred over subtidal areas. Dabbling ducks were found mostly in river mouths, whereas diving ducks were most numerous in intertidal areas. Barrow's goldeneyes *Bucephala islandica* and hooded mergansers *Lophodytes cucullatus* had significantly higher densities on booms and pilings than in any other habitats; Mute swans *Cygnus olor*, American wigeons *Anas americana*, and buffleheads *Bucephala albeola* switched from river mouths in January to intertidal areas in April; and Canada geese *Branta canadensis* moved from
fields in January to river mouths in April. Species densities were also correlated with tidal level. Surf scoters *Melanitta perspicillata* and white-winged scoters *M. fusca* had high densities in subtidal areas during low tide. Mute swans, American wigeons, and glaucous-winged gulls *Larus glaucescens* were most numerous in river mouths, and mew gulls *L. canus* were abundant at river mouths and on booms and pilings during high tide.

Wayne, M.M. Cowichan Estuarine Habitat Inventory, 1:2,500 map. Surveys and Resource Mapping Branch, Ministry of Environment, Victoria, BC. 1983.

Abstract: This map delineates habitat types and describes them as a function of substrate, vegetation, salinity and anthropogenic influences. Information is derived from interpretation of recent large scale colour air photos and ground truthing, supplemented by historical reports and air photos. Habitat types are defined for the intertidal and backshore zones of the Cowichan River Estuary.

RESTORATION

Austin, William C. Marine Environment Stewardship Project. Marine Ecology Centre, Cowichan Bay Maritime Centre. 1992

Abstract: This year long project focused on cleaning up the Cowichan Estuary. Garbage was removed from the shorelines, intertidal and subtidal areas of the bay, through the use of volunteers, school groups, professionals and the general public. Garbage materials removed included tires, styrafoam, glass bottles, plastics, boat batteries, metal and numerous other metals.

Box Culvert Installation on Spiers Creek, Cowichan Bay Road. Aquaterra Environmental Monitoring and Fisheries Consulting. Nanaimo, BC. 2000.

Bringing Back the Coho – Fish Enhancement, Treffrey Creek Coho: Rearing Ponds Project. HiLine Videoworks. Victoria, BC. 2002.

Chaster, Gerry. Maple Grove Restoration Project: Arborist Report. Gerry Chaster, Landscape consultant B. S. A., M. A. (Hort). Victoria, BC. 1994.

Abstract: Assessments of native Big leaf Maples (Acer macrophyllum) at Koksilah River Grove in Cowichan Bay, British Columbia took place in July 1994. Trees were tagged with yellow disks and numbered from north to south in the grove. Each tree was examined from ground level and rated excellent to poor on a number scale of 1-10 respectively. Conditions of the trees varied and included ratings of excellent as well as examples of burling, Maple Die Back Disease, fungus and rot. Restoration strategies for each tree were recommended including planting of young Acer macrophyllum in large spaces between trees.

Wayne, M. Possible Rehabilitation/Enhancement for Blackley Farm Habitat Conservation Management Area. Ministry of Environment, Wildlife Branch. 1985.

PLANNING

Cowichan Indian Band and BC Environment. Agreement on Joint Stewardship. Minister of Environment Lands & Parks. 1992.

Abstract: This agreement applies throughout the Cowichan area including the Cowichan and Koksilah River and Estuary. The purpose of this agreement is to create a cooperative working relationship toward improved management of the environment; to provide a framework and process in environment management activities; to provide a framework for joint recommendations toward action on environmental issues; to increase participation by Cowichan Band and BC Environment in environmental management; to communicate information regarding environmental concerns; and to provide a framework for developing subsidiary agreements on a broad range of issues affecting the environment.

Corpe, Cimarron. Coastal Zone Management: The Cowichan Estuary. University of Victoria, Geography MA Thesis. 2000.

Cowichan Bay Official Settlement Plan: Background Information. Electoral Area "D", Cowichan Valley Regional District, CVRD Land Use Services Department.

