Reed Canary grass Removal in the K'ómoks Estuary

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Final Report

Prepared for: Fish and Wildlife Compensation Program

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March 13, 2020

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Executive Summary

This report outlines the Comox Valley Project Watershed Society's (CVPWS) efforts to control and manage the spread of invasive reed canary grass (RCG) in the K'ómoks Estuary in the spring, summer and fall of 2019. This work aligned with the Fish and Wildlife Compensation Program's priority action "to implement habitat-based actions in the K'ómoks Estuary as per the CVPWS restoration plan - P1". The restoration plan P1 indicates a need for in-stream habitat enhancement projects in Mallard Creek.

During the spring of 2019, the CVPWS inventoried and mapped the extent of RCG in three priority areas in the K'ómoks Estuary: Hollyhock Marsh Conservation Area, Dyke Slough and the lower reaches of Mallard Creek. Specific regions within these areas were then targeted for eradication trials. The following seven treatments were trialed: mowing; mowing and shading; mowing and mulching; mowing, mulching and shading; manual excavation by hand; machine excavation; and machine excavation and live staking with native species. Overall, approximately 1200m^2 of RCG was removed and treated across all treatment trials.

The effectiveness of these treatments are currently being documented and monitored, and results will inform subsequent control and management efforts in the study area. At the time of reporting, the CVPWS recommends using the machine excavation and live staking technique to control large monoculture patches of RCG along the riparian area of Mallard Creek and in other regions where RCG has formed dense monocultures. This approach is an efficient and effective way to work towards this area and improving the habitat for salmonid species.

Key recommendations that resulted from this work include focusing on areas with high habitat value for salmonids such as Mallard Creek and Hollyhock Marsh as well as protecting remaining sensitive plant communities in Hollyhock Marsh. Additional and detailed recommendations are provided in the CVPWS's RCG Control/Management Plan that was produced with this funding.

There is no quick way to convert an RCG infestation into a native plant community. However, even highly infested areas can be restored to more desirable and diverse plant communities and much can be accomplished within 2-3 years. As such, efforts should focus on areas with high habitat values and using the results from ongoing monitoring efforts to guide future RCG control and management efforts.

Contents

List of Figures

Background and Introduction

Reed Canary Grass (RCG) is a perennial cool season grass that can grow up to two meters tall and expands by creeping rhizomes, vegetative fragments and seeds. It is thought that the invasive subspecies of RCG in B.C. is an escaped Eurasian cultivar. Several Eurasian cultivars have been repeatedly introduced since the early 1800s as forage for livestock. RCG cultivars and subspecies have either escaped cultivation or hybridized to become invasive in much of North America. RCG out competes other native vegetation due to its effective dispersal mechanisms, lack of dormancy requirements, and ability to shade out slower growing native species. In areas where it has been introduced it typically will dominate 50-100% of the site[1]. It can out compete native grasses within 5 to 6 months of introduction, which leads to a reduction in native plant diversity. This can cause changes in habitat and associated changes in wildlife populations that rely on a variety of native wetland and riparian plant species throughout the year for food and shelter. In addition to its effective dispersal mechanisms, RCG also out competes native plant species for space and nutrients. RCG provides little value for native wildlife, few species will eat it, and it grows too thickly for mammals or waterfowl to use for cover/nesting. Foraging juvenile salmonids have feeding opportunities reduced in areas dominated by RCG, and it constricts waterways thus preventing salmon from reaching spawning habitats. It supports less diversity of insect life and results in reduced foraging opportunities for juvenile salmon that feed on insect drop from riparian and wetland plants. It also does not provide shade and, where it grows, leads to a rise in water temperature, which decreases habitat quality for salmon and trout as well as other wildlife.

In the summer of 2018, a local subject matter expert on invasive plant species, Ernest Sellentin, requested to present to The Comox Valley Project Watershed Society's (CVPWS) Estuary Working Group (EWG). Mr. Sellentin has been working on the control and management of invasive species in the province for over 30 years. For many years, he worked with the BC Invasive Species Council and he is now the President of Sellentin's Habitat Restoration and Invasive Species Consulting Ltd. He has had direct experience managing invasive species in the Estuary and he expressed his concern to the EWG about the expansion of RCG he has observed in the Estuary. He indicated that, by his estimation, RCG is now established in approximately half of the K'ómoks Estuary and has tripled in distribution since 2004[2]. This has led to the establishment of a RCG monoculture in large parts of the area that is outcompeting native grasses. Mr. Sellentin also added that a quantitative study of the distribution of RCG has not been done and that an inventory of the extent and distribution of RCG could help target control and management measures and also help assess RCG change over time. Based on his input the EWG decided to move forward with a project to inventory and map RCG in the Estuary and develop a control management plan for dealing with this invasive species. In the fall of 2018, Project Watershed submitted an application to the Fish and Wildlife Compensation Program (FWCP) to undertake this work. The FWCP priority action that this work aligned with is "to implement habitat-based actions in the K'ómoks Estuary as per the CVPWS restoration plan - P1". This priority action is identified within the Puntledge River Watershed Action Plan. The restoration plan P1 indicates a need for in-stream habitat enhancement projects in Mallard Creek. Funding was secured early in 2019.

Goals and Objectives

The overarching goal of this project is to control and manage the spread of invasive RCG in the K'ómoks Estuary and its concomitant impacts to fish, wildlife and plant communities. The following objectives have been identified to reach this goal:

1) Inventory and map the extent of RCG in the study area (see below for a description of the Study Area).
2) Undertake field trials of various RCG control methods and determine which method(s) are the most feasible and effective.
3) Develop a control management plan based on the results of the inventory work.

This work is a habitat-based action that links closely with existing restoration and action plans, including FWCP's Puntledge River Watershed Action Plan[3]. Specifically the Puntledge River Watershed Action Plan indicates a need for in-stream habitat enhancement projects in Mallard Creek, as per the CVPWS restoration plan (see Appendix 1- Investigation of Restoration and Protection Options for Juvenile Salmonids in the Courtenay Estuary). The CVPWS Restoration Plan also indicates a need to enhance the habitat in Dyke Slough, specifically in the area above the tide gates. This area is also included in the study area for this current work.

Study Area

Based on local expert feedback through the CVPWS's Estuary Working Group (EWG) and Technical Committee, it was determined that the control/management plan should cover the high priority areas of Hollyhock Marsh Provincial Conservation Area, the lower reaches of the Mallard Creek and Dyke Slough all of which are contained within the K'ómoks Estuary, located near Courtenay, B.C. (Figure 1). The K'ómoks Estuary is one of only eight estuaries in British Columbia designated as a Class 1 Estuary. Class 1 estuaries are given the highest importance rank due to their size, intertidal biodiversity and the variety and abundance of species they support. The K'ómoks Estuary is ranked second behind only the Fraser River estuary in terms of significance[4].

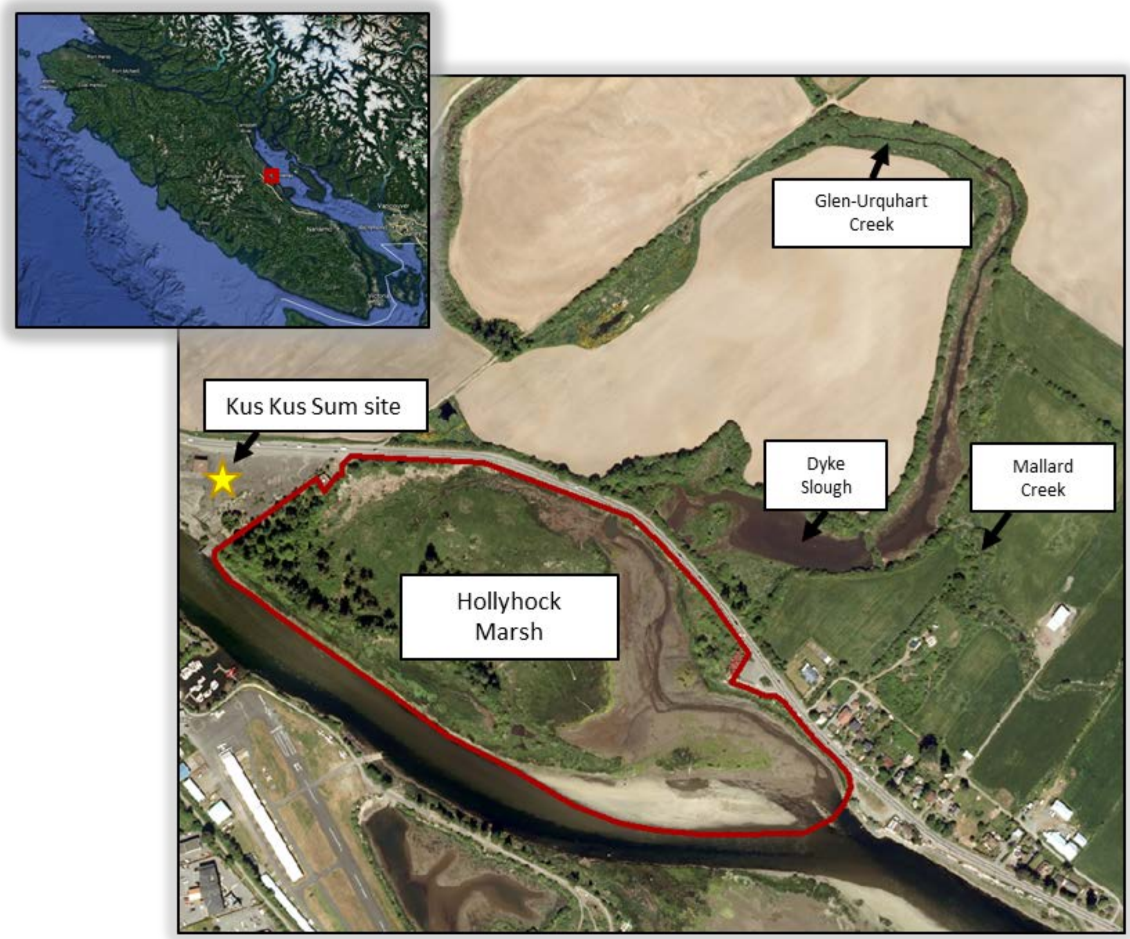

Figure 1 - Dyke Slough, Hollyhock Marsh and parts of Mallard and Glen-Urquhart Creeks that are the focus of reed canary grass control and management

The Hollyhock Marsh Conservation Area, was deemed a high priority as it contains many rare plant communities that are at risk of being taken over by RCG. Additionally, Project Watershed plans to restore the adjacent Kus Kus Sum (KKS) site[5] (Figure 1), and there are concerns that the RCG present at Hollyhock could easily spread into the newly restored site once the restoration of KKS is complete. Currently, the KKS site is almost completely covered by pavement and concrete. As part of the restoration activities, the hard surfacing will be removed, the site will be regraded and wetland channels will be created. The area will then be planted with native wetland and terrestrial plant species. However, until these native plants can become well established, the bare earth at the site will likely provide fertile ground for RCG colonization.

Additionally, the study area has been shown to have some of the highest concentrations of juvenile trout and salmon over the summer months, demonstrating that this is a key habitat area. Improving fish habitat quality of this area has been identified as a restoration priority (Appendix 1). Finally, the areas along Dyke Slough and Mallard Creek have also been shown to have high habitat values and have landowners who are engaged and supportive of conservation solutions including Ducks Unlimited Canada (Mallard Creek) and the Nature Trust of BC (Dyke Slough) as well as several private landowners who are supportive of the CVPWS's work.

The extensive background work indicating the important salmonid habitat that the Hollyhock Marsh, Dyke Slough and Mallard Creek provides coupled with supportive landowners and the planned KKS restoration make this area highly suitable for focusing RCG control and management efforts.

Methods

Objective 1: Inventory and map the extent of RCG in the study area

In order to inventory and map the extent of RCG in the study area (Objective 1) a supervised classification approach, which is commonly used to inventory and map vegetation using remotely sensed imagery was used. Supervised classification of aerial imagery is an effective way to produce vegetation maps over a large area[6].

A Biologist and GPS/GIS Technician worked in tandem to positively identify RCG patches within the study area and classify them as dominant, co-dominant or sub-dominant. Figure 2 was used to guide percent cover estimates within patches. Data was collected using a Wide Area Augmentation System (WAAS)-enabled Garmin GPSMap 78s. With the GPS set to track-mode, the perimeter of multiple patches of RCG was mapped and classified based on the level of RCG dominance within the patch.

Patches of RCG were classified as dominant if RCG was the most abundant species with high cover in relation to other species and comprised 80% or more of the patch. RCG patches were considered co-dominant if RCG comprised 50%-79% of the patch. Patches were recorded as sub-dominant if RCG comprised less than 50% of the patch.

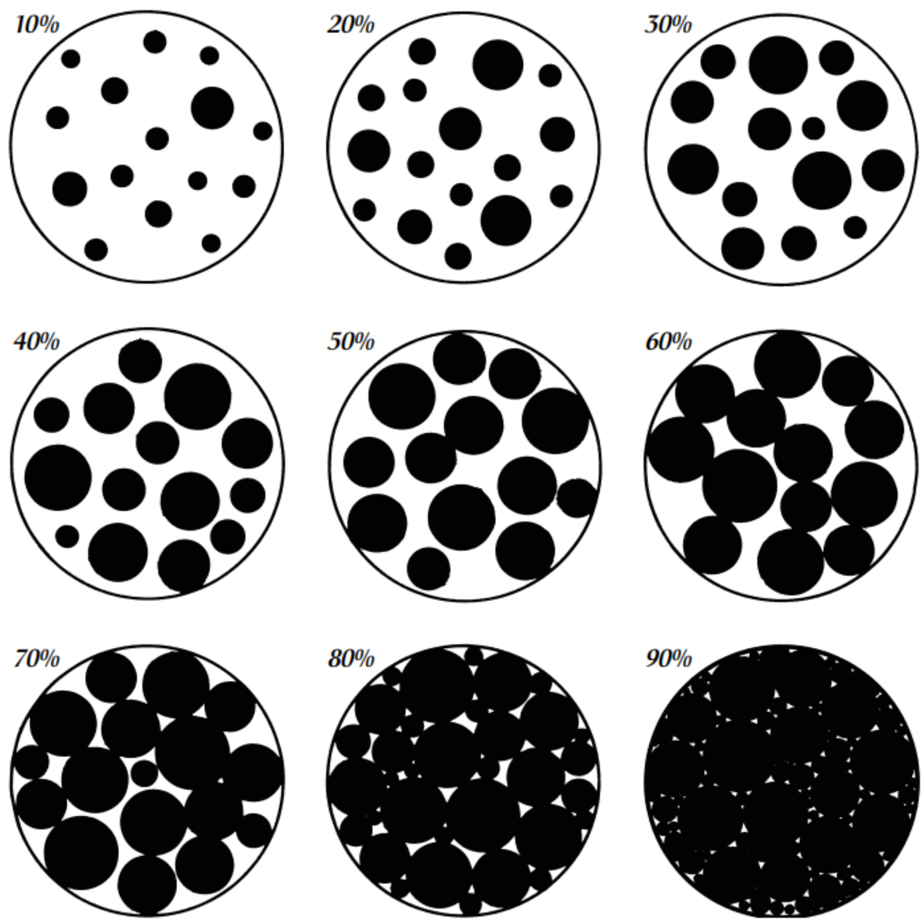

Figure 2- Reference figures for visual estimates of Reed Canary Grass cover within plant community. Adapted from Cornell Lab of Ornithology - birds in forested landscapes[7].

The GIS technician used the RCG polygon data collected in the field to classify aerial image and produce a map illustrating the extent and composition of RCG in the study area (Figure 3). Refer to Control Management Plan (Appendix 2) for details about map production.

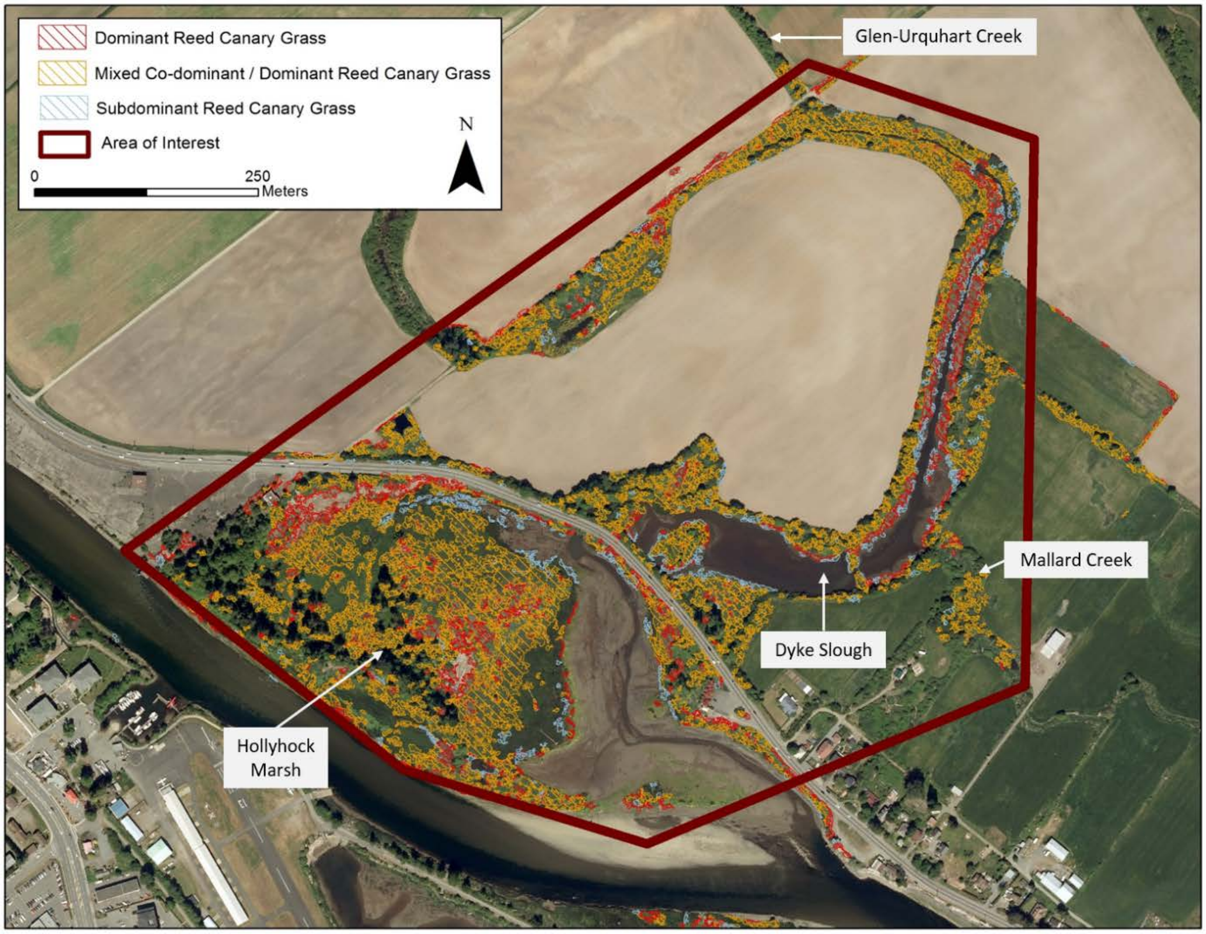

Figure 3- Map of Reed Canary Grass distribution in the study area coded as either dominant, co- dominant or sub-dominant

Objective 2: Undertake field trials of various RCG control methods and determine which method(s) are the most feasible and effective.

Once this inventory was completed, various treatment methods for controlling the RCG were then field trialed. These consisted of:

1. Mowing (Figure 4A)
2. Mulching (Figure 4B)
3. Mowing/Mulching and Shading (Figure 4C)
4. Mowing and shading.
5. Manual excavation - digging out small patches by hand (No archeological oversight needed in Hollyhock Marsh here) (Figure 4D and 4E)
6. Machine excavation - Flipping over RCG with a machine to shade it out (Figure 4F)

7. Machine excavation and live staking - Flipping over RCG with a machine and staking it with live willows (Figure 4G)

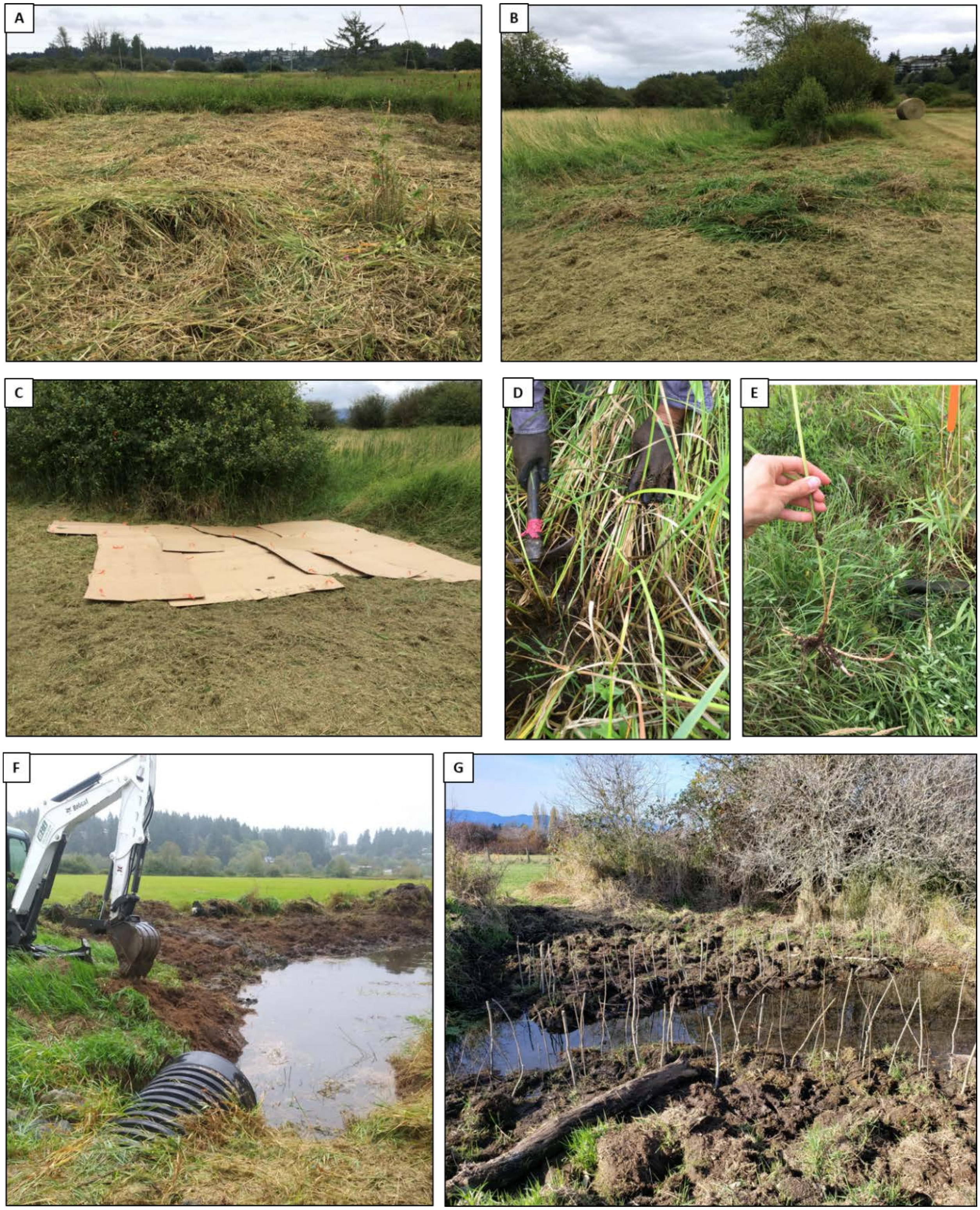

Figure 4- Treatments tested to control and manage the spread of invasive reed canary grass in the study area

The various treatments continue to be monitored using Photo Station Monitoring techniques to determine the rate and density of RCG re-growth and to guide additional control and management steps required at each treatment site

Objective 3: Develop a control management plan based on the results of the inventory work and results of treatment trials

The results of the mapping and field trials were used to guide the production of an overall control management plan and prioritize areas for further treatment (Appendix 2) and discuss considerations and recommendations for undertaking future RCG control/management initiatives.