Cowichan Bay Official Settlement Plan: By-law No. 925. Electoral Area "D", Cowichan Valley Regional District, CVRD Land Use Services Department.

Cowichan Bay Improvement Association, Revitalization Plan. Cowichan Bay Improvement Association. Cowichan Bay, BC. 1990.

Cowichan Bay Improvement Association, Action Plan. Cowichan Bay Improvement Association. Cowichan Bay, BC. 1991.

Cowichan Estuary Environmental Management Plan. BC Ministry of Environment, Lands & Parks. 1993.

Cowichan Estuary Environmental Management Plan. BC Ministry of Environment Lands & Parks. 1994.

Cowichan Estuary Environmental Management Plan. BC Ministry of Environment Lands & Parks. 1995.

Cowichan Estuary Environmental Management Plan: Plan Review and Update. BC Ministry of Environment Lands & Parks. 1995.

Cowichan Estuary Task Force Report. Province of British Columbia, Environment and Land Use Committee Secretariat. 1980.

Abstract: Contained within the report is a proposed land use and management plan for the Cowichan and Koksilah estuary. Emphasis was placed on the intertidal and backshore areas at the mouth of the Cowichan and Koksilah Rivers. Findings are grouped under the following headings; Estuarine Resources, Environmental Impacts, Public Input Program, Proposals and Demand for Industrial Development, Economics of Alternative Uses, Employment, Log Management Concepts, Alternative Industrial Locations, Proposed Flood Control Plan, Proposed Land Use Plan and Recommendations.
**For the purposes of this bibliography only ecological findings under Estuarine Resources and Environment Impacts are summarized.*
Estuarine Resources: The intertidal zone is used by at least 31 species of fish including juvenile stages of herring, steelhead and three species of salmon. Salmonid enhancement projects for the Cowichan River are under way. Crab and shrimp populations are not well documented and shellfish populations have been closed to harvesting since 1973 due to fecal coliform pollution. At least 229 species of birds are known to use the estuary and lower floodplains including migratory bird species. Existing surface water supplies are very nearly fully committed and groundwater potentials are not well documented.
Environmental Impacts: The major source of environmental impact occurs through log handling, storage and boom assembly comprising 129 hectares or 45 percent of the intertidal zone. Compaction, scouring and shading of the substrate by logs as well as accumulation of wood debris have altered or destroyed large areas of natural intertidal vegetation, an important habitat component for waterfowl, juvenile fish and food organisms. Detailed quantification of these impacts was not possible but the impacts are considered significant. Natural dispersal of fresh water over the estuary has been disrupted by dyking, land fills, bridge construction, bedload settling in the river channels and possibly by the dredging of a millpond or by channel scouring resulting from boom towing. Presently 60 percent of the natural fresh water flow of the two rivers enters the central 20 percent of the estuary altering the salinity gradient and disrupting natural vegetative communities important to Cowichan salmon stocks. Water pollution sources are primarily organic wastes from sewage treatment facilities, agricultural run-off and wood debris from log handling activities. Impacts of wood debris deposition have not been studied. A water quality problem exists in the millpond which may be due to wood debris or mill effluent. Airborne pollutants are present from prevailing airflow patterns southward from Crofton and frequent temperature inversions.

Cowichan Watershed Strategic and Operational Plan. The Cowichan Watershed Council. Duncan, BC. 1997

Abstract: This overview of the Cowichan Watershed Council includes a listing of previous and current rehabilitation and enhancement projects within the Cowichan River watershed and their status. A prioritized list of possible habitat development projects based on the potential scope of the project and the level of interest within the local community is also included.

Electoral Area "D" Zoning Bylaw No. 1015. Cowichan Valley Regional District. CVRD Land Use Services Department. 1986.

Hird, John. Cowichan Bay Development Phase One Background Research. Cowichan Fisheries Steering Committee. 1998.

Lambertsen, G.K. An Environmental Management Plan for the Cowichan Estuary: Report on the Cowichan Estuary Plan Implementation Program. Ministry of Environment and Parks, Cowichan Estuary Plan Implementation. 1984.

Abstract: This report sets forth an environmental management plan designed to achieve the goal of balanced resource use in the Cowichan Estuary.

Lambertsen, G.K., Cowichan Estuary Environmental Management Plan. Ministry of Environment, Lands and Parks, Planning and Assessment Branch. 1987.

Abstract: The estuary of the Cowichan River and Koksilah River is situated in Cowichan Bay near the city of Duncan, about 40 km north of Victoria on the southeast coast of Vancouver Island. Extensive analysis of the resource use problems in the estuary by a large, intergovernmental task force culminated in the Cowichan Estuary Task Force Report in 1980, with the Cowichan Estuary Plan Implementation Program being initiated in 1981 to implement the log storage recommendations and proposed land use plan contained in the Task Force report. This document details and includes the agreements reached with British Columbia Forest Products, MacMillan Bloedel, Doman Industries, and Canadian National Railway; the area designations; the project review process; management activities; and the Environment Management Act. A report on the Cowichan Estuary Plan Implementation Program from March 1984 is also included.

Le Blanc, Gerard and Associates. Cowichan Bay Village/Harbour Local Area Plan. Cowichan Valley Regional District, Development Services Department. Duncan, BC. May 1994.

Marine protected areas forum: report of discussions, Cowichan Bay, BC. Salasan Associates Inc. Sidney, BC. 1995.

Options for the Log Haul Channel at Doman Forest Products Cowichan Bay Sawmill. New Pacific Ventures. Vancouver, BC. 1998.

Abstract: This report addresses issues surrounding the maintenance of the distributory channel used by Doman Forest Products to transport logs to their Cowichan Bay Sawmill. Findings from benthic sampling throughout the log transport channel indicate log scour to be damaging to the benthic flora and fauna. Excavation allows the bottom to remain undisturbed for an extended period of time. Given the high water period after the excavation it is not possible to determine if any change in abundance of diversity was caused by the excavation therefore the extent of the sidecast pile should be monitored and its coverage of the mudflat confined to a modest area. Findings from the sidecast pile survey showed that the strategy of placing newly excavated material on top of the pile and allowing natural forces to redistribute it has avoided excessive smothering on the tidal flat. However increased material will shift and increase the footprint of the pile therefore the rate of growth of the pile should be monitored. Recommendations for channel maintenance included regular excavation rather than scouring as scour has been noted to significantly reduce flora and fauna within the channel.

Wagner, Rick. The Cowichan Indian Band's Environmental Concerns Regarding Detrimental Impacts on the Cowichan and Koksilah Rivers and Cowichan Estuary Due to Municipal and Industrial Activities. Ministry of Environment, Lands and Parks, Environmental Protection. Nanaimo, BC. 1992.

Abstract: This paper discusses the environmental concerns of the Cowichan Indian Bands regarding municipal and industrial activities practiced in and around the estuary. In particular the Doman log pond, the Doman hog fuel storage site, the Cowichan Bay sewage treatment facility, the R.W. Saunders and Sons Ltd. site, the Duncan-North Cowichan sewage treatment lagoons, the fish hatchery effluent, Freshwater Farms, Ocean Farms, the CVRD landfill, the CVRD incinerator are discussed in terms of their previous and current effects/impacts on the estuary. Also included is the Band's ideas/wished on what they would like to see happen at these sites.

Wayne, M.M. Cowichan River Estuary Enhancement Area Management Plan. Ministry of Environment, Wildlife Branch. 1985.

Abstract: Doman Industries dedicated 23 acres of former intertidal land in the Cowichan River Estuary to the BC Ministry of Environment (M.O.E.) in compensation for 7 acres of intertidal marsh which was filled during sawmill reconstruction. Upon dedication M.O.E. constructed a flood control dyke on the landward portion of the 23 acres in a manner consistent with the Ministry's flood control plans for the Cowichan River. This dyke provided the opportunity for returning the remaining 16.6 acres to intertidal status. A committee comprised of individuals representing both provincial and federal resource agencies and public representatives considered several rehabilitation/enhancement options. This report represents the management plan put forward by that committee and details the strategy and means by which the rehabilitation/enhancement objectives will be met.