Archaeological Considerations

There had been a concern expressed by the FWCP Technical committee who reviewed the project proposal that an archaeologist should be consulted prior to any manual digging/excavation taking place to ascertain if any archeological oversite was needed in areas that might have cultural values and the potential to unearth cultural artifacts. In the spring of 2019, the CVPWS consulted with local archaeologist Jesse Morin who pulled together the background history and relevant archeological records for the Study Area. He indicated that the only area that could potentially have cultural significance was the area in and around Mallard Creek. He indicated that he could find no archeological records for that area; and that as there is a long history of agricultural disturbance in the area the likelihood of finding anything of archeological significance is very low. However, he did indicate that simply because no archaeological investigation had occurred in the area, it would be good to have an archeological monitor should be on-site during any activities that disturb the soil (i.e., both manual and machine excavation). He recommended that we connect with Baseline Archeology, and get an Archeological review done and that we consult with the K'ómoks First Nation (KFN) to see if they had any concerns about the proposed work. In July of 2019 CVPWS consulted with both Baseline Archeological Services Ltd. and the KFN. The KFN did not express any concerns about the proposed work. Baseline Archeology relayed very much the same information that Jessie Morin had provided, namely that they could find no archeological records for the area and that the chance of the site having cultural artifacts was very low due to the extensive history of agricultural activity in the vicinity. They further indicated that we did not need to hire one of their staff to act as an Archeological Monitor.

Adaptive Management:

The initial plan was to undertake the RCG inventory, produce the Control/Management Plan and subsequently target areas for treatment. However, due to time constraints and a desire to mobilize and undertake treatment as soon as possible (and prior to RCG seed head development), it was not possible complete the Control/Management Plan prior to trialing various treatments. Ultimately, undertaking the trials prior to developing the control/management plan was actually beneficial because the most effective treatments could then be recommended for future control/management activities (refer to Appendix 2).

Results and Outcomes

High priority areas identified to trial various treatments were determined by local knowledge, previous research and field reconnaissance surveys in the area. High priority areas included the lower reaches of Mallard Creek, an area along Dyke Slough and parts of Hollyhock Marsh. Figure 5 illustrates the location and type of treatment done. Overall, approximately 1200m^2 of RCG was removed and treated across all treatment trials.

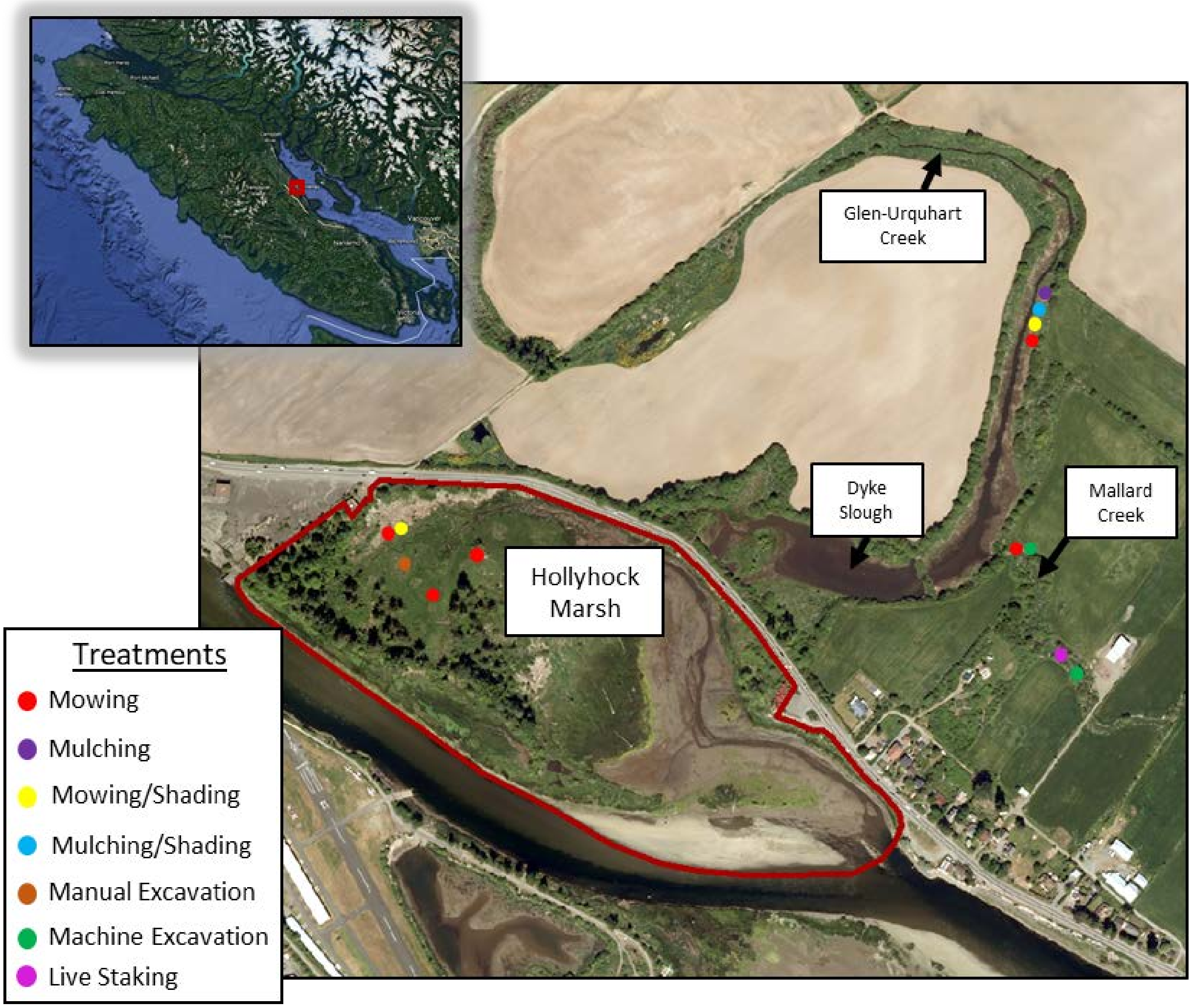

Figure 5- Map indicating the locations of treatment trials in Hollyhock Marsh, Dyke Slough and Mallard Creek.

Results of treatment trials

Mowing

A crew from Sellentin's Habitat Restoration and Invasive Species Consulting Ltd. worked on mowing down large patches of the RCG at various strategic sites within the Study Area, namely in parts of Hollyhock Marsh and along Dyke Slough and at a location along Mallard Creek (Figure 5). The RCG was mowed down, with brush cutters, during the height of the growing season in order to provide native plants an opportunity to grow without being constrained by the shade produced by the tall RCG.

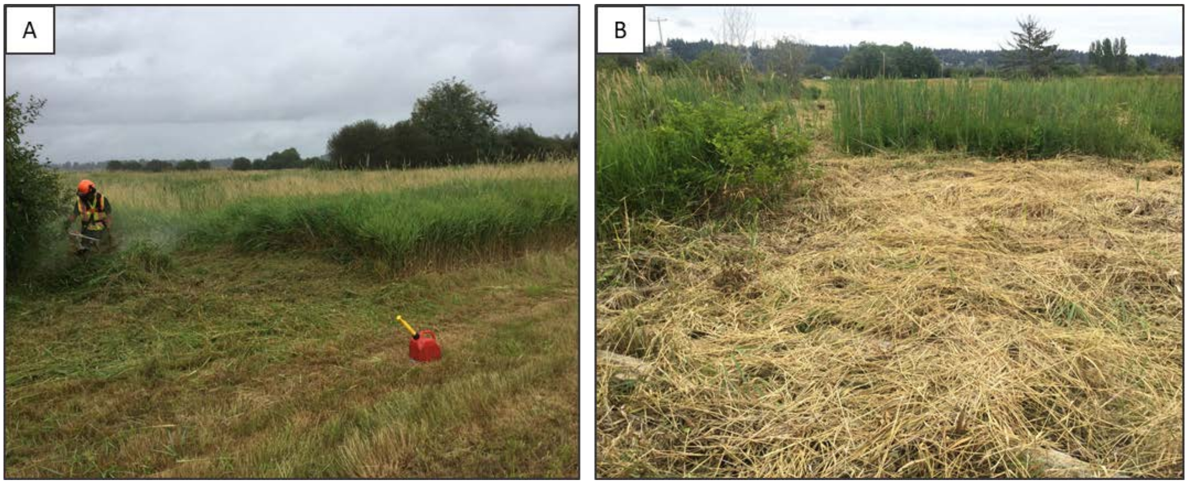

Figure 6-A) Crewmember from Sellentin's Habitat Restoration and Invasive Species Consulting Ltd. mowing reed canary grass using brush cutters. B) Mowed down reed canary grass. Native species, such as cattails in the area were avoided.

Mulching

An alternative to mowing that was trialed at one location in the study area was mulching (Figure 5), which is variation on mowing where mowed material is broken down into much smaller pieces and left to decompose (Figure 7). Mulching is more time and fuel consuming than mowing. Monitoring is currently underway to assess differences between mowing and mulching.

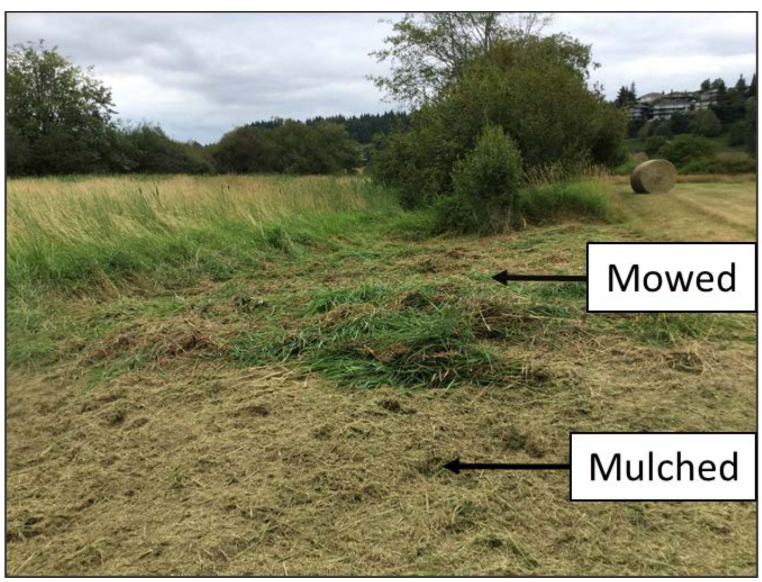

Figure 7- Image illustrating the difference between mulching and mowing

Mowing and Shading / Mulching and Shading

This combination of multiple techniques involves installing large sheets of cardboard over sections of the mowed/mulched areas to try to shade out the RCG (Figure 8). The original plan was to utilize weed cloth / geotextile fabric for this purpose. However, the decision was made to utilize cardboard as a shade material instead as it is readily available and can be obtained for free. In the case of this project, the cardboard was sourced from a local bike shop – Trail City Cycles. An additional benefit of using cardboard is that it is biodegradable and will break down over time whereas the weed cloth/geotextile fabric does not, and in fact is a plastic based product. Cardboard is also lightweight and easy to transport and install in areas that are only accessible by foot. The cardboard secured into the ground using coat hanger wire fashioned into hooks. The hooks were tied with flagging tape so they can be easily seen during eventual removal.

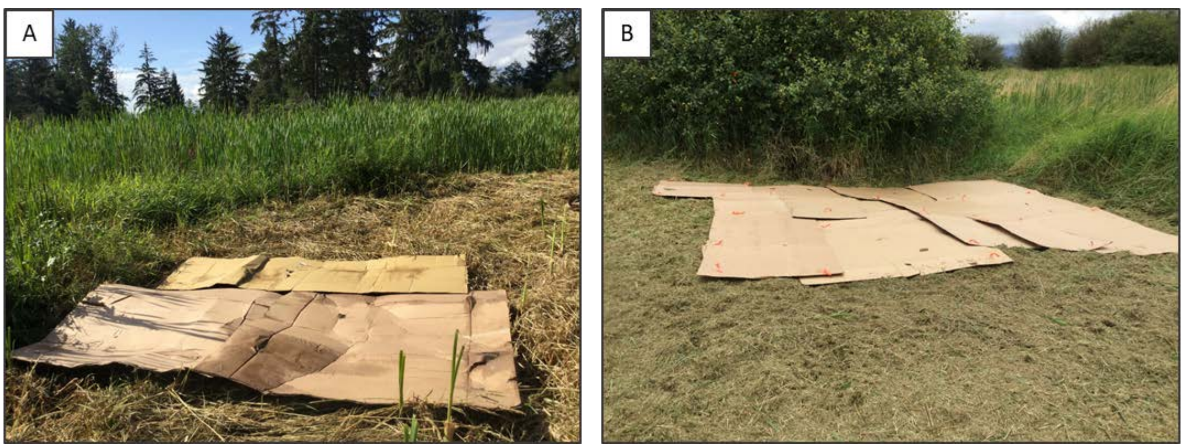

Figure 8- Cardboard installed over mowed (A) and mulched (B) areas

Another material that is worth trying out as a shade material, as suggested by local environmental professional Warren Fleenor is lumber wrap (Figure 9). Again, this material is available at no cost (from most home improvement stores), and is light and easy to transport. In addition, it is black on one side and totally occludes light. The downside of the wrap is that it is not biodegradable. A test of this shade method is recommended as part of any future work.

Figure 9- Lumber wrap used in wood transporting can potentially be useful for shading out mowed and/or mulched patches

Manual Excavation

As Hollyhock Marsh was not an archeological area of concern, a few small discrete patches of the RCG were dug out by hand with shovels (Figure 10). The unearthed plants were placed in garbage bags, hauled out on foot, loaded in to a truck and taken to the local landfill. This process proved to be very labour intensive and time consuming. Additionally, it proved very difficult to extract the entire RCG root structure, as it forms a large vegetative mat and the roots and rhizomes break relatively easily. The bagged vegetation was also very heavy to carry out of the conservation area, which is only accessible by foot.

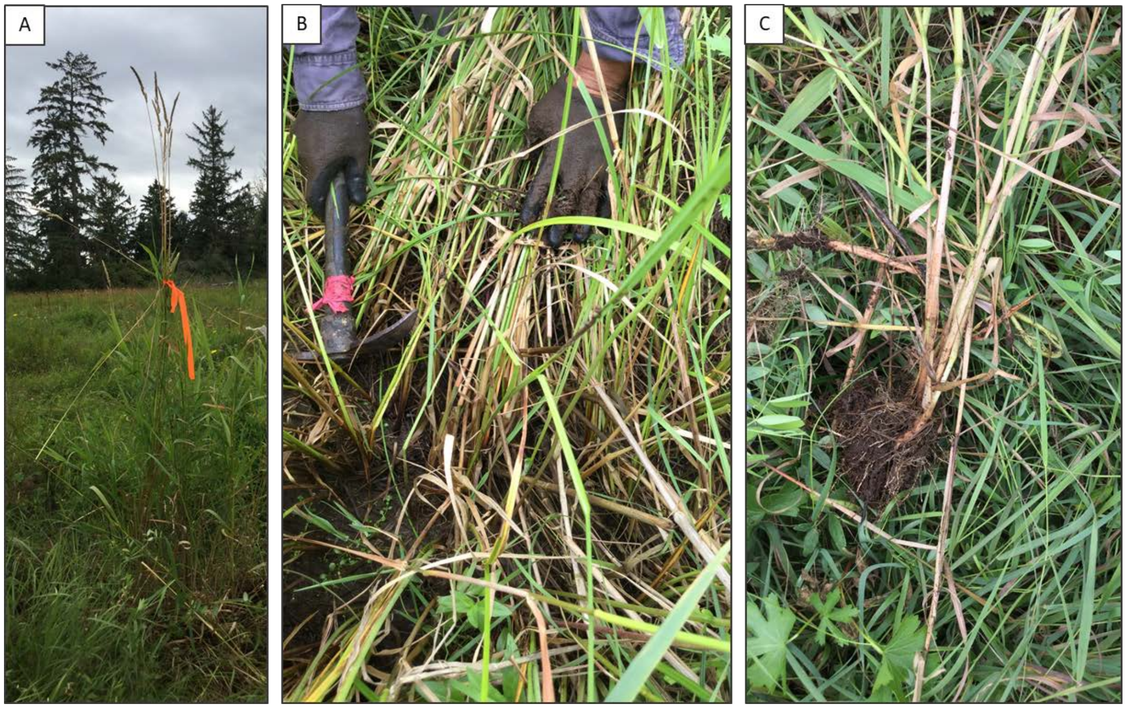

Figure 10- Manual excavation of small patches of reed canary grass. A) Small patches were identified and flagged. B) Crew members from Sellentin's Habitat Restoration and Invasive Species Consulting Ltd. removed small patches using shovels and mattocks. C) Attempts were made to remove the full roots mass and avoid breaking off rhizomes.

The CVPWS originally hoped that this technique might be suitable for volunteers. However, based on the field trials this was determined to be less feasible. The Hollyhock Marsh area in particular is very rough terrain, with drainage channels and large holes over 2 m deep that pose hazardous walking conditions. The digging itself was physically demanding, even for someone in good physical condition and comes with a high risk of causing back strain or other injuries. Finally, it takes a very long time to dig out even a small discrete area of RCG so it was determined that this technique was not suitable for volunteers to undertake. This method is most suitable for removing RCG in areas where it is encroaching on sensitive plant communities and is not suitable for large scale RCG removal activities.

Machine Excavation

This treatment technique involves using a small excavator to flip large monoculture mats of RCG, both in open areas and along stream banks. This is an effective way of removing large patches of RCG and preparing them for further treatment (e.g. live staking).

Machine excavation was trialed in two locations along Mallard Creek (Figure 5). One area was planted with live stakes (see below) and the CVPWS has plans to revegetate the remaining flipped mats with cuttings and purchased native species in Spring 2020. Figure 11 shows how large patches of RCG were removed in areas along Mallard Creek. This technique is very time-efficient and proving to be the most effective, both in terms of the amount of area that can be treated and the intensity of removal efforts (e.g., deep rhizome mats can be fully excavated).

Figure 11- A) Small excavator peeling back mats of reed canary grass (RCG) along Mallard Creek. B) Ernest Sellentin pointing at areas where RCG mats have been peeled back along Mallard Creek

Machine Excavation and Live Staking

This technique combines machine excavation and live staking. Live staking is a relatively simple way to revegetate disturbed areas and involves using living cuttings of pioneering woody species (e.g., willow, red-osier dogwood) to revegetate the RCG mats that were flipped using the machine excavator. The live staking component of this technique is labour intensive and required substantial volunteer effort to plant a portion of the area that was excavated. Harvesting and preparing the live stakes is the rate limiting step in this technique, and therefore requires substantial volunteer effort in order to accomplish. In the fall of 2020, CVPWS staff and volunteers planted 1000 live willow stakes along sections of Mallard Creek (108 m in total) where machine excavation had previously occurred (Figure 12).

Figure 12- A) Volunteer planting live willow stakes in areas along Mallard Creek where machine excavation had previously occurred. B) Row of live willow stakes along Mallard Creek and area remaining to be planted.

Monitoring and Effectiveness of treatments

Effectiveness of Treatments

The effectiveness of the various treatment methods continues to be monitored. The treated areas will be reassessed in Spring 2020 to determine the degree of RCG re-growth across the various treatments. The benefits and drawbacks of each treatment method are outlined in the Control Management Plan (Table 1; Appendix 2). In general, the machine excavation and live staking technique seems to be the most efficient and effective. Despite the cost associated with hiring the machine excavator, large RCG patches can be removed in a relatively short amount of time, making the machine excavator/live staking treatment the most efficient for controlling and managing large monoculture patches that are dominated by RCG.

Recommendations for controlling and managing co-dominant and sub-dominant RCG patches (Figure 3) are outlined in the Control Management Plan (Appendix 2). Essentially, native species that co-occur in with RCG need to be avoided during RCG removal activities. This can be done using mowing and manual excavation techniques that avoid native species and give them an opportunity to shade out the RCG.

Photo Station Monitoring

Photo station monitoring, a technique that the CVPWS uses to monitor a variety of restoration projects, was utilized to monitor treated areas and is useful for monitoring changes in plant community and cover over time. Photo station monitoring involves taking repeat oblique photographs of the whole site from the same azimuth (compass bearing) and easily described photo-station. The goal is for each photo to capture exact same image each time (i.e. same location, same azimuth).

Photo station monitoring is continuing at several of the treatment sites. Annual photo station monitoring done at the height of the growing season will be the most useful for assessing changes in RCG cover over time and the success of revegetation efforts. Figure 13 shows photo station monitoring images for the following sites:

- Mowing along Dyke Slough
- Mowing, mulching and shading along Dyke Slough
- Machine excavation at Mallard Creek culvert
- Machine excavation and live staking along Mallard Creek

Figure 13- Photo Station monitoring images from various treatment areas

Outreach and community engagement

As discussed throughout this report, this project features a strong volunteer component. Volunteer engagement and support is critical to the success of this project. Appendix 3 illustrates some of the volunteer outreach and engagement efforts associated with this project.

The next major RCG control/management project that will require substantial volunteer support is replanting and live staking areas along Mallard Creek that were excavated in the fall of 2019. The CVPWS is currently in the process of acquiring funds for this work – namely to purchase plants to supplement the live staking and enhance plant diversity and to provide snacks for volunteers who help with this work. As with all of the projects undertaken by the CVPWS, volunteer labour and support is critical and the CVPWS will continue to rely on volunteers for all future RCG control/management efforts.

Recommendations

Specific recommendations regarding control and management of RCG such as techniques recommended for the various types of infestations (dominant, co-dominant and sub-dominant) are provided in the Control Management Plan (Appendix 2).

Broader scale recommendations related to the RCG project as a whole are provided here. In general, the CVPWS recommends focusing RCG control and management efforts on Mallard Creek and areas in Hollyhock Marsh that support sensitive plant communities.

Mallard Creek

The CVPWS recommends focusing RCG control and management efforts on the riparian area of Mallard Creek. Mallard Creek supports coho, chinook and chum salmon and cutthroat trout. However, available spawning and rearing habitat for these species is limited due to RCG infestations and intensive agricultural activities in the area. RCG control and management activities in this area should involve machine excavation and riparian revegetation (live staking, planting native species) in order to aggressively shade out the RCG. The CVPWS recommends a phased approach for restoring these areas. A phased approach is recommended due to the rate limiting live staking and revegetation step. The machine excavator should flip only enough RCG mats that is feasible to revegetate with volunteers. If the mats can not be revegetated before RCG recolonizes the area, the mats will likely have to be excavated a second time which uses valuable time and resources.

Hollyhock Marsh

The CVPWS also recommends focusing RCG control and management efforts on the sensitive plant communities in Hollyhock Marsh Conservation Area. This area has been deemed a high priority as it contains many rare plant communities that are at risk of being taken over by RCG. Additionally, the area has been shown to have some of the highest concentrations of juvenile trout and salmon over the summer months indicating that this is a key habitat area. RCG control efforts should focus on removing any RCG that is encroaching on the rare plant communities. Once established, RCG monocultures and co-dominant patches are difficult to control and eradicate. It is therefore pertinent that minor infestations and newly established RCG plants be removed as soon as they are detected, particularly if they are encroaching on sensitive plant communities such as those in Hollyhock Marsh.

The role of Nature Trust of BC

RCG infestation is posing a serious threat to what remains of the sensitive plant communities in Hollyhock Marsh. The CVPWS also recommends that the information contained in this report be passed on to the Nature Trust of BC. While the CVPWS is aware that there is no quick way to convert an RCG infestation into a native plant community if control and management activities are undertaken and consistently applied, even highly infested areas such as those in Hollyhock Marsh can be restored to more desirable and diverse plant communities and much can be accomplished within 2-3 years.

Acknowledgements

Many thanks to Ernie Sellentin and the crew at Sellentin's Habitat Restoration and Invasive Species Consulting Ltd., Dave Polster, Doug Field, Dave Semmelink of Lentelus Farms, Ducks Unlimited Canada, Nature Trust of BC, Mountain City Cycle, Mike Wright of M.C. Wright and Associates, and the many volunteers for their time and support.

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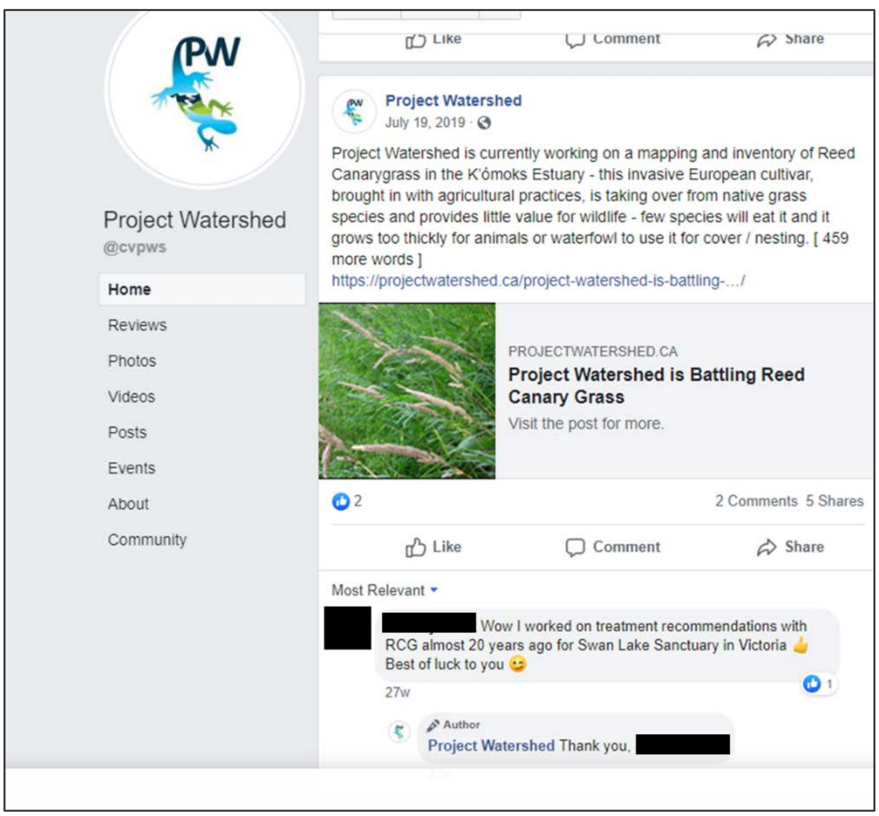
Appendices

Appendix 1 – Tryon, L. (2011). Investigation of Restoration and Protection Options for Juvenile Salmonids in the Courtenay Estuary (attached as standalone document)

Appendix 2 – Comox Valley Project Watershed Society (2019). Reed Canary Grass Control Management Plan (attached as standalone document)

Appendix 3 – Outreach and Community Engagement Materials

Facebook post by the Comox Valley Project Watershed Society highlighting the reed canary grass project and providing a link to the website post.



Volunteer call for help with reed canary grass control and management efforts

PROJECT WATERSHED

Volunteers needed for reed canary grass control and management

Dear Kathryn,

Project Watershed is currently working on mapping and inventorying reed canary grass in the K'ómoks Estuary. Reed canary grass is an invasive European cultivar that was brought in with agricultural practices. It out-competes native grass species and provides little value for wildlife - few species will eat it and it grows too thickly for animals or waterfowl to use it for cover / nesting. Foraging juvenile salmon have feeding opportunities reduced in areas dominated by this grass. It also out-competes trees and shrubs which provide important stream-side cover and keep water temperatures cooler.

As part of our work to control and manage this invasive grass we are currently doing some test treatments. Specifically mowing, shading (with cardboard) and digging it out. We will be monitoring how effective these treatments are, and then develop a control plan for longer management of this invasive plant.

We are looking for volunteers to help with this work. Specifically, we need volunteers to help:

1. Prepare cardboard – we have been using large bicycle boxes. All metal staples, tape, and plastic labels need to be removed from the boxes before we can use them for shading. Thanks to Mountain City Cycle for providing the cardboard!
2. Prepare coat-hanger "stakes" for staking down cardboard shading. This involves using wire cutters to cut metal coat hangers, bending bending the hangers into stakes, and tying a piece of biodegradable flagging tape to each stake.
3. Lay out and stake cardboard over patches of mowed reed canary grass in the estuary. This work involves walking on uneven and slippery terrain.
4. Dig out small patches of reed canary grass.

Sign Up

If you are interested in volunteering, please indicate the activity and your general availability by clicking here.

Questions?

Please contact Bea Proudfoot at: maps.projectwatershed@gmail.com or 250-703-2871.

CVPWS Website Post highlighting reed canary grass removal efforts in Mallard Creek

Mallard Creek Reed Canary Grass Removal Project

A patch of Reed Canary Grass

Reed Canary Grass (RCG) is a perennial cool season grass that can grow up to 2 meters tall and expands by creeping rhizomes, vegetative fragments and seeds. It out-competes other native vegetation due to its effective dispersal mechanisms and ability to shade out slower growing native species. In areas where it has been introduced it will quickly dominate from 50-100% of the site. Since 2004, it is estimated that the amount of RCG in the K'ómoks Estuary has tripled. RCG provides little value for native wildlife and insects, few species will eat it, and it grows too thickly for mammals or waterfowl to use for cover/nesting. Foraging juvenile salmon and trout have feeding opportunities reduced in areas dominated by RCG, and it constricts waterways thus preventing salmon from reaching spawning habitats.

Project Watershed, with funding support from the Fish and Wildlife Compensation Program, has been working to inventory and map the extent of invasive RCG in the K'ómoks Estuary and to come up with a management plan for this invasive species. Once we started our inventory work this past spring and summer we quickly realized that there was a significant issue with Mallard Creek (not to be confused with Millard Creek on the opposite side of the Estuary!). Mallard is a local creek that flows into the Dyke

Slough and supports coho salmon and cutthroat trout. However, RCG, which can grow on land and in water up to 2 meters in depth, has completely choked o this creek in the last few years, leaving little to no open water access for fish or other wildlife.

Once we realized this was the case, Project Watershed mobilized to tackle this issue. We brought an excavator in to clear out and flip upside down the large vegetative mats of RCG alongside about 200 meters of the west side of creek this past September. Then with the help of our wonderful volunteers, we harvested long native willow stakes, cut them down to 2 meters lengths and transplanted them in the areas along the creek where the grass had been removed. The willow, which is densely planted, will regrow from these cuttings and shade out the RCG, preventing it from re-establishing. The fall is the ideal time to do this type of restoration work as the willows are dormant. With fantastic volunteer support, we managed to harvest and transplant 600 willow stakes alongside the creek at the end of October!

Volunteers, Rio North and Isadora Datt, who helped that helped harvest the willow stakes rest on the result of their labours.

Volunteers work to cut willow stakes down to size for planting.

Volunteers after planting willow stakes around Mallard Creek (see stakes in the background) – From left to right: Stuart Swain, Jean Swain, Pat, Norman Matthew, MariAnn Matthew.

WE ANTICIPATE DOING MUCH MORE OF THIS WORK IN THE FUTURE. ANYONE THAT IS INTERESTED IN THIS PROJECT CAN CONNECT WITH US AT: ESTUARY.PROJECTWATERSHED@GMAIL.COM

CVPWS Website Post highlighting Reed Canary Grass Project

Website in collaboration with Pod Creative.

Project Watershed is Battling Reed Canary Grass

Photo: Invasive Species Council of BC

Project Watershed is currently working on a mapping and inventory of reed canary grass in the K'ómoks Estuary. This invasive European cultivar, brought in with agricultural practices, is taking over from native grass species and provides little value for wildlife. Few species will eat it and it grows too thickly for animals or waterfowl to use it for cover or nesting. Foraging juvenile salmon have feeding opportunities reduced in areas dominated by this grass. It also out-competes trees and shrubs which provide important stream-side cover and keep water temperatures cooler. In particular, dense stands are starting to form in the Hollyhock Marsh conservation area, Dyke Slough and the lower reaches of Mallard Creek. In fact it is starting to constrict the creek impeding fish access.

As part of our work to control and manage this invasive grass we have been doing some test treatments. Specifically mowing, mowing/shading (with cardboard) and digging it out. We are currently monitoring how effective these treatments are, and we will soon be developing a control plan for long-term management of this invasive plant. You may notice our crew out in the estuary this summer doing some of this work. If you come across areas where we are working on controlling the grass with cardboard we ask that you not disturb these sites.

We would like to acknowledge the financial support we have received for this project from the Fish and Wildlife Compensation Program and the cardboard that has been kindly held and donated by Mountain City Cycle.

Control Methods

We are looking for volunteers to help with this work.
Specifically, we need volunteer help to:

1. Prepare cardboard – we have been using large bicycle boxes. All metal staples, tape, and plastic labels need to be removed from the boxes before we can use them for shading.
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Investigation of Restoration and Protection Options for Juvenile Salmonids in the Courtenay Estuary

March, 2011

Prepared for:
Comox Valley Project Watershed Society
PO Box 3007, Courtenay B.C. V9N 5N3

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With financial support of:
BC Fish and Wildlife Compensation Program
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1

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EXECUTIVE SUMMARY

The Comox Valley Project Watershed Society is a non-profit group working in the Comox Valley to promote "community stewardship of Comox Valley watersheds through information, education and action" since 1993 (Project Watershed, n.d.). In their efforts to achieve this mission, they have identified the Courtenay River estuary as a critical area of interest, partly due to its importance in sustaining healthy salmon runs. The Courtenay River estuary has experienced past and ongoing impacts from human population growth and development and there was a need to understand how these impacts affect salmon in the estuary.

The goal of this study was to provide a foundation for future activities that will help to restore and protect important habitats in the estuary for salmon, including the food webs of which they are a part and the processes that support them. In consideration of the highly complex nature of the Courtenay River estuary, reaching this goal required an ecosystem management approach. Key aspects to ensuring the success of this project were to include ecological principles into the methodology; to identify critical ecological processes that supported healthy salmon populations in the estuary; to include the knowledge and expertise of stakeholders; and finally, to ensure that the results could be interpreted and applied, and were adaptable as new information arose.

This study resulted in an overall ecological characterization of the estuary and the development of a comprehensive list of restoration and protection options. Estuary characterization involved a field investigation of habitat requirements of juvenile salmonids from the upper to the lower estuary over the spring and summer of 2010. In alignment with ecosystem management principles, this project used chinook (*Onchorhynchus tshawytscha*) and coho (*O. kisutch*) fry (under-yearling) as indicator species. Fry stages of these species were marked and monitored for recaptures, fish were identified and counted, water conditions were recorded, snorkel counts were conducted and habitats were mapped. Data from past studies were analyzed to identify changes in the residency period and size classes of these salmon. The results helped to identify important habitat requirements of these species, and aided in the development of a comprehensive list of restoration and protection options.

The development of restoration and protection options was a multistage process that involved information from past strategy reports, meeting minutes from the Estuary Working Group[2] (EWG), and input from various experts and stakeholders. After initial compilation, EWG technical committee members participated in a detailed review of the options. Some of the results were then discussed with three interviewees that had government, non-profit, and expert associations. Finally they were formally presented on March 17th, 2011 to an audience made up of potential stakeholders and project participants (volunteers, EWG members, government staff, experts, etc.).

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[2] A committee of the Project Watershed Society that met regularly to discuss and strategize around the protection, conservation and restoration of the estuary.

Overall, the estuary provided the necessary ecological requirements for chinook and coho fry to survive and benefit from their residence over the spring and summer of 2010. Chinook and coho fry stages were more dependent on the estuary than the smolts, which moved through the estuary quickly. Chinook and coho fry were in the estuary by early spring when sampling began. Coho fry were found as late as December, while most of the chinook fry had left by the beginning of July.

The mark-recapture component of the study revealed that chinook frequently migrated between habitats while coho had high site fidelity. Visible Implant Elastomer (VIE) tagging made it possible to track fry movements between habitats. In total, there were 742 chinook fry tagged, and 446 coho fry. Despite the greater number of marks, there was only one recapture of chinook, compared to eight of coho. This indicated a greater movement between habitats of the chinook fry compared to coho. Only one of the eight coho recaptures had moved from the place it was marked. The recaptured chinook fry had migrated between the Courtenay Slough and Dyke Slough (below the tide gates), and the coho had migrated from the Airpark Lagoon to the Dyke Slough. This coho also had the longest minimum estuarine residency period of 125 days.

The Tsolum River relic channel, the Courtenay River above the mudflats, the Courtenay Slough at Simms Park, the Airpark Lagoon, and the Dyke Slough pool below the tide gates all provided important estuary habitats for juvenile salmon. Chinook fry were present in greater densities at most sites than coho fry, though they experienced poorer growth rates in backwater areas that had good refuge compared to habitats more exposed to the river. Coho fry appeared to be more sensitive to predation based on their patchy distribution that confined them to areas of good refuge. However, these habitats evidently had good food conditions for coho as reflected by high growth rates later in the season despite higher temperatures than in other habitats.

Food production and salmonid diet had important links with detrital and riparian sources. Gammarid amphipods were important food items for chinook fry and smolts and coho smolts. The fry stages of both species were highly dependent on insects, especially from May through July. The invertebrate-based diet of trout captured with the chinook and coho indicated that good invertebrate food production could decrease the potential for trout predation on the fry. During April, potential competition with chum fry in the same habitats as the coho and chinook was alleviated by differences in diet. Forage opportunities for these salmonids are closely linked to habitats that support their invertebrate diets, including healthy marsh and riparian ecosystems.

Chinook fry would benefit from restoration projects that improved food production and habitat connectivity throughout the upper and lower estuary by naturalizing hardened shorelines, creating deep water refuge habitat adjacent to upper intertidal marsh habitats, and ensuring frequent velocity refuge opportunities along the estuarine continuum for all tide heights. Coho fry would benefit from restoration projects in the upper estuary that increased the area and quality of refuge habitat by restoring riparian habitats for improved insect production and creating and restoring off-channel habitats. Similarly, protection projects that ensure existing areas with these features for coho and chinook remain healthy will benefit both the salmon and their ecosystems.

There were 41 restoration options and 33 protection options identified for the estuary[3]. The greatest number of restoration options fell under the “Off-channel Habitat Enhancement” and “Riparian Restoration” project types. “Channel complexing” and “Saltmarsh Planting” were also common. As such, the restoration options would mostly benefit refuge requirements for juvenile salmonids. The majority of protection option types identified were “Education” (15), followed by “Land Protection” (11). There were also important projects identified under the “Voluntary Incentives” and “Regulatory incentives” project types, such as an Estuary Valuation Program, and a comprehensive Coastal Shoreline Protection Management Plan for the estuary.

The restoration and protection options were prepared to serve as a baseline for planning projects in the estuary that could be used by various stakeholders and adapted over time. To be adaptable, there must be a periodic review that involves stakeholders that have an interest in, or have been involved in, project implementation. Adaptation is important because project priorities will change over time depending on the circumstances, the people involved, and the available information. Ensuring continuity in the planning process will save time that might otherwise be spent researching similar problems of the past. In this way, we can move towards the goal of achieving a healthy thriving estuary ecosystem for salmon and other species that rely on it.

[3] These options are provided in Appendix, or excel versions may be obtained by contacting the author, or Project Watershed.

CONTENTS

LIST OF MAPS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 Background

Human activities have impacted juvenile salmonid habitat in the Courtenay River estuary. These activities include altered flow regimes from hydroelectric operations, historical dredging and log storage, dike development, shoreline hardening, riparian development, recreational boat use, and point and non-point source pollution. The resulting impacts to the habitats used by juvenile salmon can affect both their survival and fitness as they migrate from freshwater habitats to the marine environment. These salmon require a healthy ecosystem with interconnected habitats throughout the estuary continuum (upstream to downstream, high water to low water) that will provide seasonal refuge from predators, adverse water quality and extreme flows (Thorpe, 1994). Implications of habitat loss to local salmon populations include a decrease in genetic diversity and reduced ability to withstand environmental perturbations (Hilborne et al, 2003). Impacts to juvenile salmon habitats reflect impacts to the overall health of the estuary, including the ecological communities and processes linked to salmon.

A diversity of management interests affect the Courtenay River estuary, making it difficult to measure or predict the outcomes of any one management action on estuary health. Multiple organizations, jurisdictions and levels of government make decisions that affect the estuary. Three local governments border the estuary, and four local governments have jurisdiction over watersheds that drain into it. Both federal and provincial governments have administrative powers that can influence estuary health. Treaty negotiations are underway with the K'omox First Nation, which will likely result in further divisions of management authority. Non-governmental management initiatives, such as restoration and education programs, can also influence estuarine health. Many of these agencies divide the estuary into different management units and/or have management responsibilities that extend beyond the estuary. The management body that oversees the Courtenay River Estuary Management Plan is the only one that regards the estuary as a comprehensive management unit. Furthermore, while most of these agencies have planning and management objectives related to ecosystem health, measures to assess impacts to these objectives are not always known or provided (LeBlanc et al 2010).

1.2 Ecosystem Based Management

An opportunity to overcome diverse management objectives involves the application of ecosystem based management (EBM) principles where the objectives include achieving estuarine health (Meffe et al, 2002). EBM models are similar to other management models in that they involve the development of policy and goals, a planning component, and project implementation, monitoring and evaluation (Figure 1). Ecosystem principles can be incorporated into this basic model by ensuring that indicators of ecosystem health are used to monitor and evaluate ecosystems, and that there are feedback mechanisms that allow the model to become adaptable as new conditions and information arise.

The planning stage of an EBM system involves monitoring the status of a system, and modelling it to identify gaps to achieving management goals and objectives. This typically involves collecting data to tell a story about the system, identifying gaps to achieving management goals and objectives, and identifying indicators to monitor the success of management actions. Indicators that relate to ecosystem structure, function and composition can be used to monitor the status of estuarine ecosystems and can also be used in the project monitoring and evaluation components of an EBM to determine the success of management actions (Noss, 1990). Under-yearling chinook and coho salmon (referred to as “fry” in this report) in the Courtenay River estuary make good candidates as indicator species due to their high sensitivity to environmental conditions, their reliance on the estuary as a linkage between their freshwater and marine life stages, as well as their intrinsic cultural and provisional values to society. Puntledge summer chinook are particularly sensitive, as their population has experienced dramatic declines since the development and operation of the Comox Dam (Trites et al, 1996). Coho salmon populations are also considered sensitive due to region-wide declines (Fisheries and Oceans Canada, 2009). Furthermore, coho that rear in the estuary represent a unique life history type different from freshwater rearing that can contribute to population’s diversity and resilience to withstand environmental disturbances (Koski, 2009).

1.3 Habitat Requirements

Habitats can be characterized by measuring their contribution towards the survival and fitness of juvenile stages of coho and chinook as they rear and migrate in the estuary. Simenstad and Cordell (2000) introduced three measures of habitat attributes: capacity, opportunity, and realized function, to assess the ecological and physiological responses of juvenile salmonids to restored estuarine habitat. Measures of capacity include habitat attributes that promote fish production. Measures of opportunity indicate how well fish can access and benefit from the habitats they occupy. Measures of realized function are directly related to the response of fish to capacity and opportunity habitat attributes, and indicates how these have affected fitness and survival (Simenstad and Cordell, 2000). While these measures can be applied to monitor restored habitat as Simenstad and Cordell (2000) propose, they can also be applied to monitor the status of existing habitats, to help characterize an estuary and provide baseline information for future monitoring, and to assist in identifying management actions.

1.4 Mapping

The use of mapping to communicate habitat information helps to facilitate understanding and cooperation among stakeholders. It can be a useful tool for making decisions about restoration and protection (Fraser, 2001; Johannes et al, 2002). Furthermore, mapping can promote positive action among stakeholders to protect and restore habitats even without the threat of regulation or fines (Serveiss, 2002).

1.5 Stakeholder Involvement

Restoration and protection planning involves decisions based on more than just the requirements of target species and communities. It involves a complex decision making process that has political, social and economic roots as well as the requirement for scientific understanding (Rapport et al., 1998). Restoration projects must not only improve habitat for the target species, but be financially feasible and not create unresolvable conflicts. For example, the removal of tidal gates that prevent saltwater intrusion and fish access to a tidal slough might be of great benefit for juvenile salmonids and associated predators, but it may also ruin valuable farmland.