Appendix B: Chronological table of references

Author	Title	Year	Publisher
Austin, William C.	Survey of habitats, potential food and remediation requirements in juvenile Chinook nursery areas of the Cowichan Estuary		
Kennedy, Kathryn and Barbara Raymond Waters	Cowichan River Estuary	1974	Fish and Wildlife Branch BC, Nanaimo BC
Lill, A.F.; D.E. Marshall; R.S. Hooton	Conservation of Fish and Wildlife of the Cowichan - Koksilah Flood Plain	1974	Environment Canada & BC Department of Recreation and Conservation
Low, D.D. and T.J. Tevendale	Shellfish growing water sanitary survey of Cowichan Bay, British Columbia	1974	Environment Protection Service, Vancouver
Blood, D.A.; J. Comer & J. Polson	Migratory Bird use of the Duncan-Cowichan Bay area in 1975	1976	Canadian Wildlife Service
Sibert, J., T.J. Brown, B.A. Kask, and J.D. Fulton	Observations on the lower trophic levels of the Cowichan Estuary, Vancouver Island, BC.	1976	Fisheries Resources Board Canada, Vancouver Island
Armstrong, R.W. and A.W. Argue	Trapping and coded wire tagging of wild coho and Chinook juveniles from the Cowichan Rivers system	1977	Fisheries and Marine Service
	Cowichan Estuary Task Force Report	1980	Province of BC
Burns, Ted	Observations on the Lower Intertidal and Upper Subtidal Zones of the Cowichan Estuary	1982	
Hunter, R.A., M.M. Wayne, A. Campbell and H.J. Quesnel	Cowichan Estuarine Habitat Inventory Map	1982	BC Ministry of Environment, Victoria
Wayne, M.M.	Cowichan Estuarine Habitat Inventory, 1:2,500 map	1983	BC Ministry of Environment, Victoria
Stoner, J.	Cowichan Estuary nesting waterfowl count	1983	Fish and Wildlife Branch, BC Ministry of Environment and Parks, Nanaimo
Lambertsen, G.K.	Report on the Cowichan Estuary Plan Implementation Program	1984	BC Ministry of Environment, Victoria
Austin, William C.	An annotated checklist of marine invertebrates in the cold temperate northeast	1985	Khoyatan Marine Laboratory, Cowichan Bay
Wayne, M.M.	Cowichan River Estuary Enhancement Area Management Plan	1985	BC Ministry of Environment, Victoria