Inclusion of stakeholders into resource management decisions is critical to successfully achieve goals (Meffe et al, 2002). Stakeholders are people whose personal and professional lives are directly affected by the estuary and those that have an overall or individual interest in restoration and protection options (Meffe et al., 2002). This includes First Nations rights-holders, elected officials, government staff, consultants, landowners, community groups, and funders of protection and restoration projects.

In this study, ecosystem management planning principles are applied to assess the status of the Courtenay River estuary and to make recommendations for restoring and protecting its health. Social realities of achieving restoration and protection options were addressed by including the knowledge and expertise of stakeholders in the development of these options, and by developing maps to communicate the results with managers.

2 GOALS AND OBJECTIVES

The goal of this study is:

To provide a foundation for future salmon habitat restoration and protection activities that will ensure a healthy thriving estuary ecosystem for salmon and other species that rely on it.

The objectives of this study are:

1. To characterize the estuary based on the habitat requirements for juvenile coho and chinook; and
2. To develop a comprehensive list of restoration and protection options from ecological information and past assessments of the estuary.

3 STUDY AREA

The Courtenay River estuary is a large salt wedge estuary located along the east coast of Vancouver Island (Map 1). Its main tributaries are the Tsolum and Puntledge Rivers, which collect and deliver a mean annual discharge of 53.7m^3 to the estuary from approximately 842 km^2 of watershed area (Morris et al 1979). Other smaller tributaries enter the estuary at various locations, and include the Glenn Urquhart Creek, Mallard Creek, and Brooklyn Creek along its northeastern shoreline, and Millard Creek, Roy Creek and Trent River along its southwestern shoreline.

The estuary is highly important both culturally and ecologically. Historically, the Courtenay River was a very productive salmon system. Evidence for this is provided in the approximate 150,000 stakes that make up the ancient weirs of a traditional K'omox First Nation's salmon fishery that dates back at least 1200 years (Nancy Greene, personal communication). The estuary has over 2000 hectares of river channel, mudflat, saltmarsh, and riparian habitats that support a diverse array of plants, fish, birds, and mammals. There are five species of salmon that use the estuary, including a severely depressed population of summer chinook (Trites et al, 1996). The estuary is internationally recognized as an Important Bird Area for Trumpeter Swans, and nationally recognized for waterfowl concentrations (IBA Canada). Seals are evident in the estuary, and have historically used booming areas as haul outs (Olesiuk et al, 1996). Morris et al (1979) and Asp and Adams (2000) provide detailed lists of the plant and animal life recorded or known to occur in the estuary.

The Courtenay River estuary is defined for the purposes of this study as extending from the confluence of the Tsolum and Puntledge Rivers at the upper end to Goose Spit and the Trent River estuary at the lower end, and is inclusive of the estuaries of smaller systems that occur between these boundaries. The upper ecotone refers to the tidally influenced, channelized river section that is bordered on both sides by terrestrial vegetation. The lower ecotone begins where at least one bank of the main channel is bordered by mudflats. The outer estuary refers to the area where the mudflats transition to subtidal.

The estuary can be characterized by several main features that have significance related to both fish habitat and historical and current human uses. In the main channel, approximately 500 meters below the Tsolum/Puntledge confluence (the section referred to as the Courtenay River), there is a tidally inundated channel that was historically fed by the Tsolum River (referred to as the Tsolum relic channel). Further downstream within the upper ecotone is Simms Park, where a Courtenay Slough branches off of the main channel along with some constructed off-channel fish habitat. Other features of the upper ecotone include shoreline armouring along both the Lewis Park riverbank near Simms Park, as well as along the historical Fields Sawmill site. Immediately adjacent and downstream of the Field Sawmill site is Hollyhock Flats, a natural area where rare plant species and diverse bird fauna occur (Lacelle, personal communication).

Near the transition between the upper and lower ecotones, there is a constructed lagoon along the south side of the river channel, and Dyke Slough on the north side. The lagoon on the south side once functioned as a sewage lagoon for the City of Courtenay, but has since been restored as fish habitat. The Dyke Slough was historically cut off from upper tidal habitats by tide gates, and continue to prevent saltwater intrusion to upstream farmland. There is a large wetland-slough above the tide gates, and a deep pool below with a tidal channel that leads to the river.

Fringing the lower ecotone and outer estuary are eelgrass beds made up of *Zostera japonica* and *Zostera marina*. At the southeastern boundary of the mudflats is the Royston Wrecks, a jetty composed of rip-rap, fill and sunken ships that was constructed in 1911 as a breakwater for a historical booming ground in the mudflats that operated until 1978 (Wild, 2006). At the northeastern tip of the outer mudflats there is a large marina (the Comox

Marina), and a sand spit (Goose Spit) where there is a military site, a K'omox First Nations reserve, and a popular recreational area. Goose Spit curls around to create a lagoon, into which Brooklyn Creek drains.

4 METHODS

Characterizing the habitat requirements for juvenile coho and chinook salmon in the Courtenay River estuary involved 2010 field data collection and analysis with historical fish capture data. The development of the restoration and protection options and associated concept models involved the compilation of historical analysis, habitat requirement characteristics from the 2010 study, input from stakeholders, and the mapping of potential restoration locations.

4.1 Habitat Requirements: Data Collection

Methods of characterizing habitat requirements for juvenile salmonids involved fish and water quality sampling in 2010 and comparison to historical fish capture data, snorkel surveys in 2010, lower river sampling in the late summer of 2010, and mapping of habitat features at specific locations in the estuary.

4.1.1 Fish and Water Quality Sampling

Sampling for fish and water quality took place between March 30th to August 19th, 2010 at 20 estuary sites. Sampling of three lower river sites began in early-mid July and ended in late August. Sample site descriptions are provided in Table 1, and map locations in Map 2. Sampling involved the capture of fish, marking under-yearling coho and chinook, measuring the lengths and weights of chinook and coho, recording species and numbers encountered, collecting information on diet and food availability, and collecting water quality information.

Fish captures were carried out using beach seining, pole seining, minnow trapping, and to a small extent, mini-purse seining techniques. Sampling was done from shore or assisted with a boat. Boat sampling involved beach seining during high tides in the upper river, and during low tides in the lower estuary. Most shore-based sampling involved beach seining during mid to low tides.

Where beach seining was done, the area covered by each seine was estimated at the time of sampling. The beach seine was 14m in length, 3m deep and made up 3 panels. The middle panel, or bunt, was 1/8" mesh size. The wing panels were 3/8" mesh size. Seining involved spreading the net across a habitat, pulling it in to shore from both ends, then pulling in the bunt to corral the fish. The pole seine was 1.5m in width with a ¼" mesh size. Use of the pole seine involved two people spanning the net over a section of habitat and periodically scooping it up to retrieve fish. All minnow traps were ¼" wire mesh and were set from 1 hour to overnight in pools and backwaters.

Most age 0+ coho and chinook were marked with Visible Implant Elastomer (VIE) tags, colour coded for each site. Marking of 446 coho fry and 742 chinook fry took place throughout the estuary from March 30 to June 24, 2010. A tag retention test was undertaken on chinook fry at the Puntledge River hatchery that found some occurrences where colour codes were misidentified or miscounted, however, the results were consistently close (Table 2).

Depending on the size of the catch either a subsample or all of the coho and chinook captured were measured for length and weight. Fork length was collected to the nearest millimetre using a fish ruler, and weight to the nearest tenth of a gram using an Ohaus Scout SC4010 scale.

All captured fish were identified to species when possible, or sub-sampled for species composition for very large catches. Sub-sampling involved using the dipnet to collect a known volume of fish for counting and measuring, then counting the number of dipnet scoops as the remaining fish were released. The subsample was then extrapolated by the appropriate number of scoops to estimate the total catch. Species identification was done by a qualified biologist or a technician trained in identification techniques.

Benthic and stomach samples were collected to characterize the diet of fish. Benthic samples were collected along a cross section of habitat using a D-net. An area of 30cm x 30cm was disturbed above a D-net of 500 micron mesh over 3 locations representative of the habitat type for a total benthic area of $0.27m^2$. Benthic samples were stored in plastic bottles. Stomach samples from fry and smolt stages of chinook and coho were collected, along with samples from four steelhead ranging from 151 to 219 fork length, and one cutthroat with a length of 181mm. Stomach sampling involved either the collection and preservation of the entire fish or their dissected stomachs. Stomach samples were typically only collected when there were accidental mortalities as a result of sampling stress. Where there were no mortalities yet a stomach sample was desired, the fish were anaesthetized with MS222 until they perished. Both stomach and benthic samples were fixed with 10% formalin which was later decanted and replaced with ethyl alcohol to preserve the samples.

Water conditions were measured with a YSI 556 MPS multi-meter at each site prior to fish sampling. Salinity and temperatures were collected at the surface, and when possible, at 0.5m at each site.

Length and temperature data from 2001 (Hamilton et al, 2008) were also analyzed in this study.

4.1.2 Snorkel Surveys

The upper ecotone (3.1 km) was snorkelled once per week from May 11 to August 16th, 2010. Fish observations were recorded at six transect sites that were delineated above the high water line with flagging ribbon placed 25m apart. Prior to snorkelling, the underwater visibility was determined using a measuring tape. A total of five snorkelers participated in the snorkelling, with two snorkelers during each snorkel event. Tides during snorkelling ranged from 0.3m to 3.5m, with an average tide of 1.5 $^{+}/_{-}$ 0.5m (95 % confidence intervals). Counts were used to estimate densities per unit area, and general observations during the swim were used to help characterize fish usage of the upper ecotone.

4.1.3 Lower River Sampling

Late summer sampling of the Puntledge River Condensory side-channel and lower Mallard and Glen Urquhart Creeks was carried out to identify if marked fish re-entered the lower rivers later in the season, and to compare the size of fish found in the freshwater with those captured in estuary sample sites. Techniques involved the use of pole seines and minnow trapping. Fish were identified to species, counted, measured for fork length, and examined for VIE tags.

4.1.4 Habitat Mapping

Six areas that spanned the estuary from the upper ecotone to the outer estuary were chosen for detailed habitat characterization. Polygons were initially delineated using 2007 aerial photos. The plant communities, substrates, and important features such as fish and wildlife habitat, exotic species, and anthropogenic influences that fell within these polygons were assessed in the field. Transects and field observations were geo-referenced using a Trimble. The results were later used to compile species lists for each site, and to prepare habitat maps for presentation purposes. The data was stored in the Project Watershed Mapping Centre data base for application to future monitoring and restoration projects.

4.2 Characterization of Habitat Requirements

Habitats were characterized based on their contribution towards the survival and fitness of juvenile stages of coho and chinook as they reared and migrated in the estuary by incorporating measures of opportunity, capacity, and realized function (Simenstad & Cordell, 2000). Table 3 outlines the criteria, measures, and the associated habitat attributes used to characterize the estuary in this study.

4.2.1 Fish presence

Catch per unit effort (CPUE) was estimated temporally and between sites to infer the opportunity for fish to access and use sites over the season and throughout the estuary. Sites were assessed for relative use by coho and chinook based on the CPUE using beach seine methods only. CPUE was calculated for each site by dividing the number of fish caught per day by the number of sets. All size classes of chinook and coho that were captured were included in the CPUE estimates.

4.2.2 Life history composition

Life history composition was assessed to determine the temporal opportunities for fish of various size classes to use the estuary over the sampling period. Fork length data from unclipped chinook and coho captured in 2001 and 2010 were compiled by species and month for each sample year. Size classes were then visually estimated based on their length/frequency distributions. The size classes were interpreted as age classes, and are referred to as cohorts in this report. Cohorts were numbered based on their size and time of detection in the estuary. Cohort 1 represented the largest size class and was representative of the smolt stage (age 1+ or under-yearling smolts). Cohort 2 was the next size class down and was representative of the fry stage (age 0+). Cohort 3 entered the estuary later in the season, and was also representative of the fry stage (age 0+). The modal lengths for cohort 2 of each species were used to estimate growth rate (see section 4.2.6).

The data were analyzed for significant differences between size classes where the sample sizes were large enough. The type of statistical analysis that was done depended on the number of size classes being compared and the distribution of data. For two normally distributed size classes, the student's t-test was used to compare means. Where there were two non-normal distributions, medians were compared using the Mann-Whitney test. Where there were multiple size classes being compared, ANOVA was used for normally distributed data and the Kruskall-Wallis was used for non-parametric data. The statistical software package Graphpad Prism Version 5.01 (GraphPad Software Inc., San Diego, CA) was used in the analysis of fork length data.

4.2.3 Proximity to migration routes

To further assess the opportunities for juvenile coho and chinook to access and use habitats in the estuary, habitats were categorized based on their proximity to the freshwater influence of the Puntledge and Tsolum Rivers. This resulted in the identification of areas that were numbered consecutively from upstream to downstream to reflect the net movement of migrating salmonids from freshwater to saltwater.

Area delineation of the estuary was based on the following:

- the upper extent of tides and the influence of normal high tides.
- characteristics of the upper and lower ecotone and their associated access to high and low water habitats
- salt wedge characteristics measured and interpreted in 2001 (Hamilton et al, 2008)
- distinct habitat features of the lower ecotone and outer estuary, including subtidal confluence with the mainstem channel, Comox Bay Marina, Goose Spit, and Royston Wrecks.

The rationale to applying this system was that it reflected the relative importance of habitat to juvenile salmonids along an upstream to downstream gradient and over the season, with Area 1 being of the greatest importance early in the season, and subsequent areas increasing in importance as the season progresses. This assumes that early in the season, under-yearling salmonids are most vulnerable as they first enter the estuary due to their small size and the osmotic stress associated with physiologically adapting to increasing concentrations of saltwater. These assumptions are supported by a study by Otto (1971), who found that coho smolts survived longer than fry when rapidly exposed to higher salinities, and that the under-yearling coho required more time in dilute salinities to survive the freshwater/saltwater transition. Other studies also support the importance of upper estuarine areas to early rearing of chinook fry (Healey, 1991).

4.2.4 Diet

Fish diet can be used to estimate the capacity of specific habitats to promote fish production (Simenstad and Cordell, 2000). Three sites and five species of salmonids were analyzed for benthic invertebrates and stomach contents from April through to July of 2010.

Diets were analyzed by comparing prey items in the gut to those found in the habitat where the fish were captured. This information was applied to the Strauss index to determine the selectivity of fish for each prey item (Bowen, 1996). The results ranged from -1 to +1, with values below zero indicating high selection, and above zero indicating less selection.

Laboratory analysis of the benthic and stomach samples was done by Zotec Environmental Services. The methodology used to analyze the benthics involved first rinsing samples through a 250um mesh with tap water, then draining them for 10-15 minutes. Samples were then weighed prior to collection of a random subsample for analysis, which was also weighed. Organisms were identified to characterize the diet of the salmonids, and included identifications to class, family and genus.

Stomach content analysis was done by pooling stomach contents from the same species caught at the same day and site. Stomach contents were retrieved by cutting the stomachs and scraping out the contents into a petri dish. Total volume was collected from the individual and/or pooled stomachs. Water was added to each sample before analyzing under a dissecting microscope. All taxa were identified and counted, and the total proportion by volume of each taxa observed was estimated for each sample.

4.2.5 Water Quality

Temperature was used to indicate the physico-chemical capacity of estuarine habitats to support juvenile salmon rearing. The upper and lower thresholds that identify ideal conditions for rearing coho and chinook (12-14°C), as well as the lethal temperatures (>25°C) were taken from Bjornn & Reiser (1991). Linear regression was used to analyze for trends in surface temperatures during similar ranges in tides in Areas 4 and 6 for 2001 and 2010. Temperature differences between these years were visually compared. Tidal ranges for the 2001 and 2010 comparison are provided in Table 4.

4.2.6 Growth

Growth rate and condition factor of chinook and coho juveniles were analyzed to characterize the contribution of different habitats to survival and fitness. Growth rate was determined for the dominant fry coho and chinook cohorts (cohort 2) by comparing the mean fork length differences that occurred over time. Growth rate was calculated from the difference between the mean monthly fork lengths of each species over the season.

Condition factors of the chinook and coho fry captured in 2010 were compared for each species between sites to provide a relative comparison of fish health. The statistical software package Graphpad Prism Version 5 (GraphPad Software Inc., San Diego, CA) was used in the analysis condition factor data. The statistical analysis approach was the same as was done for the length analysis (4.2.2).

A size comparison of coho fry captured in the estuary and lower river sites involved comparing the mean fork length of late season (July and August) captures.

4.2.7 Residence time

Residence time was used as a measure of realized function to reflect the behavioural response of fish to habitat attributes that promote survival. Residence time was estimated from mark-recapture results. The potential residency periods were calculated for specific sites and for the estuary as a whole from the difference between the recapture date and the potential marking dates.

4.2.8 Density

Density was used as a measure of realized function to reflect the behavioural response of fish to habitat attributes that promote survival. Snorkel survey observations provided an estimate of densities per square meter of shoreline throughout the sample areas.

4.3 Mapping

Habitat mapping of specific sites involved a photo interpretation of habitat units, followed by ground-truthing during low tides to prepare habitat maps that were accompanied by information on plant assemblages, substrates, exotic species presence, and anthropogenic features. Table 5 provides a list of sites mapped and the dates they were mapped. Results were used to compare the diversity of trees, shrubs, herbs and algae at each site, and to compare the relative numbers of exotic plants that had established there. Exotic plants were determined based on information from the BC Ministry of Environment Conservation Data Centre[4].

4.4 Restoration and Protection Options

The restoration and protection options were compiled into a comprehensive list that included information on the project names and descriptions, location, rationale, opportunities and constraints, information requirements, key people to involve, and potential resources. This involved discussions with stakeholders early on in the process to identify potential information sources and key people, compilation of historical and current ecological information on the estuary. Once the tables were compiled, they underwent a review process that involved more discussions with stakeholders and experts that had insight into all or specific projects. Once the tables were at or near finalization, there were three interviews where ideas in the tables were brought up to assess feasibility and to provide more information on techniques and opportunities. The final results were the comprehensive lists of restoration and protection options and accompanying concept models to provide a brief overview of the contents.

4.4.1 Stakeholder Involvement

During the planning phase for this project, there were many groups that were consulted on the project and were made aware of opportunities for them to be involved:

[4] BC Species and Ecosystems Explorer: http://www.env.gov.bc.ca/atrisk/toolintro.html

- **The Estuary Working Group (EWG) and affiliated subcommittees** on restoration and land protection provided an opportunity to gather input from various stakeholders on these options.
    - *The EWG and its sub-committees were organized by the Comox Valley Project Watershed Society. They involved a variety of people from different backgrounds and representing different groups, including government and non-profit, and areas of varying expertise from historical, technical, biological and career oriented. This information was gathered from the direct attendance of EWG and subcommittee meetings, or from the minutes provided from these meetings.*

- **Several key people were sought for opinions on specific projects**, including expert staff from Fisheries and Oceans Canada, a local biologist with vast experience working on the Puntledge River watershed, a member of the Naturalists' Society, and a local historian.

- **Three formal interviews** were conducted with the new environmental planner for the City of Courtenay, the vice-president of the Fish and Game Protective Association, and an expert on coastal eelgrass research and restoration.

- **Anecdotal information was also gathered during the course of field** work in this project, as many of the volunteer assistance came from people involved in various stewardship groups and government organizations, and varying backgrounds of expertise.
    - *Volunteers ncluded streamside landowners, volunteers from the Tsolum River Restoration Society, the Fish and Game Protective Society, the Millard/Piercy Watershed Stewards, the Brooklynn Creek Stewards, the British Columbia Conservation Federation, and in-kind assistance from Fisheries and Oceans Canada and the Ministry of Agriculture, Food and Fisheries.*

4.4.2 Process

Development of restoration and protection options was a multi-stage process:

- A table of restoration options (referred to as the Restoration table) was initially compiled from three documents. The first document was the minutes from a February, 2003 workshop for federal and provincial government employees on knowledge gaps and future directions to manage fisheries resources in the Courtenay River estuary (Courtenay River Estuary Workshop Minutes, 2003). The second document provided the results of a reconnaissance tour undertaken on February 25th, 2004 of potential restoration sites in the estuary (E. Guimond & D. Poole, personal communication, Feb. 25th, 2004). The third document was another summary of a field tour of potential restoration sites carried out on October 1st, 2009 (D. Davies, personal communication, October 1st, 2009). Further information and new sites were added to the Restoration table following the 2010 field sampling season. This information was based on direct observations and experience of the project biologist and from ideas and perspectives found in the EWG and sub-committee meeting minutes.

- A table of protection options (referred to as the Protection table) was compiled from discussions provided in the minutes of 2009 and 2010 EWG meetings, and the land acquisition sub-committee (EWG, n.d.).

Both the restoration and protection options tables that resulted were subsequently reviewed by representatives of the EWG and the respective sub-committees. In addition, specific sections were further refined based on input from people with site-specific knowledge, the method proposed, the history of the site, and the social and political conditions surrounding the project.

Mapping of the restoration options involved pinpointing them in Google Earth[5], and creating an electronic .kmz file that could be easily uploaded by anyone who has the Google Earth program on their computer.

4.4.3 Concept Model

The purpose of the concept model was to create a visual diagram of the connections between project goals and anticipated outcomes. This was to facilitate understanding of where, why and how for each project. It was also done to highlight the emphasis of particular project types over others. The concept models are not stand-alone; they are meant to provide an initial overview of projects that are provided in detail in the Restoration and Protection tables.

Concept model development for the Restoration Options began with an overall goal of restoring the estuary to achieve greater health for chinook and coho salmon. As mentioned in section 4.2.3, the estuary was partitioned into areas based on a conceptual migration route of juvenile chinook and coho salmon. The restoration concept model was also organized in this way. The areas that occurred in the outer estuary (Areas 6, 7, 8 and 9) were combined to reflect the later stages of migration of fish from the Courtenay River, though still considering the importance of these habitats to salmon from tributary creeks. Another section, “Lower river restoration”, refers to restoration of freshwater habitat in the lower sections of smaller creeks that may provide rearing habitat to juvenile salmonids both prior to and following estuarine rearing. Each Area shown in the Restoration concept model was connected to restoration project types. In this way, the relative importance of project types for each area could be inferred. The relative contribution of the all the project types to the refuge, water conditions and forage potential for juvenile salmonids was indicated pictorially by applying different weights to the arrows that pointed to these descriptors on the concept model.

Concept model development for the Protection Options highlighted the main categories and the cub-categories for protection. This is a simplification of the process required to plan protection projects, and as such, some important connections are not explicit, such as the need for fundraising in order to implement all of the protection project types. To avoid the complexity that would result if all interconnections between the options were shown in the concept model, it was designed to provide a clear path for achieving this connections, while

[5] Google Earth can be downloaded for free from http://www.google.com/earth/index.html

keeping in mind the interrelated benefits of one type of action on another. For example, though it is not explicit in the concept model, achieving support for land acquisition may require financial incentives for landowners to transfer title to public ownership for conservation. These types of details are instead provided in the Protections Table. However, the importance of communications and education as encompassing all protection options is highlighted in the concept model.