Wayne, M.M.	Possible Rehabilitation/Enhancement for Blackley Farm Habitat Conservation Management Area	1985	BC Ministry of Environment, Victoria
Burns, T. and B.D. Tutty	Coho colonization potential of the Cowichan-Koksilah watershed: a habitat evaluation.	1986	Fisheries and Oceans Canada, Vancouver
	Doman Forest Products Lt. Cowichan Bay Division Subsurface Environmental Assessment	1986	Envirochem Special Projects Inc., N. Vancouver
Dawe, Neil K. and Lindsay E. Jones	Vegetation of the Koksilah Marsh, Cowichan Estuary: a pre-restoration study	1986	Canadian Wildlife Service
Argue, A.W., Bruce Hillaby, and C.D. Shepard	Distribution, timing, change in size, and stomach contents of juvenile Chinook and coho salmon caught in Cowichan Estuary and Bay, 1973, 1975, 1976	1986	
Quesnel, Harold J. and Tarje Vold	Baseline soil Data for Blackley Farm, Cowichan River Estuary, Cowichan Bay, British Columbia	1986	Ministry of Agriculture and Food and Ministry of Environment
Lambertsen, G.K.	Cowichan Estuary Environmental Management Plan	1987	BC Ministry of Environment Lands & Parks, Victoria
Campbell Prentice, Alison	The effects of dyke breaching on the vegetation, bird use and soil salinity at the Blackley farm and Koksilah marsh habitat enhancement areas of the Cowichan River	1988	Fish and Wildlife Branch, BC Ministry of Environment and Parks, Nanaimo
Campbell Prentice, Alison & W. Sean Boyd	Intertidal and Adjacent Upland Habitat in Estuaries Located on the East Coast of Vancouver Island - A pilot assessment of their Historical Changes	1988	Canadian Wildlife Service
Ferguson, A., G. Holman and R.U. Kistritz	Wetlands are not wastelands: application of wetland evaluation methods to the Cowichan Estuary, British Columbia: Pacific and Yukon Region Pilot Study	1989	Canadian Wildlife Service
Campbell, Alison Prentice	Vegetation change on to three years following dyke breaching at the Blackley farm enhancement area, Cowichan River estuary	1989	Fish and Wildlife Branch, BC Ministry of Environment, Nanaimo, BC
	Site Assessment at Westcan Terminals Ltd. Cowichan Bay	1990	Envirochem Special Projects Inc., N. Vancouver
	Subsurface Environmental Assessment	1990	
	Baseline Contamination Study: Nearshore area of Cowichan Bay Doman Forest Products Ltd. Cowichan Bay Division	1990	Envirochem Special Projects Inc., N. Vancouver
Bigg, M.A., G.M. Ellis, P. Cottrell, and L. Milette	Predation by harbour seals and sea lions on adult salmon in Comox Harbour and Cowichan Bay, British Columbia	1990	Fisheries and Oceans Canada, Nanaimo

Frith, Russ H., Blair Humphrey, Peter Wainwright & Karl English	Cowichan Estuary State of the Environment Report	1993	LGL Limited & EnviroEd Consultants Ltd.
Cowichan Estuary Management Plan	Cowichan Estuary Environmental Management Plan	1993	BC Ministry of Environment Lands & Parks, Victoria
Chaster, Gerry	Maple Grove Restoration Project: Arborist Report	1994	
Vermeer, K., K.H. Morgan, G.E.J. Smith and A.N. Wisely	Habitat use by waterbirds in the Cowichan River estuary	1994	Canadian Wildlife Service
Vermeer, K., M. Bentley and K.H. Morgan	Comparison of the waterbird populations of the Chemainus, Cowichan, and Nanaimo River estuaries	1994	Canadian Wildlife Service
	Cowichan Estuary Environmental Management Plan	1994	BC Ministry of Environment Lands & Parks, Victoria
Cotrell, Paul Edward	Diet, activity budgets, and movement patterns of harbour seals (Phoca vitulina) in Cowichan Bay and adjacent areas	1995	University of Victoria
Candy, J.R., D.A. Nagtegaal, B. Riddell	A Preliminary report on juvenile Chinook production in the Cowichan River during 1993 and 1994	1996	Fisheries and Oceans Canada, Nanaimo
Nagtegaal, D.A., E.W. Carter and B.E. Riddell	A preliminary report on the adult Chinook productivity study conducted on the Cowichan River during 1995	1996	Fisheries and Oceans Canada, Nanaimo
	Environmental Assessment and Proposed Long Range Plan for the Maintenance of the Cowichan Bay Sawmill Access Channel	1997	New Pacific Ventures and Northwest Hydraulic Consultants, Vancouver
	Sensitive Ecosystems Inventory: East Vancouver Island and Gulf Islands	1997	BC Conservation Data Center, Victoria
Nagtegaal, D.A. and E.W. Carter	Adult Chinook escapement assessment conducted on the Cowichan River during 1996	1998	Fisheries and Oceans Canada, Nanaimo
	Options for the Log Haul Channel at Doman Forest Products Cowichan Bay Sawmill	1998	New Pacific Ventures, Vancouver
Austin, William C.	Dredgate dumped on intertidal estuary in Cowichan Bay	1998	Marine Ecology Station
Nagtegaal, D.A., C.J. Hillier and E.W. Carter	A preliminary report on juvenile Chinook production in the Cowichan River, 1998	1999	Fisheries and Oceans Canada, Nanaimo

Austin, William C.	Proposed Breakwater in Cowichan Bay, BC: Initial Environmental Impact Assessment	2000	Khoyatan Marine Laboratory, Cowichan Bay
	Box Culvert Installation on Spiers Creek, Cowichan Bay Road	2000	Aquaterra Environmental Monitoring and Fisheries Consulting, Nanaimo
Rideout, Paul, Bernie Taekema, John Deniseger, Russ Liboiron; Duncan McLaren	A Water Quality Assessment of the Cowichan and Koksilah Rivers and Cowichan Bay	2000	BC Ministry of Environment, Lands & Parks, Victoria
Nagtegaal, D.A. and E.W. Carter	Adult Chinook Escapement Assessment Conducted on the Cowichan River During 1999	2000	Fisheries and Oceans Branch
	Bringing Back the Coho - Fish Enhancement, Treffrey Creek Coho: Rearing Ponds Project	2002	HiLine Videoworks, Victoria
Costa, Maycira	Four-scale remote sensing approach for investigating water quality of Cowichan estuary, BC, Canada	2003	Alliance for Marine Remote Sensing Association, Halifax

Appendix C: Notice of Cowichan Estuary Workshop

NOTICE

THE COWICHAN COMMUNITY LAND TRUST
WILL BE HOSTING A WORKSHOP ON

'Ecological Strategies for the Cowichan Estuary'

The Cowichan Community Land Trust Society (CCLT) is currently reviewing previous areas of research and restoration in the Cowichan Estuary. The project is being funded by the BC Ministry of Water, Land and Air Protection and seeks to gather input from the scientific and local community for the purpose of developing an Ecological Restoration Strategy for the Cowichan Estuary Management Plan Area.

As part of this project the CCLT will review and report on studies done in the Cowichan Estuary since the early 1980's to facilitate discussion at the 'Ecological Strategies for the Cowichan Estuary' workshop to be held on Thursday, September 25th. This workshop will focus on identifying areas for future research and restoration as well as potential monitoring programs.

It is hoped that this workshop will provide an opportunity for interested parties to explore strategies for the future management of the Cowichan Estuary that will protect the natural beauty and ecological biodiversity of this vital and vibrant habitat.

If you have any suggestions or know of studies that have been undertaken since the early 1980's please let us know. A partial bibliography of known studies and reports are presently posted on our website at *www.island.net/~cclt* for review. If you know of any work that is not included in this bibliography or have further information regarding research or restoration in the Cowichan Estuary or are interested in attending please contact:

Ann Archibald,
Project Co-ordinator
Cowichan Community Land Trust Society
#6-55 Station Street
Duncan, BC V9R 5R6

Ph. 746-0227
email: cclt@island.net

August 25, 2003

Appendix D: Advertisements and media clippings

COWICHAN ESTUARY WORKSHOP

Ecological Strategies for the Cowichan Estuary

Thursday, September 25th
8:00 to 4:30

Travellers International Ocean Front Resort
1681 Cowichan Bay Rd.

This workshop seeks to gather input from the scientific and local community in order to develop sound ecological strategies for the Cowichan estuary management plan area. The workshop will feature presentations by Arvid Charlie of the Cowichan Tribes and Bill Austin, noted Marine biologist. Tours of the estuary will be led by members of Cowichan Tribes, the Cowichan Valley Naturalists, the Cowichan Estuary Preservation Society, The Nature Trust, Ducks Unlimited and Bill Austin.
If you have any questions or would like to attend please contact the Cowichan Community Land Trust office at 746-0227 or by email cclt@island.net.

Appendix E: Agenda

Ecological Strategies for the Cowichan Estuary
Workshop
Thursday, September 25th, 2003
8 am – 4:30 pm
Traveller's International – Oceanfront Grand Resort & Marina
1681 Cowichan Bay Road, Cowichan Bay

The purpose of this workshop is:

- to share information on the state of knowledge of the biological health of the Cowichan Estuary;
- to identify restoration projects that would benefit the estuary ecosystem, and determine priority projects; and
- to identify elements of an environmental monitoring program that could be used to gauge the estuary's health over time.