5 RESULTS

5.1 Habitat Requirements

Chinook and coho fry stages were more dependent on the estuary than the smolts, which moved through the estuary quickly. Chinook and coho fry had already entered the estuary by late March of 2010 when sampling started. The residency of chinook fry in the estuary peaked in June, and most had left by July. Coho fry remained into the estuary for the entire summer, and were still found during two post-study sampling sessions in October and December of 2010. The smolt stages of these species were more abundant, but left the estuary sooner. By July, there were very few chinook fry or smolts captured in the estuary.

There was only one recapture of chinook, compared to eight of coho. Only one of the coho recaptures had moved from the place it was marked. The recaptured chinook fry had migrated between the Courtenay Slough and Dyke Slough (below the tide gates), and the coho had migrated from the Airpark Lagoon to the Dyke Slough. This coho also had the longest minimum estuarine residency period of 125 days. All of the other coho recaptures stayed in the habitats in which they were marked (Table 15).

Chinook fry had a preference for habitats in the upper ecotone and near freshwater sources throughout the season. Areas 1, 2 and 4 were particularly important to chinook throughout the 2010 sampling season (Figure 2). They were found in pools and alcoves bordered by sedge habitats, near large woody debris, among large rocks and pilings, near eelgrass beds, and in areas where there was a strong influence of freshwater.

Coho fry that reared in the Courtenay River estuary occupied habitat with good refuge and a reliable source freshwater inflow. They remained in the estuary throughout the spring and summer and during this time experienced better growth than their freshwater counterparts (Figures 18 and 19).

Early season (May-June) growth rates were low for chinook fry compared to coho fry in the Dyke Slough pool below the tide gates (site 4). Growth rates of chinook were <0.4mm/day compared to up to 1.43mm/day for coho. The diet of chinook during this time indicates a preference for insects, though these were not prolific in the benthic samples. In comparison, coho fry appeared to select for gammarid amphipods which were prolific.

5.1.1 *Fish Presence*

CPUE results indicated high fish densities in Areas 1, 2, and 4 for both chinook and coho. May had the highest CPUE of the sampling period for both chinook and coho in Areas 1 through 4. Area 4 had the highest CPUE for both species. Area 2 was important for both chinook and coho in the Courtenay Slough as well as along mainstem channel margins where there were deep water alcoves and sedge habitat. CPUE for all sites and sampling days are provided in Figure 2 for chinook and Figure 3 for coho.

Other species that were encountered in the estuary included steelhead (*O. mykiss*) and sea-run cutthroat (*O. clarkii*) trout, sculpins (*Leptocottus armatus* and *Cottus spp.),* threespine stickleback (*Gasterosteus aculeatus*) and perch, amongst smaller numbers of other species. As the sampling season started at the tail end of the pink salmon migration, very few of this species were encountered. Figure 4 identifies the relative catches of each species.

5.1.2 *Life History Composition*

Length frequency distributions indicated multiple age classes (cohorts) of chinook and coho utilizing the estuary during certain periods of the study. In 2001, the length frequency distributions for chinook indicated two size classes[6] in July and August. In 2010, there was slight evidence of a third size class in July for chinook (captures in August were too small to compare). There were two statistically different size classes ($P<0.0001$) detected for chinook in May, June and July in 2001, and in June for 2010. Two size classes of coho were detected in May and June of 2001, and in April and May of 2010 ($P<0.0001$ for all). The June of 2001 cohort 1 chinook had a similar mean length as the hatchery chinook that were identified with an adipose clip, and therefore may represent hatchery stock (Table 6).

Figure 5 and Figure 6 provide the length-frequency distributions for chinook in 2001 and 2010, respectively. A box plot indicating significant differences in size classes for each species, year and month is provided in Figure 7. Tables 7 and 8 provide information on the statistical results where significant differences in size class were found.

5.1.3 *Proximity to migration routes*

The map indicating the sample sites and Areas is provided in Map 2. A description of each area and the associated 2010 sampling sites is provided in Table 9.

5.1.4 *Diet*

Results from the stomach analysis of five species of fish over three sites indicated dietary differences between species and sites over the season. In April, chum salmon (*O. keta*) had a diet dominated with copepods (mostly harpactacoid), and chinook fry with gammarid amphipods. Subdominant food items indicated that copepods were also important for chinook fry, and likewise amphipods for chum.

[6] These are referred to as cohorts 1 and 3, based on their size classes. There were not enough data to statistically test for a difference in the middle (cohort 2) size class.

In May, there were dietary differences detected between chinook and coho fry and smolts at the Dyke Slough below the tide gates. The fry had a diet almost entirely of insects, while smolts had a diet dominated by gammarid amphipods. Steelhead trout and sea-run cutthroat had diets dominated by gammarid amphipods and isopods, respectively, without evidence of predation on other fish found in their guts.

In June, chinook fry diet was almost entirely composed of insects. Coho fry diet was also dominated by insects, with a substantial component (20-25%) of gammarid amphipods. In July, insects were also an important dietary component for coho fry.

While gammarid amphipods made up the dominant part of the diet of chinook fry through April and May, dietary overlap analysis did indicate them to be a preferred item due to their high abundance in the benthic samples (Figure 8). They were found to be a preferred food item for coho, however. In May, chinook demonstrated a strong selection for insects, and coho for copepods. Insects were also strongly selected for in June by coho.

The dominant and sub-dominant prey items found in the stomachs of fish sampled are provided in Table 10. The composition of invertebrates found in benthic samples in the estuary in 2010 is shown in Figure 8. Dietary overlap indicating selection for (positive values) and selection against (negative values) food items by coho and chinook are shown in Figure 9 and 10, respectively.

5.1.5 Water Quality

Figure 11 compares temperatures at four sample sites to ideal and lethal levels for salmonids (Bjornn & Reiser, 1991). Temperatures during sampling of Areas 1-3 were typically below the optimal conditions until approximately mid-June, when they exceeded optimal levels. Area 4 exceeded optimal levels by the third week of May. There were no recorded instances where temperatures reached lethal levels.

There was a general increase in surface temperatures in Areas 4 and 6 over the season, with higher late-season (post-June) temperatures detected in 2010 compared to 2001 (Figure 12 and 13).

5.1.6 Growth

Growth of chinook and coho fry (cohort 2) varied between Areas and sampling period. The highest short term growth rate for chinook was estimated at 0.79mm/day in late May in Area 1. There was negative growth detected at Area 4 in early May for chinook. Coho demonstrated very good growth early in the season in Area 4, while coho in Area 1 experienced negative growth in late July (-0.57 mm/day). Figure 14 and Figure 15 compare seasonal (~1-2 months) growth between Areas for chinook and coho fry, respectively.

Tables 11 and 12 provide estimated growth rates for different areas over narrow time periods (~ 1-4 weeks) for chinook and coho fry, respectively.

Area 2 had significantly higher condition factors ($P<0.05$, Table 13 and Table 14, Figure 16 and Figure 17) than Area 3 for both chinook and coho fry in April. Differences between Areas 1, 2 and 4 were also similar for both species in May, with Areas 1 and 4 having greater condition factors than Area 2. Condition increased overall in June, with all areas and both species exceeding a condition factor of 1. The greatest condition factors for chinook occurred at Area 4 in June. Area 5 had coho fry with consistently high condition factors throughout the season.

End of the season size analysis indicated that coho captured in Areas 4, and in the lower river areas that fed into Area 4 (Glen Urquhart and Mallard Creeks) were of greater size than for the lower Puntledge River upstream of the upper ecotone, and in Areas 1 and 2 (Figure 17 and Figure 18). Coho captured in August in Area 5 were of greater size than those captured in the Condensory side-channel.

5.1.7 Residence Time

Overall 742 chinook fry and 446 coho fry were marked with VIE tags between March 30 and June 24, 2010. There were 1 chinook and 8 coho recaptures between May 6 and October 7, 2010.

Mark-recapture data indicated site fidelity of coho fry in Areas 2, 4, and 5. During the period from April to May, coho fry in Area 2 (captured in site 2a, Courtenay Slough) had a minimum residency period of 8 days. Recaptures at this site in June found an increase in the minimum residency period to 23 days. Known mark and recapture dates of a coho in Area 4 (site 4, Dyke Slough pool below the tide gates) found a residency period of exactly 41 days. Recaptures in Area 5 (Millard estuary) indicated a coho had resided there for at least 66 days.

The longest estuarine residency period was at least 125 days for a coho that was marked in Area 3 (Airpark lagoon) and recaptured on October 7, 2010 at site 4. One chinook fry was recaptured; it had a minimum residency period of 20 days and had moved from Area 2 to site 4.

Lower river sampling did not find any VIE tagged fish.

Table 15 provides details of species recaptured in the estuary and potential marking dates along with calculated ranges in residency periods.

5.1.8 Density/Snorkel observations

Density estimates of juvenile chinook and coho (fry and smolts combined) during the 2010 sampling period ranged from 0 to 4 salmon per m^2. Greatest densities were detected from June through to early July, particularly at Snorkel Site 2. Site 2 was located in a back eddy along a rip rap/boulder shoreline along the left bank of the river ~230m below the Tsolum/Puntledge confluence. Chinook made up the majority (87%) of juvenile salmon observations in June. Observations in early July were not identified to species. The lowest densities were detected at Snorkel Site 6. However, snorkelers observed difficulty in viewing fish at this site especially at the lowest tides due to a shallow sandy slope.

General observations noted by snorkelers are provided in Table 16. Map 5 provides an overview of salmon and trout densities for each of the six transects assessed weekly from May 11 to August 16th, 2010 along the 3.1km of the upper ecotone. Figure 20 provides a chart of overall densities from the Tsolum/Puntledge confluence to the end of the upper ecotone (beginning of the mudflats).

5.1.9 Mapping

Detailed habitat mapping of six different sites in the estuary provides a comparison of the diversity in aquatic and riparian vegetations that occurred from the upper ecotone to the lower estuary, and an indication of the relative numbers of exotic plants that have established in these areas. Maps were created for the Tsolum Relic Channel (Map 6), Simms Park (Map 7), the shoreline and mudflats adjacent to the river channel and Airpark Lagoon (Map 8), the Dyke Slough below the tide gates (Map 9), Millard estuary (Map 10), and the areas north and south of the Royston Wrecks (Map 11 and Map 12, respectively).

The greatest overall diversity of tall (>10m) and short (<10m) riparian vegetation and aquatic herbaceous vegetation occurred at the Tsolum Relic Channel in Area1. There was also the least number of different exotic plant species at this location. Millard Creek estuary also had a high diversity of native vegetation, but had the highest number of exotic plant species. Site comparisons of the riparian, herbaceous aquatic, and exotic vegetation is provided in Figure 21. Table 17 and Table 23 provide plant species lists for each of these sites.

5.2 Restoration and Protection Options

5.2.1 Restoration Options

In total, there were 41 restoration options, including 12 project types identified for the estuary (Figure 22, Appendix 6). The majority of these projects were located in Area 2 along the upper ecotone. There were 15 projects listed as “Other” that were wither not within one of the delineated areas or they spanned multiple areas. The greatest number of options fell under the “Off-channel Habitat Enhancement” and “Riparian Restoration” project types. “Channel complexing” and “Saltmarsh Planting” were also common. As such, most of these projects were determined to benefit refuge requirements for juvenile salmonids.

5.2.2 Protection Options

In total, there were 33 protection options identified that spanned the categories of “Education”, “Land Protection”, “Voluntary Incentives” and “Regulatory Incentives” (Figure 23 23, Appendix 7). The majority of project types identified were “Education” (15), followed by “Land Protection” (11).

The final Restoration and Protection options are provided in Appendices 6 and 7, respectively. The respective concept models are provided in Figures 22 and 23. An Excel spreadsheet of these options and the Google Earth map file (.kmz) is also available from the author or from Comox Valley Project Watershed Society.

5.2.3 Stakeholder Involvement

Results from stakeholder interviews and comments following presentation of the results to stakeholders are provides in Appendices 6 and 7, respectively. These summaries provide insight from various stakeholders of the results of this study and the feasibility of implementing restoration and protection options in the estuary.

6 DISCUSSION

This study provides current knowledge of habitats that are important to rearing salmonids in the Courtenay River estuary and possible solutions to ensuring the long term health of the estuary for all species. The application of an ecosystem-based management approach ensured that the results can be applied widely across the estuary and by different stakeholders. Key ecological linkages between juvenile salmon and their habitats were identified and applied to the development of the restoration and protection options along with stakeholder input. The restoration and protection options that resulted from this study identified 74 potential projects that could benefit estuary health to varying degrees.

Measures of opportunity, capacity and realized function introduced by Simenstad and Cordell (2000) were applied in this study to assess the ecological and physiological responses of juvenile salmonids to estuarine habitats. Overall, the estuary provided the necessary habitat requirements to support the survival and fitness of juvenile salmonids in 2010 to varying degrees. In particular, the opportunity for salmon to access and benefit from the habitats in the estuary was provided by the two different size classes of chinook and coho found in the estuary. Life history diversity has been linked to both ecological and genetic diversity within salmon populations, and can promote resilience to disturbance similar to the resilience provided by a diverse stock portfolio (Waples et al, 2009, Schindler et al, 2010). Likewise, the long residence time of coho fry in the estuary provides evidence that estuary habitats were functioning to promote the survival of this life stage (Simenstad and Cordell, 2000).

6.1 Habitat Requirements

The Tsolum River relic channel, edge and large woody debris habitat along the upper ecotone of the Courtenay River, the Courtenay Slough at Simms Park, the Airpark Lagoon, and the Dyke Slough pool below the tide gates all provided important estuary habitats for juvenile salmon. These areas were located mostly in the upper and mid-ecotones, they all had a combination of shallow and deep water refuge, and at least some intact riparian areas. These habitat characteristics have been identified as important estuarine habitats for both species (Healey, 1982; Kjelson et al 1982; Aitkin, 1998; Simenstad and Cordell, 2000).

Chinook had a preference for habitats that provided both high and low water refuge, and provided good refuge from predators and poor water conditions. These habitat preferences reflect chinook behaviour observed by Healey (1982) in the Nanaimo River estuary where they did tidal migrations between low tide refugia and high water marsh habitats. Areas

1, 2 and 4[7] were particularly important to chinook throughout the 2010 sampling season. They were found in pools and alcoves bordered by sedge habitats, near large woody debris, among large rocks and pilings, near eelgrass beds, and in areas where there was a strong influence of freshwater. There was only one chinook recapture compared to eight for coho, and that recapture had migrated in May or June between Simms Park (Area 2) and Dyke Slough (Area 4) over a minimum period of 20 days. This is likely due to a seaward migration later in the season, which was also found for chinook in the Nanaimo River estuary (Healey, 1982).

Coho fry that reared in the Courtenay River estuary had a long residency period in habitats of the upper ecotone that provided good refuge and feeding opportunities. Their preference for backchannels and sloughs despite poor water quality conditions encountered at these sites later in the summer season indicated they were sensitive to predation. They also grew relatively well in higher temperatures compared to chinook. High food conversion efficiencies have been reported for salmonids at higher temperatures where there are good food opportunities[8] (Wurtsbaugh & Davis, 1977; Bjornn & Reiser, 1991). During their estuarine residency in the spring and summer, coho fry experienced better growth than their freshwater counterparts, with some reaching the same size as smolts found in the estuary the previous April. Tschaplinski (1988) also found that the coho grew much faster in the Carnation Creek estuary than their freshwater counterparts. This could provide estuarine reared coho with an advantage over freshwater reared coho, as larger size upon entry to the marine environment has been attributed to greater survival when overall marine conditions are poor (Holtby, et al., 1990). Coho tended to stay in the same habitats for long periods of time, as indicated by the mark recapture results. These results indicated a range in residency periods in the same habitats that lasted at least 23 days in Area 2, 41 days in Area 4, and 66 days in Area 5. Only one of the eight coho recaptures had moved from the place it was marked. This coho also had a minimum estuarine residency period of 125 days, the longest of all the recaptures.

While this study did not find any indication of coho that moved to the marine environment after their spring and summer residency period, Tschaplinski did find that Carnation Creek coho were able to tolerate salinities up to 19 $^{0}/_{00}$ [9] by the end of the summer, therefore this scenario is possible. The survival of these fish to return to spawn is indicated in an otolith sample taken from a mature adult coho in 2009 from the Puntledge River Hatchery that had an estuarine rearing signature (Tryon, unpublished). As such, there is some evidence that this life history provides a contribution to coho survival in the Puntledge River system, however the proportion of estuarine reared coho that survive to spawn is unknown. Furthermore, whether this life history results from early displacement of fry from the rivers and creeks, or if there is an active migration to the estuary is also unknown (Koski, 2010).

[7] For a description of the Areas, see Map 2.

[8] Up to a maximum temperature threshold, after which conversion efficiency declines despite good food conditions.

[9] Seawater is typically 30 $^{0}/_{00}$

It is important to distinguish between salmon use of a habitat and the ability of that habitat to support salmon. Although chinook were found in high numbers at the Dyke Slough (Area 4), monthly length comparisons indicate low growth rates (>0.4mm/day) early in the season (May-June). This may be due to immigration and emigration to the site, or to the low composition of preferred diet items in the benthic environment. Habitats that have the capacity to provide preferred prey items to juvenile salmonids have been identified as important contributors to their survival (Simenstad and Cordell, 2000), and lack of preferred prey items, despite the presence of other food, can lead to reduced energetic efficiency for growth (Higgs et al, 1995). Gammarid amphipods had the greatest relative densities in the benthic samples and dominated chinook diet at this site, however, dietary overlap analysis indicated a preference for insects, which were not prolific in the benthic samples. This may be due to the sampling method not encountering the insects, or the interpretation may have large errors (error analysis of the Strauss Index was not undertaken). This argument is plausible as chinook fry had significantly higher condition factors ($P<0.05$) at this site compared to other sites. However, if insects were indeed limiting at the Dyke Slough site, this could explain the low growth rates of chinook during this time. In comparison, coho fry at this site grew very well (up to 1.43mm/day) from April through June, during which time they fed mainly on amphipods and insects. Coho fry appeared to select for both diets, therefore may have been better able to take advantage of the greater densities of amphipods in the environment than chinook fry.

Food production and salmonid diet had important links with detrital and riparian sources. Gammarid amphipods and copepods were important components of salmonid diet in this study. They are epi-benthic organisms, and likely lived in the same habitats where they were consumed (Pauley et al, 1988). Furthermore, amphipods in general are sensitive to environmental changes and their presence and abundance can be used as indicators of environmental quality (Gross and Pauley, 1989). Harpacticoids are also important dietary components for salmonids due to their high food conversion efficiencies (Coull, 1990). Insects were an important dietary component for chinook and coho fry in the upper ecotone throughout the spring and summer. Riparian vegetation provides an important contribution for insect production, both indirectly as an organic source of insect food, or directly from insect fall from surrounding riparian areas (Brennan et al 2009). The upper ecotone had intact riparian areas with a healthy diversity of tree and shrub species (Figure 21), which may have contributed to insect production in this area. Chinook were found to feed preferentially on insects in this study. In May in the Tsolum relic channel (Area 1), insects dominated chinook fry diet and they also experienced high growth rates. High growth rates have been linked to a diet on preferential food items that meet salmonid energy requirements (Higgs et al, 1995).

6.2 Restoration and Protection Options

This study identified habitat restoration and protection options that could benefit chinook and coho fry that rear in the estuary. Chinook fry would benefit from restoration projects that improved food production and habitat connectivity throughout the upper and lower estuary by naturalizing hardened shorelines, creating deep water refuge habitat adjacent to upper intertidal marsh habitats, and ensuring frequent velocity refuge opportunities along the estuarine continuum for all tide heights. Coho fry would benefit from restoration projects in the upper estuary that increased the area and quality of refuge habitat by restoring riparian habitats for improved insect production and creating and restoring off-channel habitats. Similarly, protection projects that ensure existing areas with these features for coho and chinook remain healthy will benefit both the salmon and their ecosystems.

Other management actions that affect salmon include hatchery management, watershed development, and flow regulation. These are not directly addressed in the restoration and protection options, however they are in other management systems such as the Wild Salmon Policy (Fisheries and Oceans Canada, 2005), Nature Without Borders (Fyfe, 2008) and the Puntledge River Water Use Plan (BC Hydro, 2003). These actions can and do impact salmon in the estuary in different ways, therefore the estuary should be considered in these decisions as well.

6.3 Study Limitations

The characterization of and development of restoration and protection options involved a comprehensive process that brought in information from many sources. Given the high complexity of the estuary ecosystem and the myriad of perspectives amongst stakeholders on how to achieve a healthy estuary ecosystem, there were some limitations associated with this study. In the ecological characterization of the estuary, information gaps associated with data and budget limitations were addressed by referring to past studies. For example, Healey (1982) provided a good description of chinook and coho use of the Nanaimo and Nitnat river estuaries that helped to attribute importance of similar habitat features found in the Courtenay River estuary. Tschaplinski (1988) provided a detailed account of coho fry rearing in the Carnation Creek estuary that contributed to identifying the benefits of this unique life history trait in coho fry from this study. Water temperature interpretation required drawing upon conventional stream habitat requirements for salmon provided by Bjornn and Reiser (1991). This approach was supported by Tschaplinksi (1988) who identified that freshwater thresholds were similar for estuarine reared coho. Significant differences in habitat types based on salinity in the Courtenay River estuary in 2001 (Hamilton et al. 2008) helped with Area delineation in this study. Finally, the investigation into measures of capacity, opportunity and realized function by Simenstad and Cordell (2000) formed a basis for characterizing estuarine health. While these measures were developed to monitor restoration projects, their value in assessing existing habitats and establishing a baseline for future monitoring was recognized for this study.

Further challenges were associated with the development of the restoration and protection options. These included time and budget limitations that prevented input from all stakeholders, in particular First Nations rights-holders. However, by including the diverse group of stakeholders that make up the Estuary Working Group (EWG) in the process, and by conducting the three interviews across three different stakeholder types, there was a healthy cross-section of input from non-profit, government and expert associations. Furthermore, the adaptive nature of the final outcomes partially address these limitations by making them applicable to different management systems and by providing an opportunity for involvement at a later date during periodic reviews.

7 RECOMMENDATIONS

Cooperation and communication are essential to achieving management actions. To ensure the greatest value of the effort and resources that many people have put into this study and into past research, restoration and protection projects, it is important to:

1. clearly recognize a common goal amongst stakeholders; and
2. to ensure ongoing efforts related to the estuary strive to meet that goal.

In this study, the goal was to provide a foundation for future salmon habitat restoration and protection activities that will ensure a healthy thriving estuary ecosystem for salmon and other species that rely on it. The outcomes provide a broad overview of estuary conditions and the current social systems that affect its management.