Agenda

8:00 am Registration, coffee
Introduction: John Scull, Director, Cowichan Community Land Trust
Review of the day's agenda: Judith Cullington, Facilitator

8:30 am Arvid Charlie, Cowichan Tribes
A First Nations perspective on the Cowichan Watershed

9:30 am Bill Austin, Director, Marine Ecology Station *(note that Bill Austin was unable to attend and was replaced by Cheri Ayers)*
The marine biology of the Cowichan Estuary

Hand in 'priority projects' sheets

10:30 am Group tours
There will be five different tours. Choice of tours will be determined by lottery. Leaders are:
Bill Austin, Marine Biologist *(cancelled)*
Arvid Charlie, Cowichan Tribes
Dave Thompson, Cowichan Estuary Preservation Society
Dan Buffet, Ducks Unlimited
Dave Aldcroft, Cowichan Valley Naturalists

12:30 – 1:30 pm *Lunch (provided)*

1:30 pm Introduction to the small group sessions
Judith Cullington (facilitator)

1:35 pm Restoration Projects: Small group discussions
Participants will work in small groups to identify their priorities for restoration projects

2:20 pm Plenary discussion of priority restoration projects

2:45 pm *Break*

3:00 pm	Small group discussions of monitoring projects Participants will work in small groups to discuss monitoring needs and priority projects for the Estuary
3:45 pm	Plenary discussion of monitoring needs.
4:15 pm	Summary Next Steps: Peter Law, Ministry of Water, Land and Air Protection
4:30 pm	Adjourn

Appendix F: Priority Projects Sheet

Ecological Strategies for the Cowichan Estuary Workshop
Thursday, September 25th, 2003

Priority Projects Sheet

This workshop focuses exclusively on projects related to the biological health of the Cowichan Estuary. We are NOT re-visiting the Environmental Management Plan! We ARE trying to identify:
restoration projects that would provide net benefit to the Estuary ecosystems; and
an environmental monitoring program that could be used to gauge the Estuary's health over time.

We have included a brief summary of studies and restoration work relating to the biological health of the Estuary to help identify priorities for restoration and monitoring (see annotated bibliography). By identifying these priorities, strategies that are developed to protect the health of the estuary will be more focused and relevant to current conditions.

To help us prepare for the afternoon discussions at the workshop, please answer the following two questions:

1. What, in your opinion, are the top TWO priorities for restoration projects in or around the Cowichan Estuary?

2. What, in your opinion, are the TWO most important needs for an improved monitoring program for the Cowichan Estuary?

Name: _____ Organisation: _____

E-mail: _____

Appendix G: Small group discussion restoration and monitoring sheets

Ecological Strategies for the Cowichan Estuary Workshop

Thursday, September 25th, 2003

Small Group Discussions: Priority Restoration Projects

Topic: _____

1. **What/where is the issue?** (*e.g. degraded waterfowl nesting sites at site x*)

(Please mark the location on the map, and identify the landowner/manager, if known.)

2. **How could this be addressed?** (*e.g. planting with native marsh species, restricting public access during nesting season*). Note what additional information/research might be required to undertake this project.

3. **What makes this a priority project?** Group can determine how they rate 'priorities.'

Ecological Strategies for the Cowichan Estuary Workshop
Thursday, September 25th, 2003

Small Group Discussions: Priority Monitoring Projects

Topic: _____ (e.g. water quality)

4. **What do we need to know about this topic?** (e.g. for water quality might want to know physical and chemical quality at series of sites in different parts of the estuary)

5. **What do we already know?** (list ongoing monitoring programs, frequency of data gathering, who does monitoring, etc.) (*e.g.*

6. **What gaps do we need to fill?** (What monitoring programs do we need, Is new research required?)

7. **What are the top TWO priorities for new monitoring initiatives?**