The next steps require stakeholders of the estuary - environmental organizations, First Nations rights holders, politicians, government staff, landowners, professionals, funding organizations – to assess how their goals and objectives align with the results of this study, and then, their involvement in reaching a common goal of a healthy estuary. Assessment of goals and objectives may involve the confirmation or redefining of the meaning of estuary health and how it is measured. Involvement can include different levels of support, including verbal and written support, financial support, and active support in project implementation. It can also include taking charge of a particular project, including its proposal, design, implementation and monitoring.

The protection and restoration options in this report provide a guide to stakeholders to assess their potential involvement in future projects that affect the estuary. These can be used in existing management planning systems used by different organizations, or applied to new systems. The implementation of specific projects will require greater scrutiny and likely more detailed and site specific research. There will also be requirements for broader scale research into the Courtenay River estuary, including:

- Ecological prioritization of specific restoration projects to help with management decisions
- Periodic (ex. annual) reviews of restoration and protection options to add new projects ideas, and update or remove current projects
- Periodic (ex. annual) reviews of social and economic conditions that affect the health of the estuary and feasibility of implementing specific projects
- Development of more habitat maps of specific areas not covered in this study
- Further analysis of existing data to compare annual trends in habitat requirements for juvenile salmonids beyond what was done in this study
- Continued monitoring of salmonid use of estuarine habitats

Finally, the most important element to ensure that the Courtenay River estuary remains a healthy system for all species, including humans, is to include a strong communications component in all management planning. This will help to foster cooperation amongst stakeholders, facilitate information sharing, identify opportunities and constraints, access resources, and ensure continuity and long term success in reaching management objectives and goals.

8 ACKNOWLEDGEMENTS

This study involved a long process and many people in all aspects from planning, financing, implementation, writing and reviewing. The Comox Valley Project Watershed Society sponsored the funding application administered the project. The BC Hydro Fish and Wildlife Compensation Program provided the necessary financial support. The people of the Estuary Working Group reviewed and provided input on restoration and protection options. In particular, Dave Davies of Fisheries and Oceans Canada and Wayne White were valuable participants in the field work and technical review. In addition, Bev Bravender and Shannon Anderson from Fisheries and Oceans Canada reviewed various aspects of this project. Dave Lacelle and Norma Morton of the Comox Valley Naturalists Society provided historical information. Mel Sheng and Scott Northrup of Fisheries and Oceans Canada met with me for site visits and discussed restoration projects. Esther Guimond provided information on the Dyke Slough tide gates and found a marked coho with the longest estuarine residency period when she sampled there in October. Patrick Walshe shared information he collected on the Airpark Lagoon. Cynthia Durance of Precision Identification, Ron Watanabe of the Fish and Game Protective Association, and Nancy Hofer of the City of Courtenay participated in the formal interviews. The Puntledge River hatchery provided the facilitates and the chinook fry to test the VIE tagging on.

Many people and organizations were involved in the field component of this project. The Tsolum River Restoration Society provided regular volunteers and a boat. Members of the Courtenay Fish and Game Protective Association volunteered in the the estuary and helped with lower river sampling. Frank and Karl, private landowners on Mallard Creek, and Noah and Brett Knight, Glenn Urquhart Creek, also helped with lower river sampling. Noah also came out regularly to help with the estuary work. Wendy Kotilla brought youth as part of the Youth and Ecological Restoration program on a regular basis to help in the estuary. In addition, volunteers from the Millard/Piercy Watershed Stewards, Brooklyn Creek Stewards, and Excel Community College assisted in the estuary. German environmentalist Eduard Fischer came out regularly to help. The Ministry of Agriculture and Lands provided staff and a boat. The British Columbia Conservation Foundation provided us with Shayne Johnson, expert snorkeler. Most field equipment was provided by Fisheries and Oceans Canada, with emergency back-up supplies provided by Current Environmental and EcoDynamic Solutions.

This project was also helped along with the assistance of contractors with various talents. In particular, I would like to acknowledge the tremendous efforts of Joanne Ellefson. She helped with the field work as a crew leader, did data entry, crew organization, conducted snorkel surveys, helped with mapping, managed the books, and organized communications amongst many other tasks. Michele Jones, along with the Project Watershed Mapping Centre

(Caila Holbrook, Don Chamberlain and Mark Shroeder) helped with the mapping. Kayt Chambers assisted with interviews and report formatting. Bev Bravender organized historical data for analysis, and provided volunteer assistance in the report review. Corey Frank and Mike White provided field assistance with sampling and snorkelling. Candice Salmon carried out data entry tasks. Carol Cooper of Zotec Environmental Services sorted through the benthic and stomach samples. Lynda Fyfe's volunteer assistance in reviewing the final report is also greatly appreciated.

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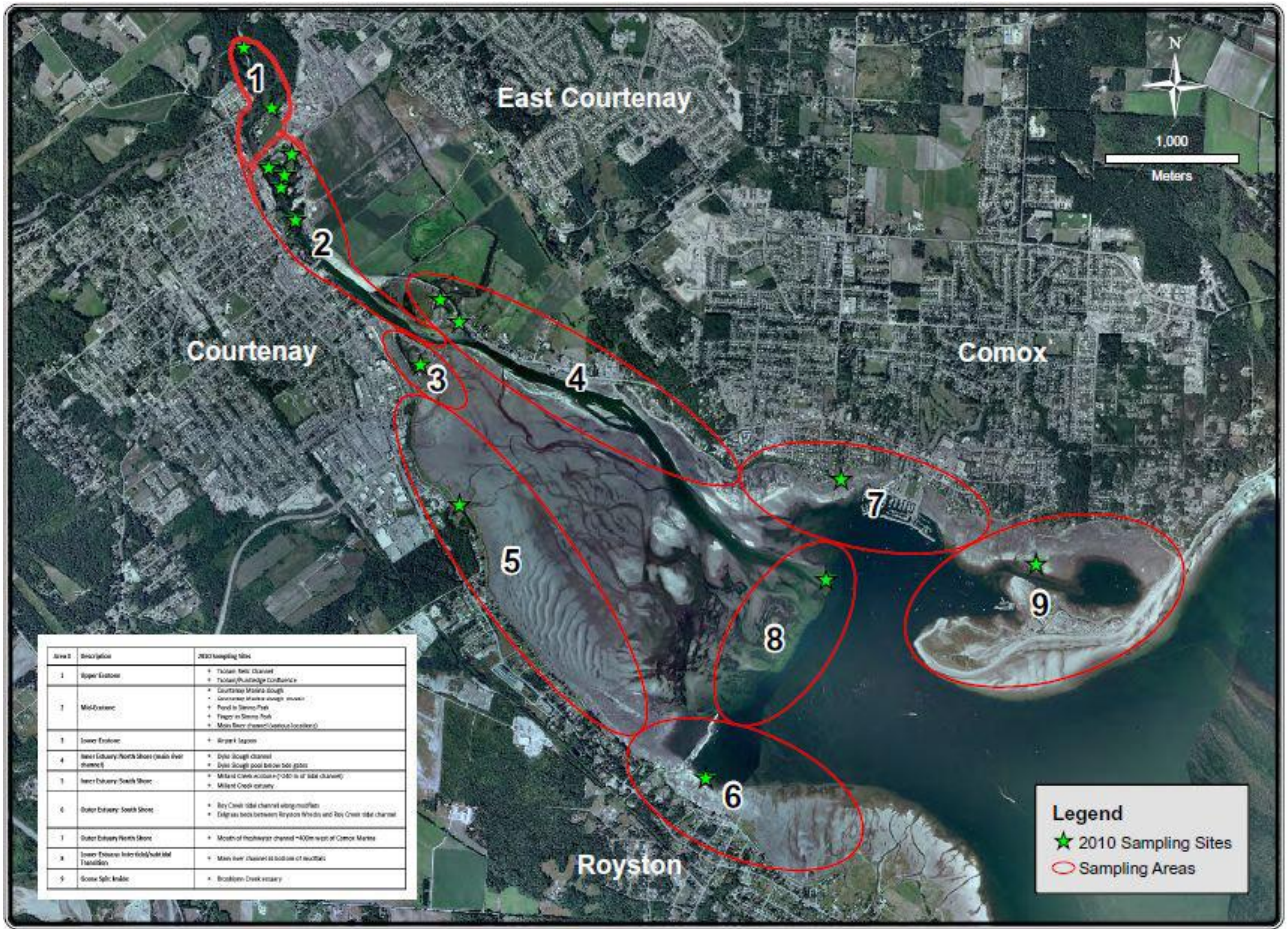
APPENDIX 1: MAPS

Map 1: Map of Vancouver Island indicating the location of the Courtenay River estuary.

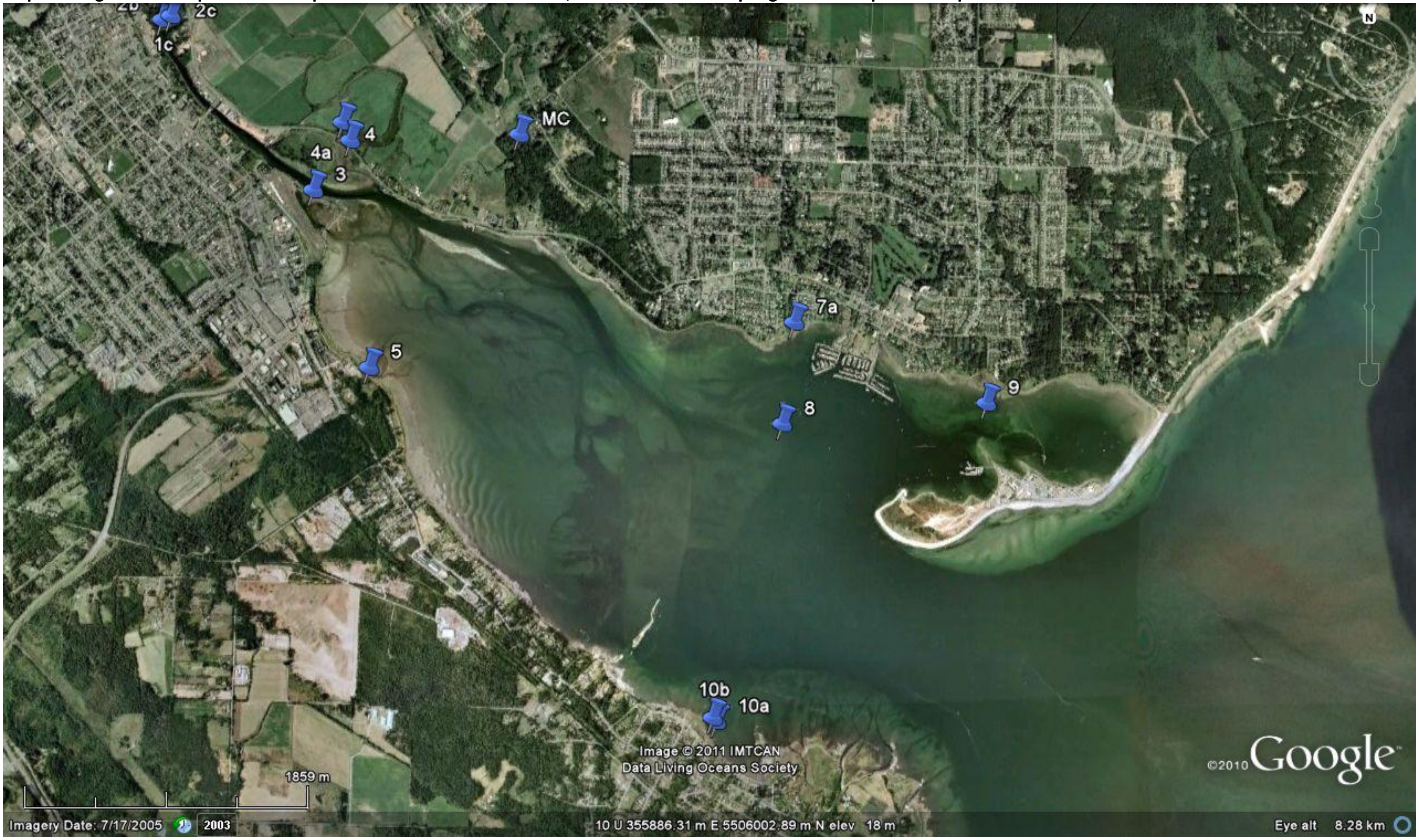
Map 2: Area delineation of the estuary, numbered consecutively to indicate conceptual migration route of anadromous salmonids[10].



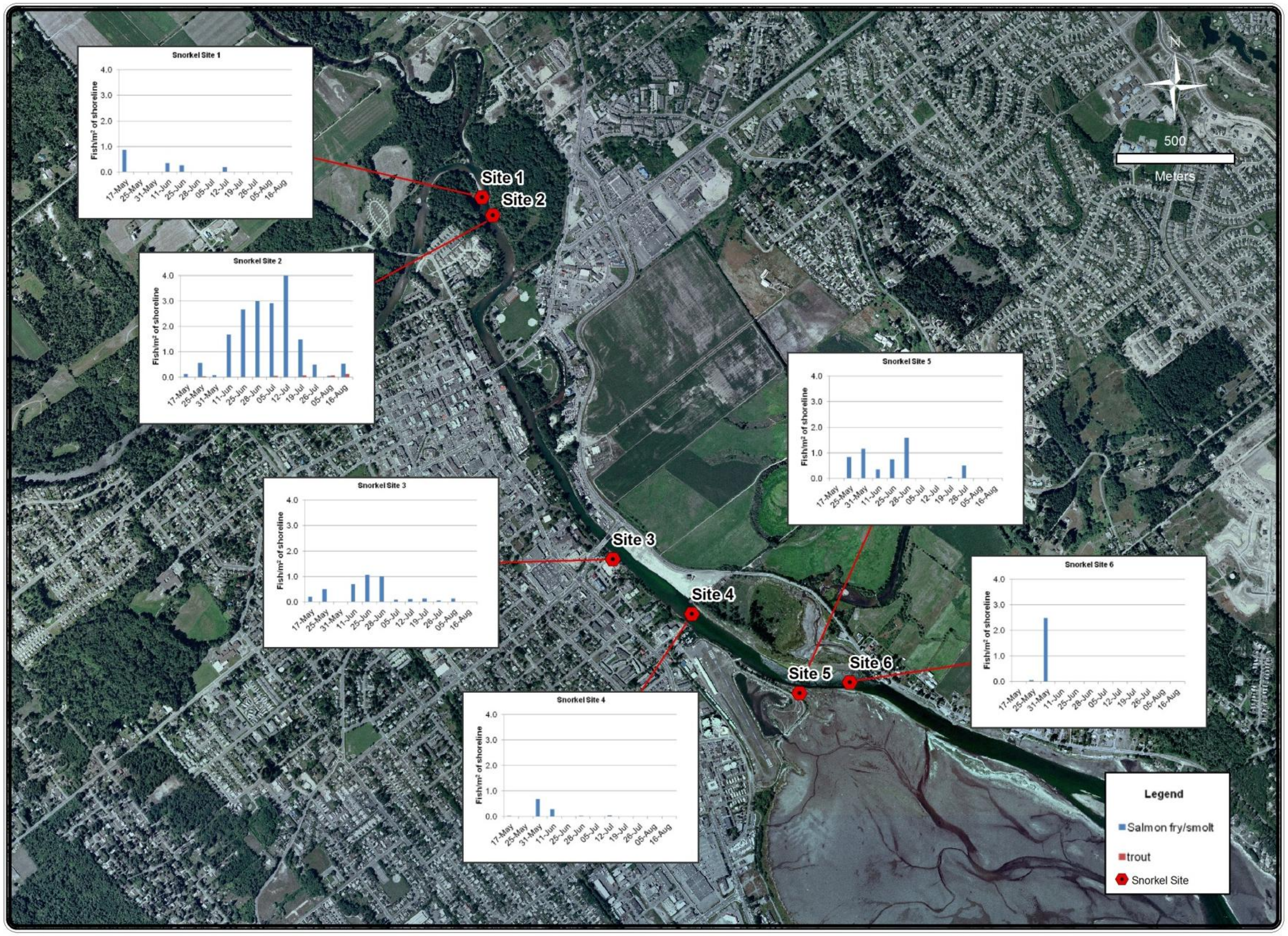
[10] Refer to methods section 4.2.3 for details. Inset table also provided in Table 9.

Map 3: Google Earth map of 2010 Sample sites locations for Areas 1 and 2 and lower river sampling. Site descriptions are provided in Table 1.

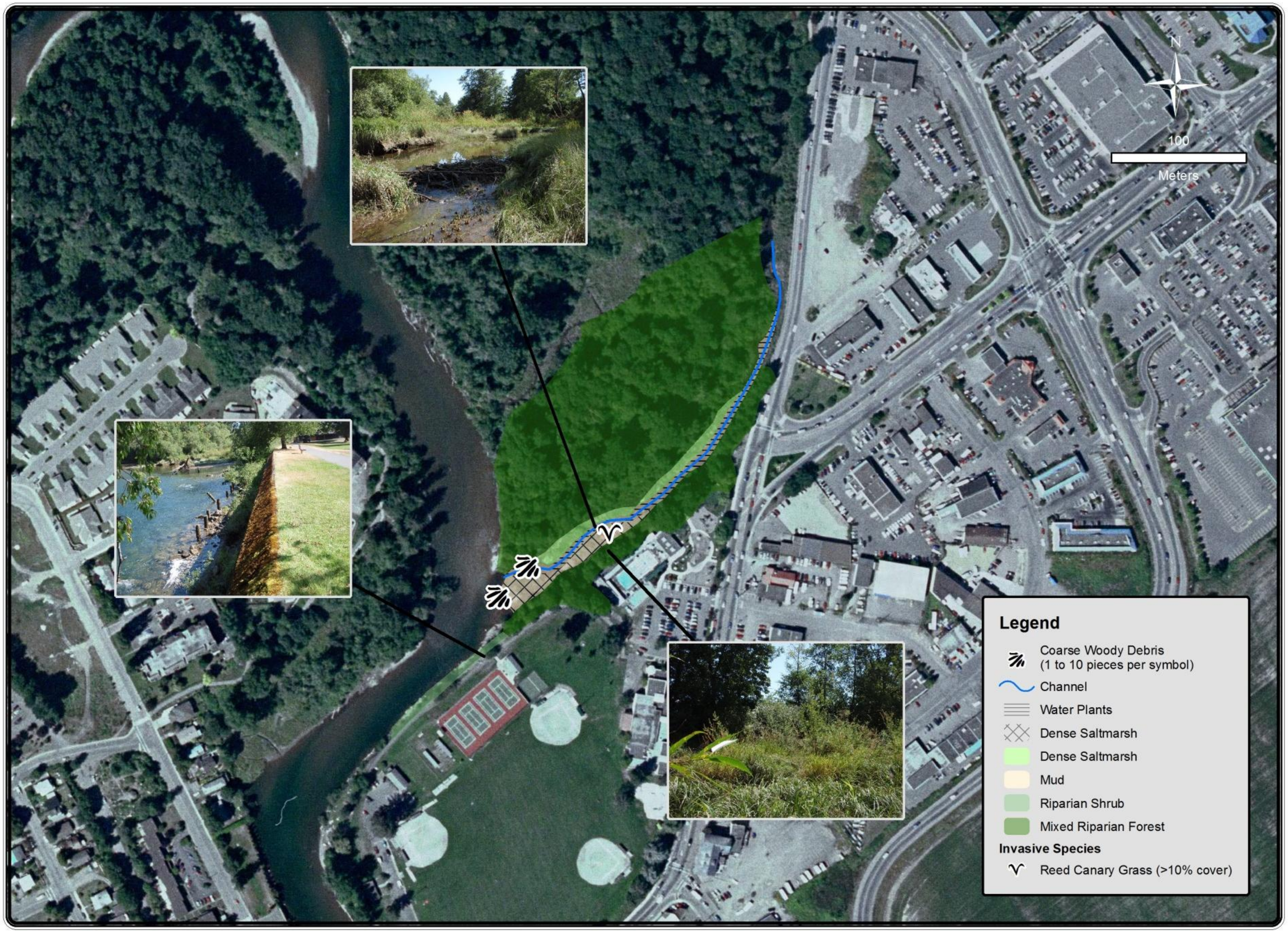
Map 4: Google Earth map of 2010 Sample sites locations for Areas 3-9, and lower river sampling. Site descriptions are provided in Table 1.



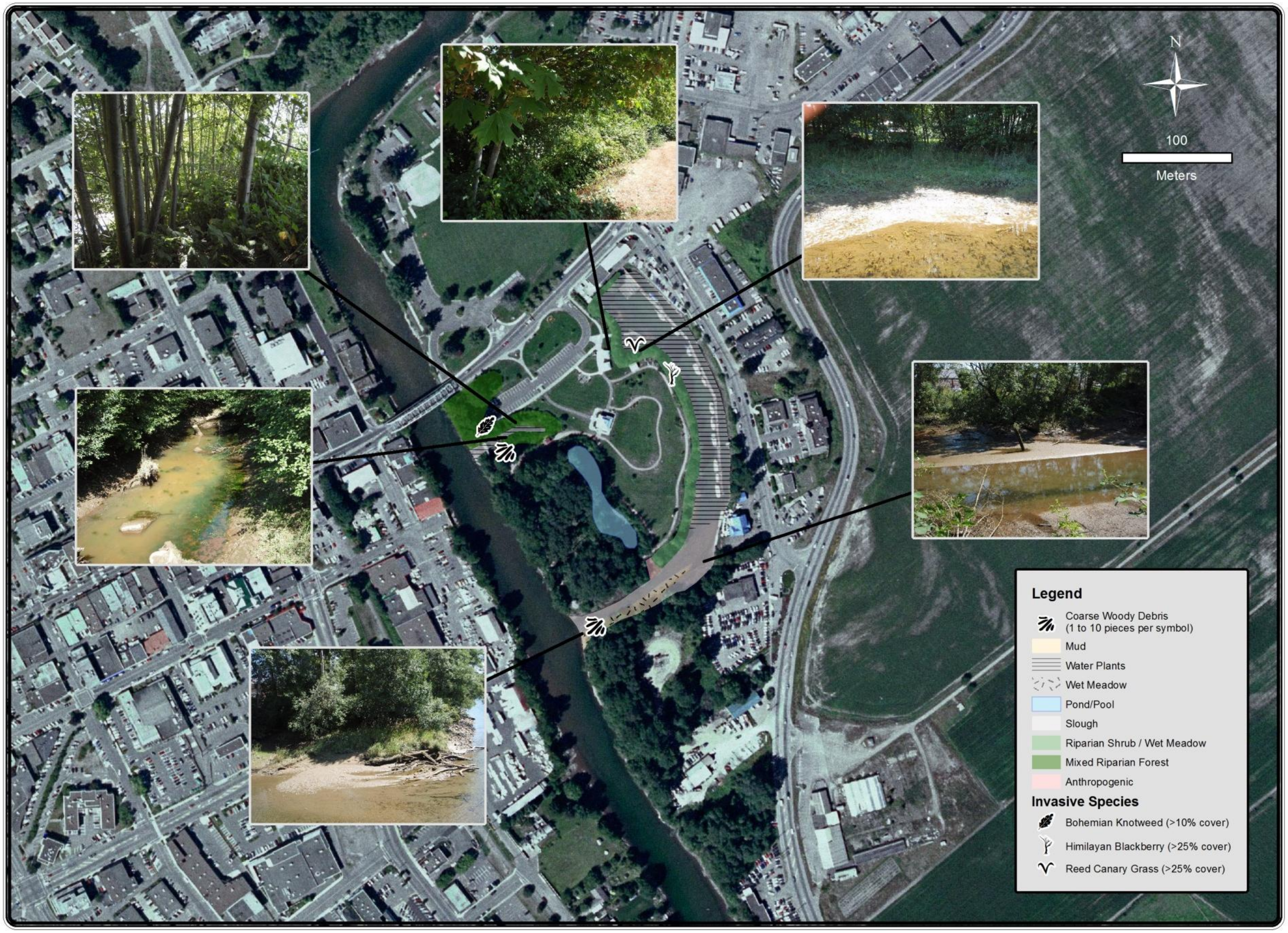
Map 5: Snorkel sites where density transects were located and assessed on a weekly basis between May 11 to August 16th, 2010.



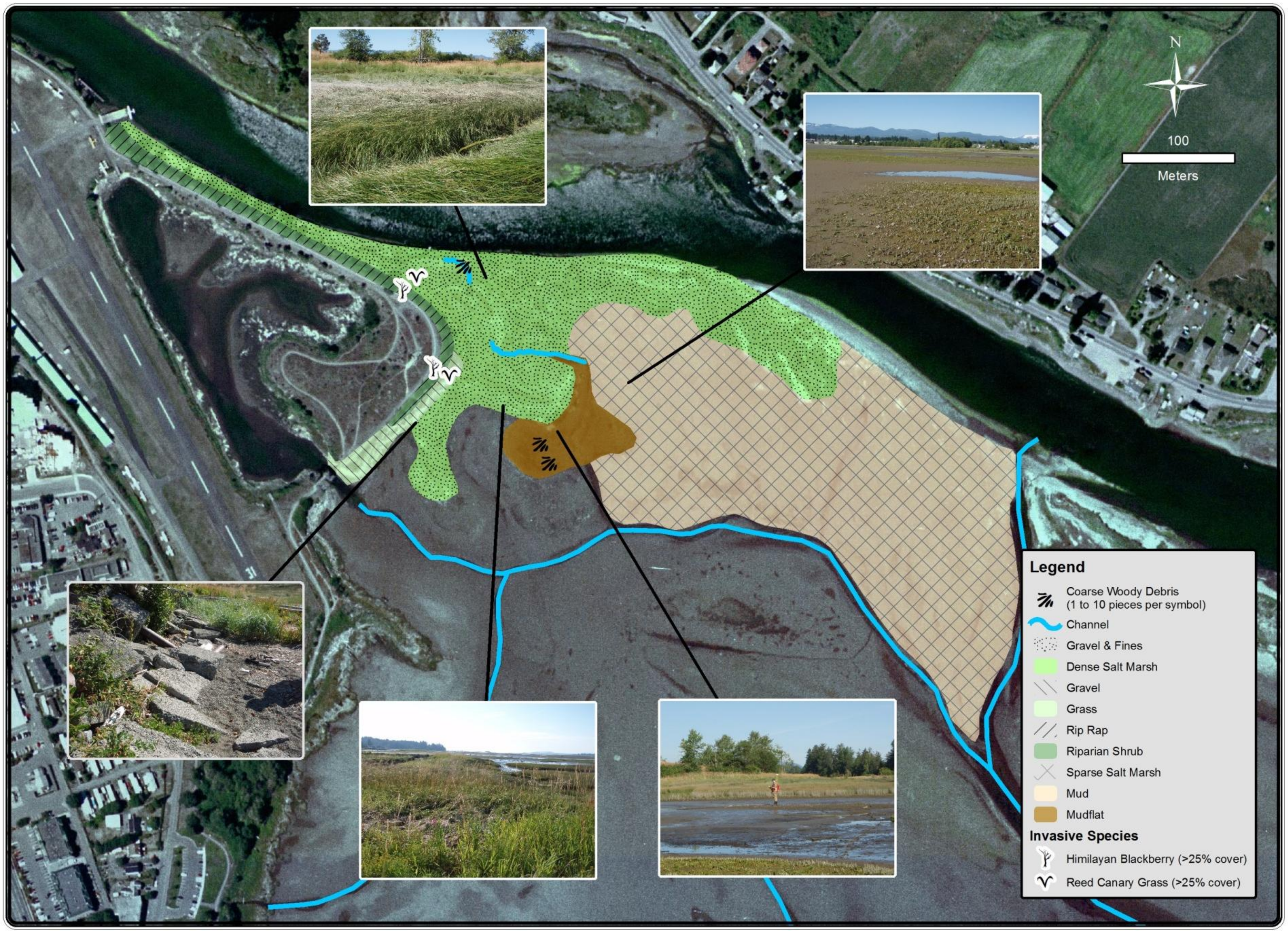
Map 6: Habitat map of site 1a, the Tsolum Relic Channel.



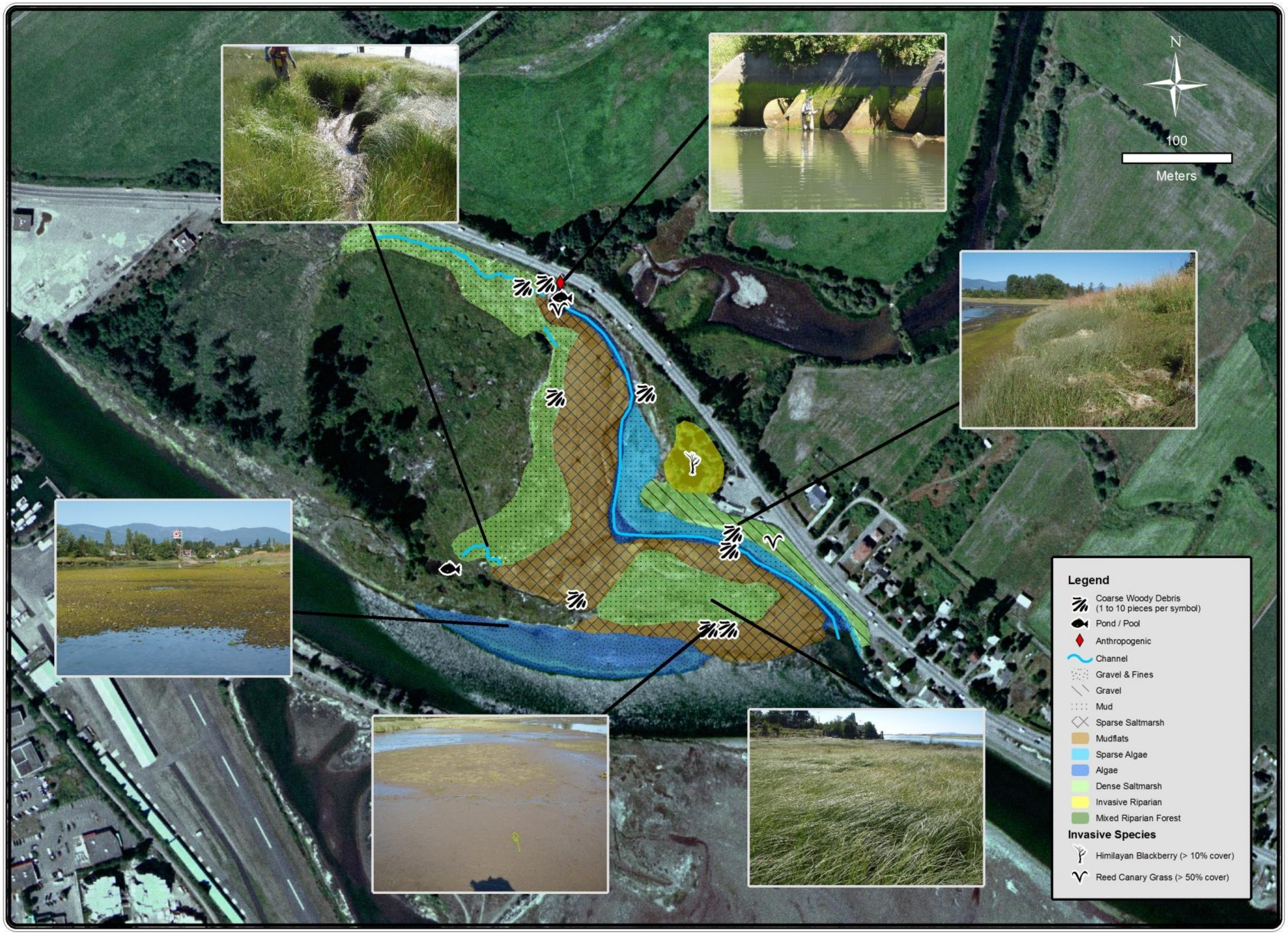
Map 7: Habitat map of Simms Park and Courtenay Slough.



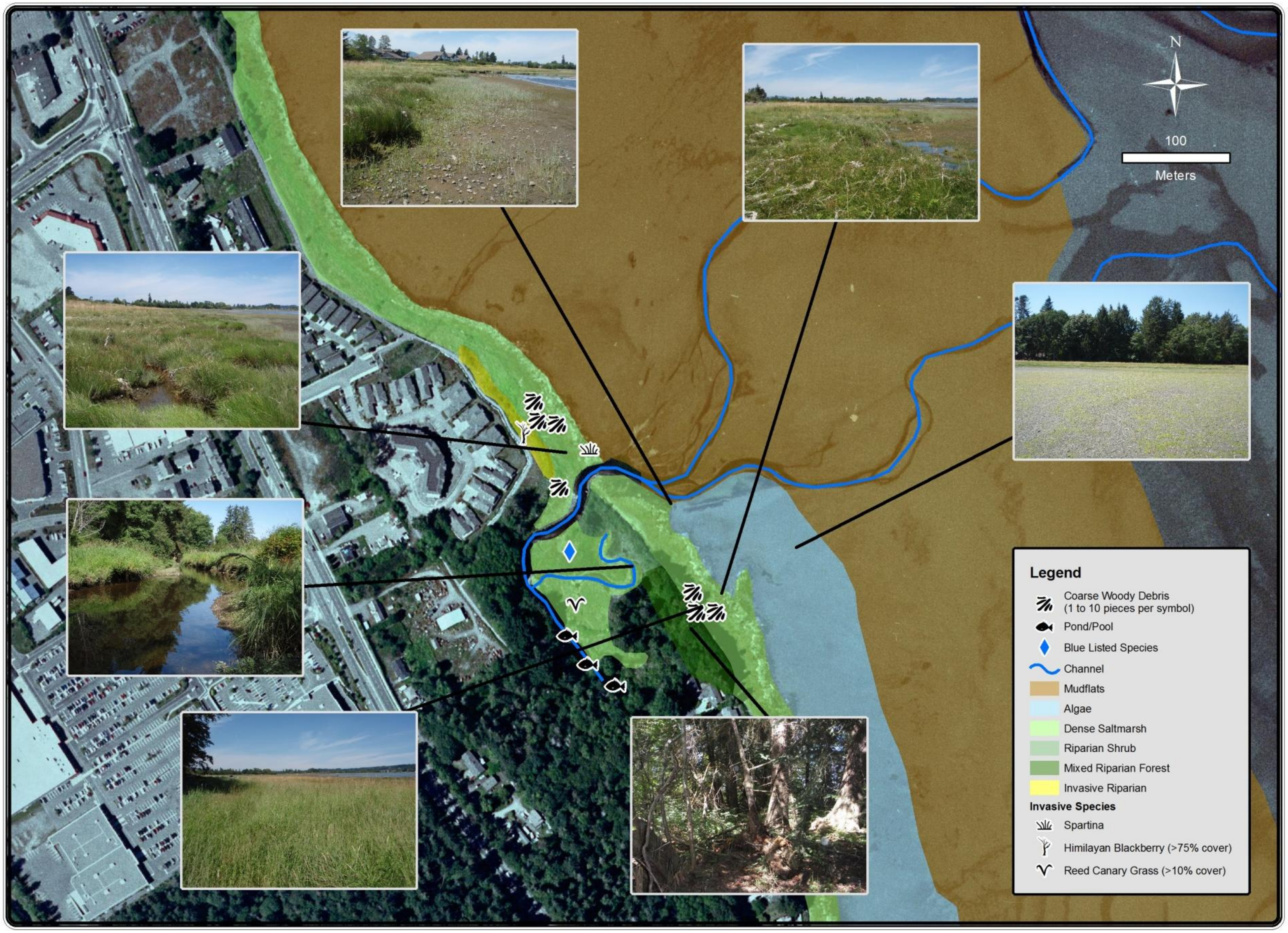
Map 8: Habitat map of the upper and lower ecotone transition located adjacent to the Courtenay Airpark.



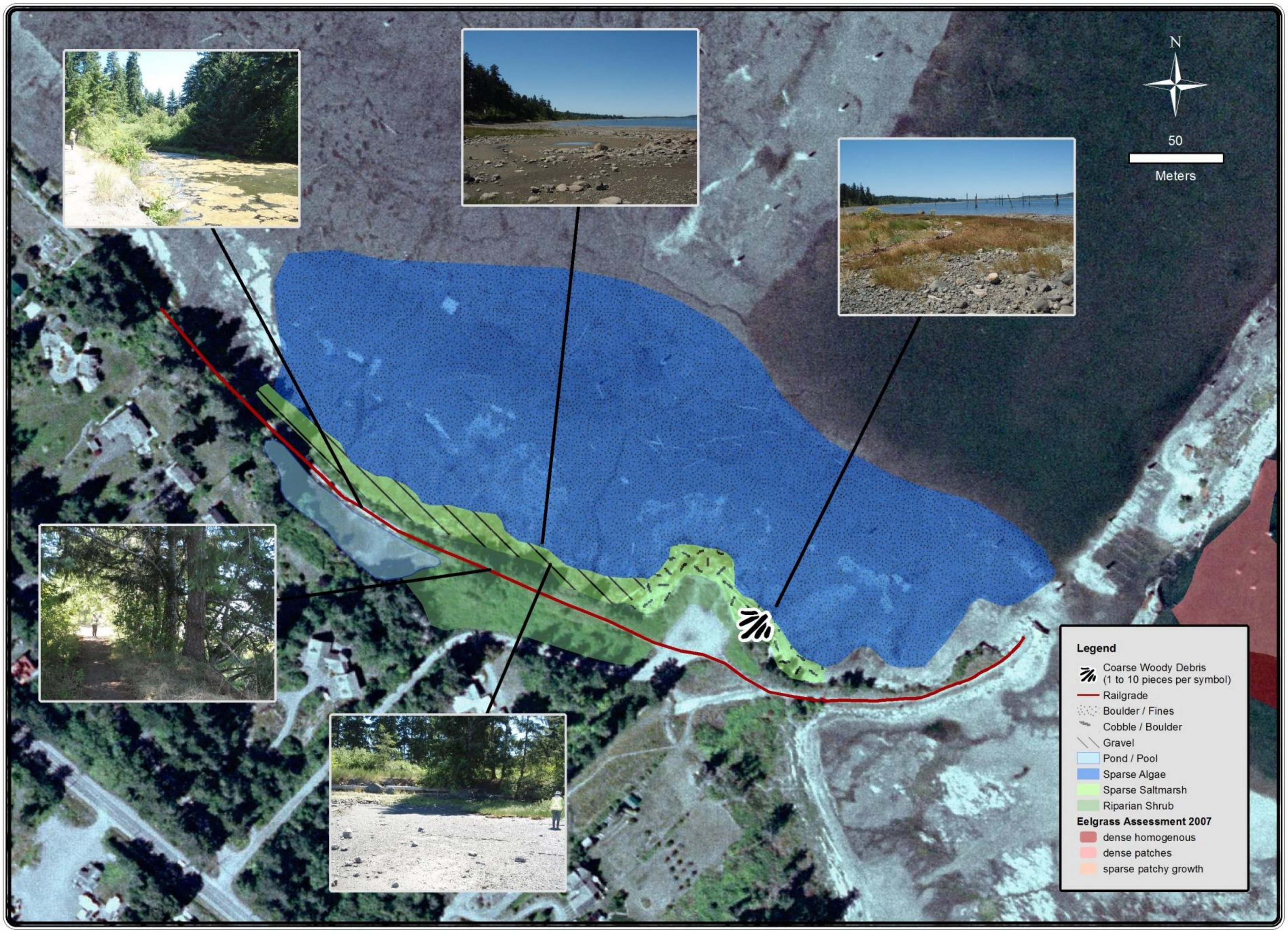
Map 9: Habitat map of Dyke Slough downstream of the Comox Ave. tide gates.



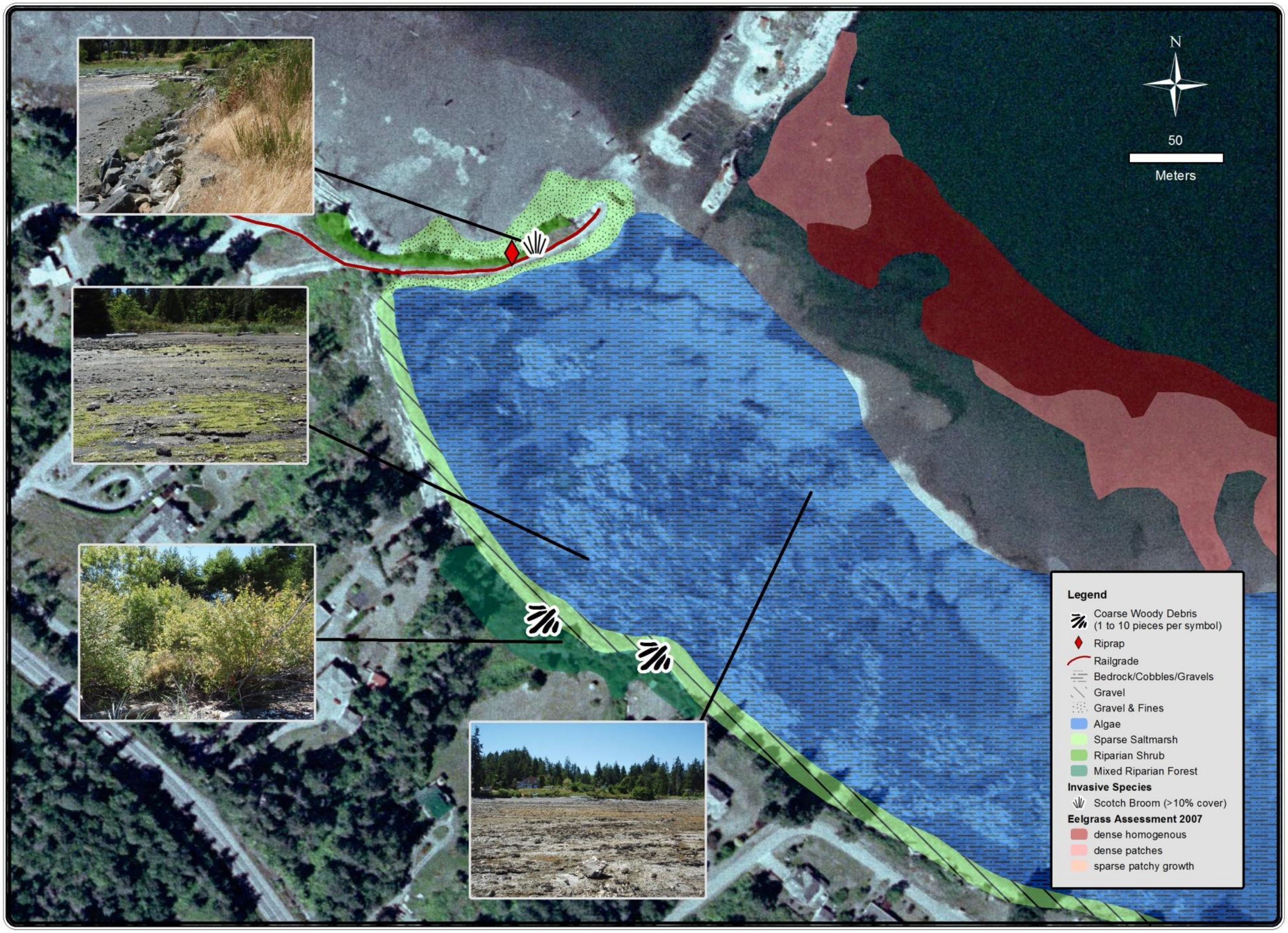
Map 10: Habitat map of the Millard estuary (site 5).



Map 11: Habitat Map of the Royston shoreline north of Royston Wrecks.



Map 12: Habitat map of the Royston shoreline south of Royston Wrecks.



APPENDIX 2: FIGURES

Figure 1: Basic ecosystem based management (EBM) model (adapted from Meffe et al, 2002). The green circle indicates where this study fits into this management system approach.

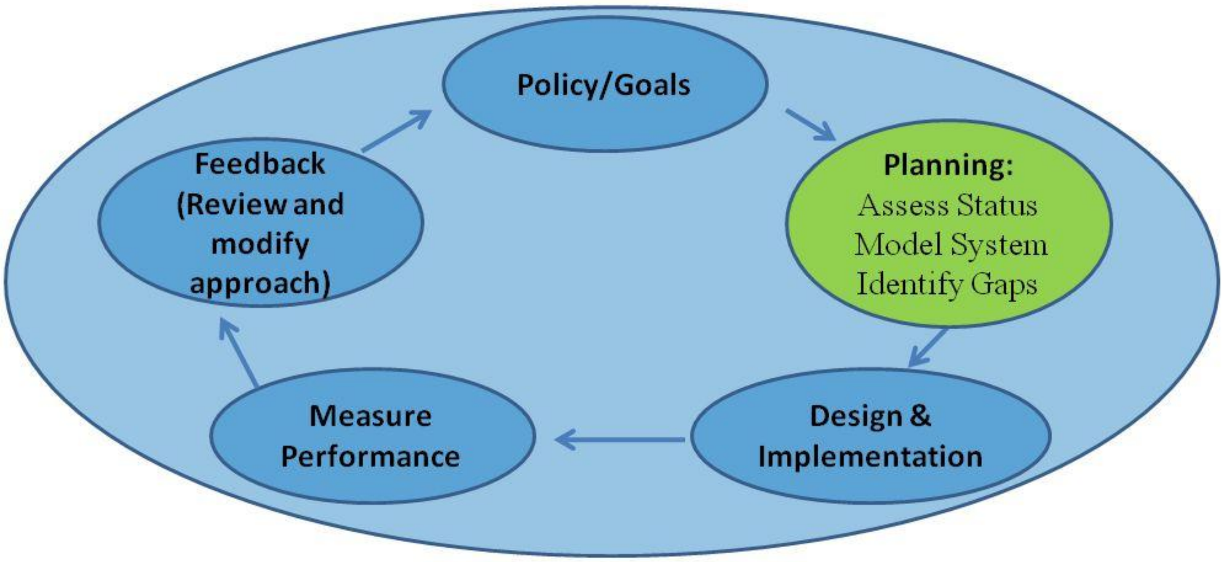


Figure 2: Catch Per Unit Effort by site for chinook (fry and smolt stages) captured over the 2010 sampling season.

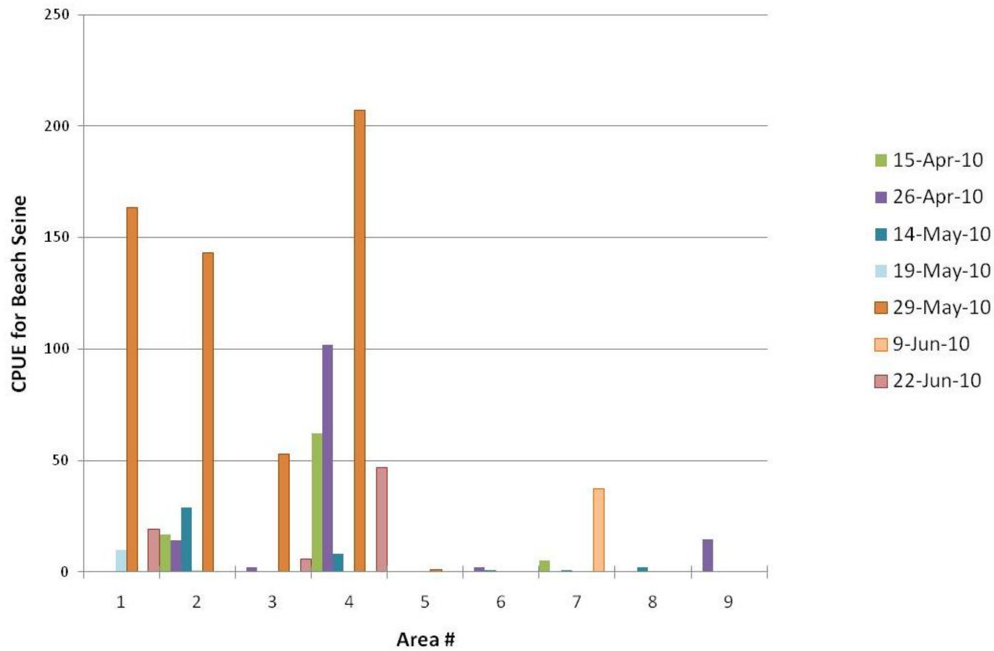


Figure 3: Catch Per Unit Effort by site for coho (fry and smolt stages) captured over the 2010 sampling season.

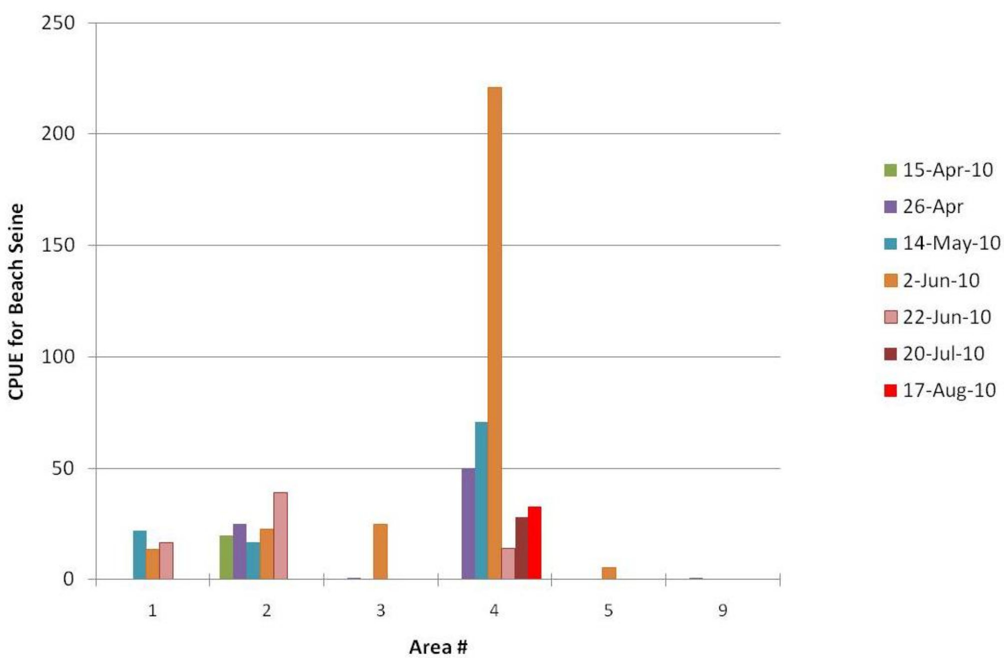


Figure 4: Relative captures of fish throughout March 30 to Aug 19, 2010 sampling period in the estuary.

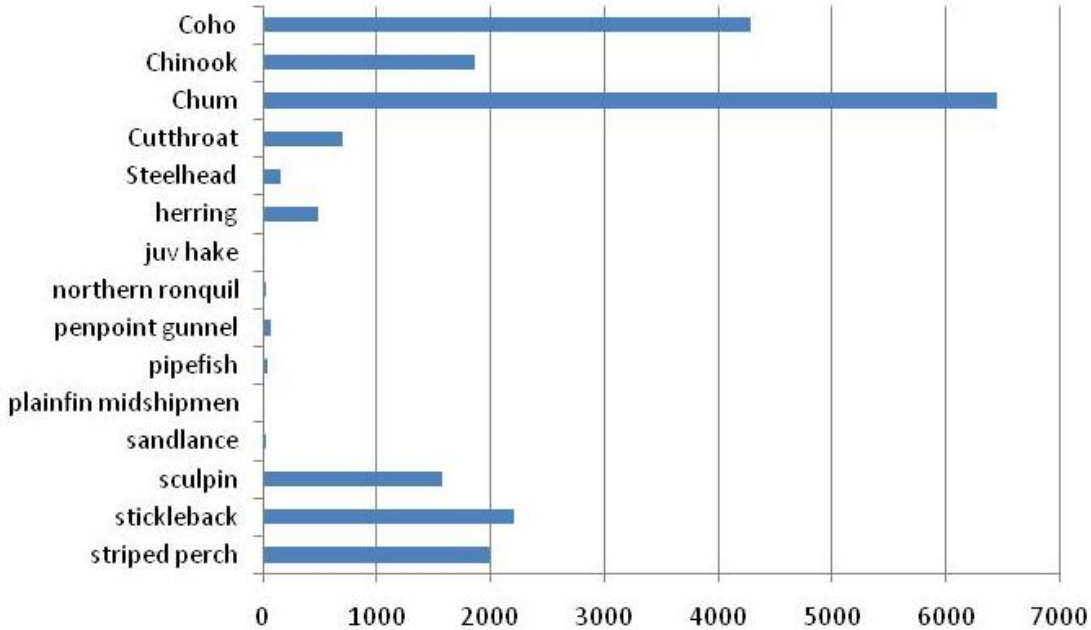


Figure 5: Length frequency chart of chinook captured in the estuary in 2001.

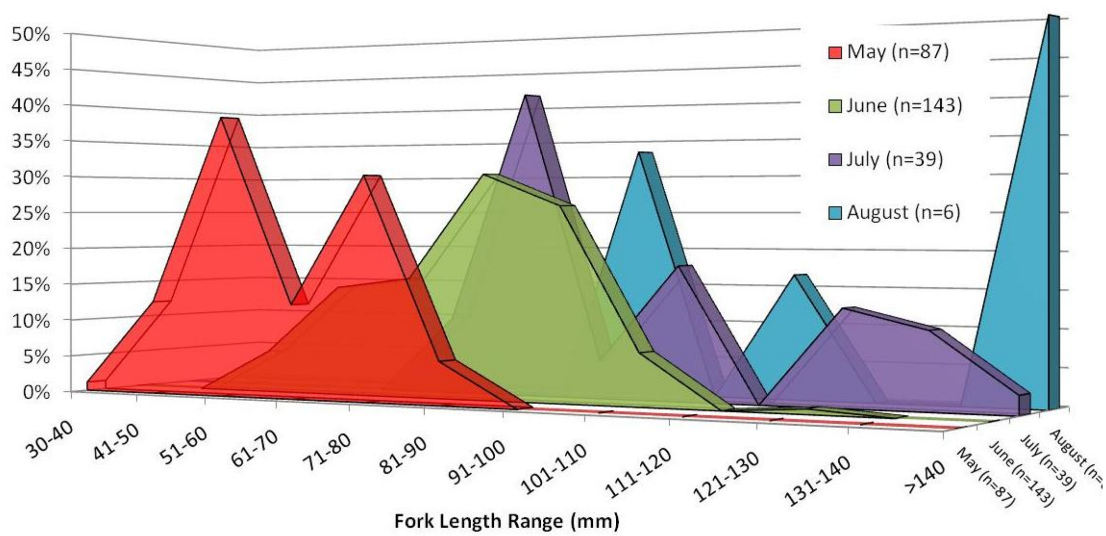


Figure 6: Length frequency chart of chinook captured in the estuary in 2010.

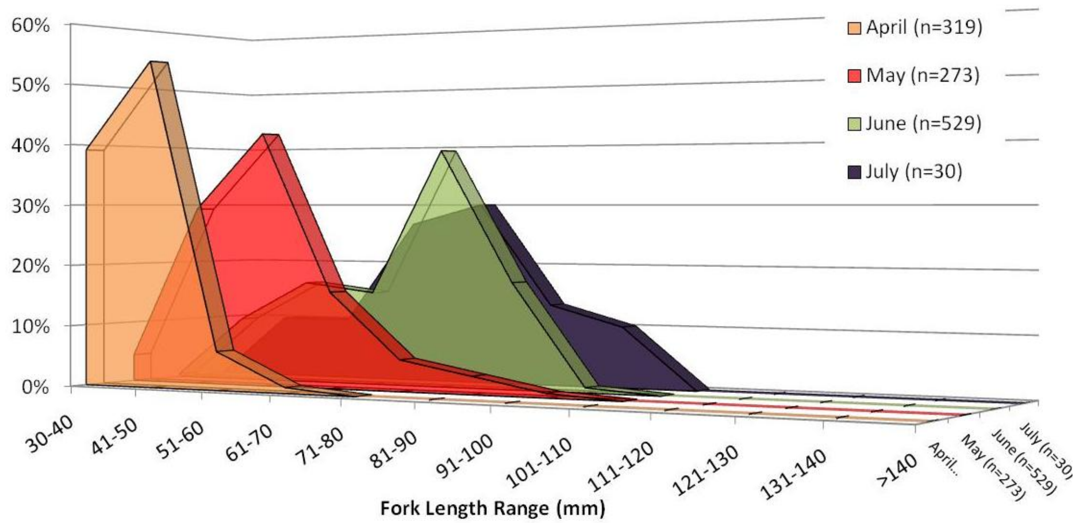


Figure 7: Box Plots comparing median fork lengths of chinook (CN) and coho (CO) cohorts sampled in 2001 and 2010. Size ranges were determined using length frequency analysis. Box plots indicate the max and minimum size ranges for each cohort, the boxes indicate the lower and upper 25th and 75th percentiles within which the majority of fish fork lengths reside, with the intersecting line indicating the median fork length for each cohort. Only samples with sufficient sample size were shown. Cohorts two and three were assumed to represent fry stages, while cohort one represented smolt stages for each species.

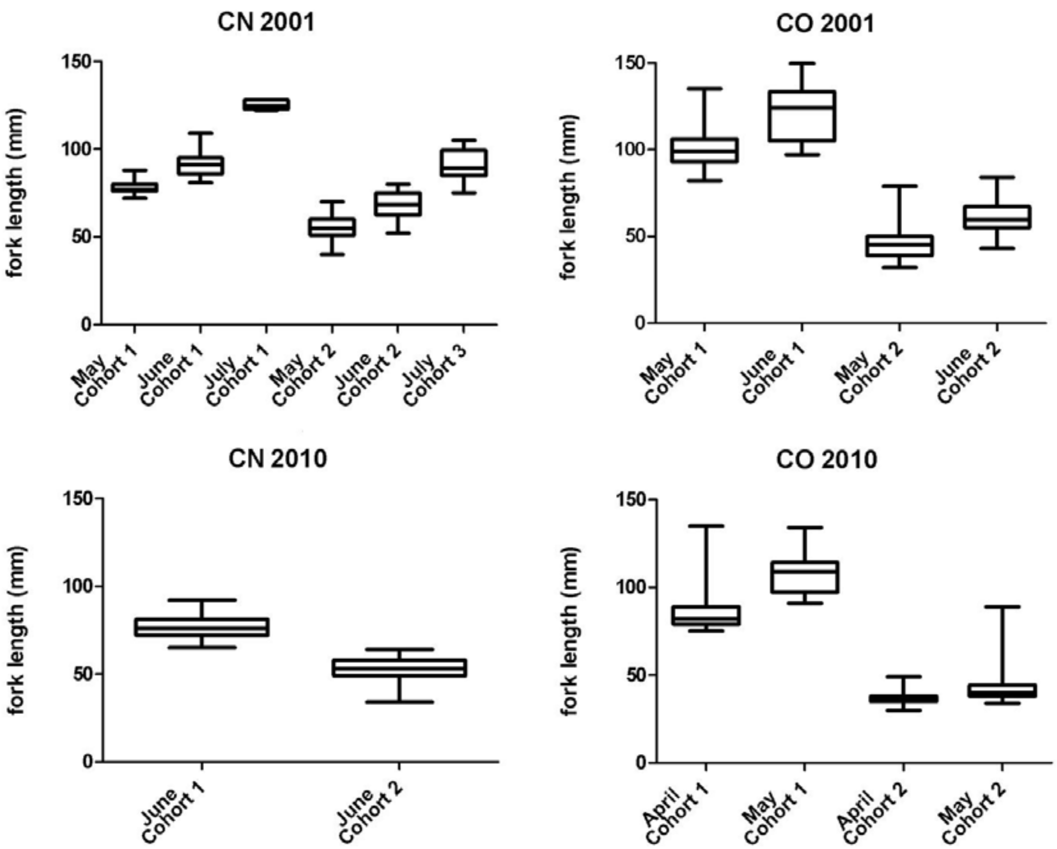


Figure 8: Composition of food items found in benthic habitats sampled in 2010.

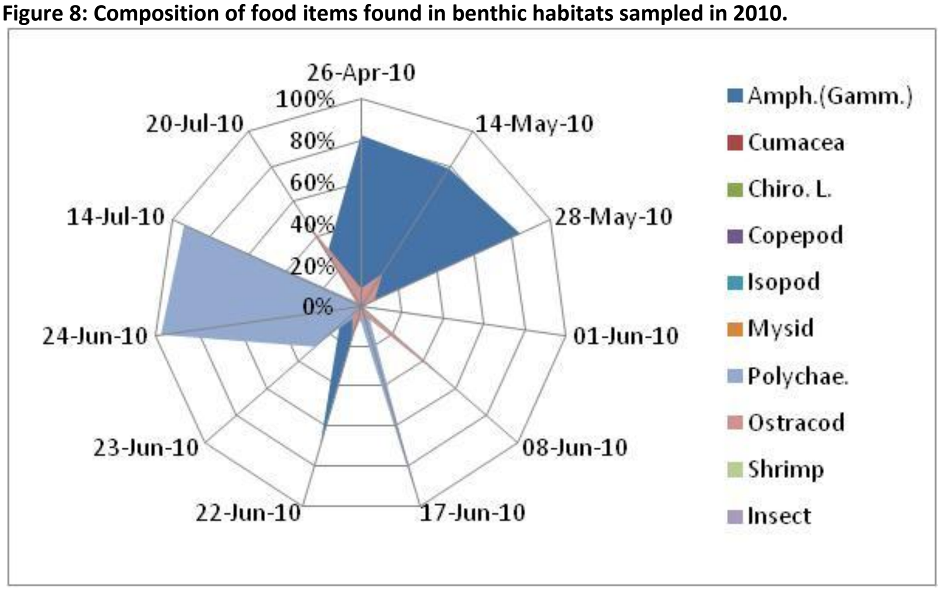


Figure 9: Strauss Index of forage selectivity for chinook fry in the Dyke Slough in 2010. Increasing negative values indicate increasing avoidance of the prey, and increasing positive values indicate increasing prey preference. Zero indicates random foraging without selection.

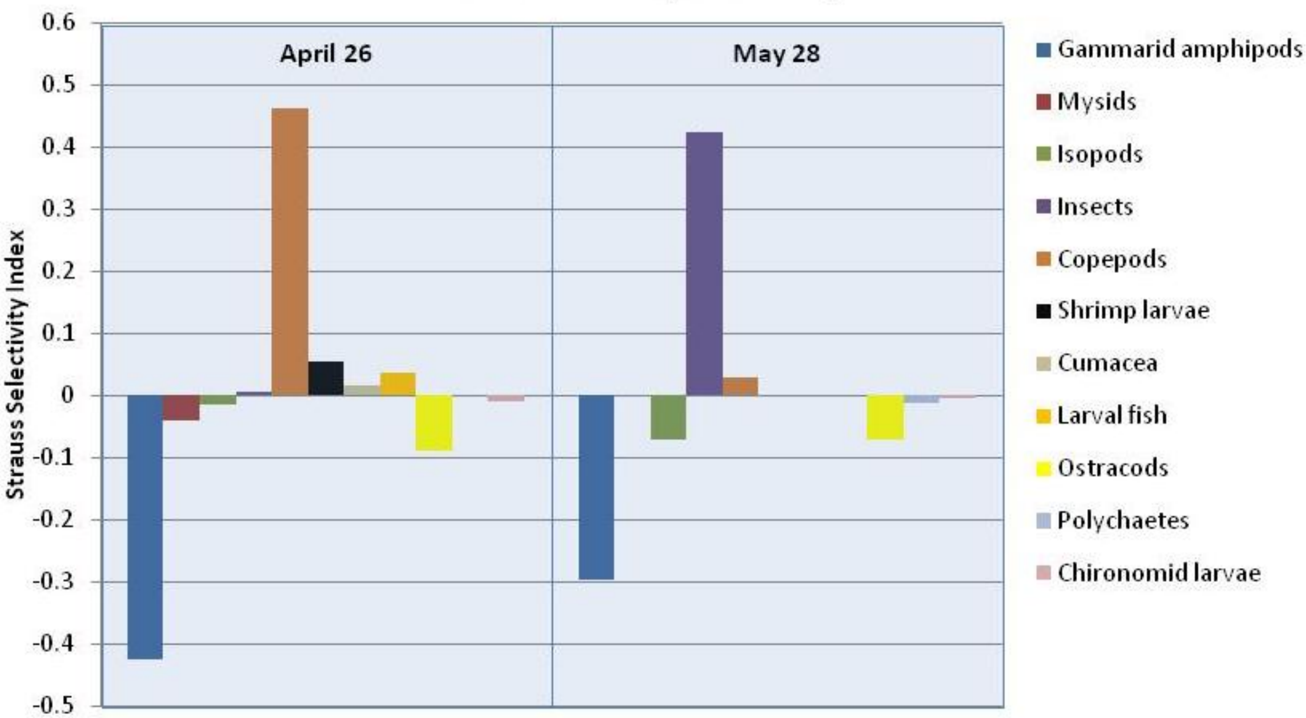


Figure 10: Strauss Index of forage selectivity for coho fry and smolts in the Dyke Slough in 2010. Increasing negative values indicate increasing avoidance of the prey, and increasing positive values indicate increasing prey preference. Zero indicates random foraging without selection.

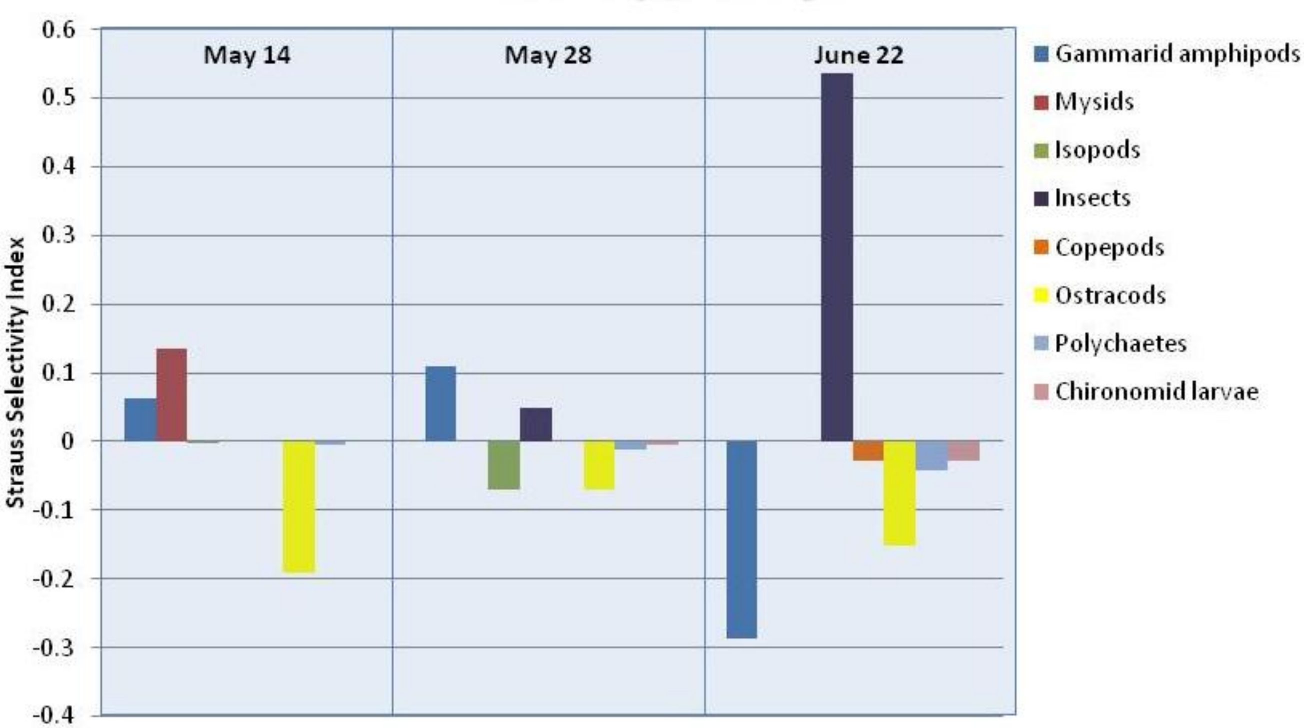


Figure 11: Seasonal temperatures and associated tide heights by Area during 2010 fish sampling. Purple lines indicate optimal forage temperatures for chinook and coho, red bands indicate lethal levels (from Bjornn & Reiser, 1991).

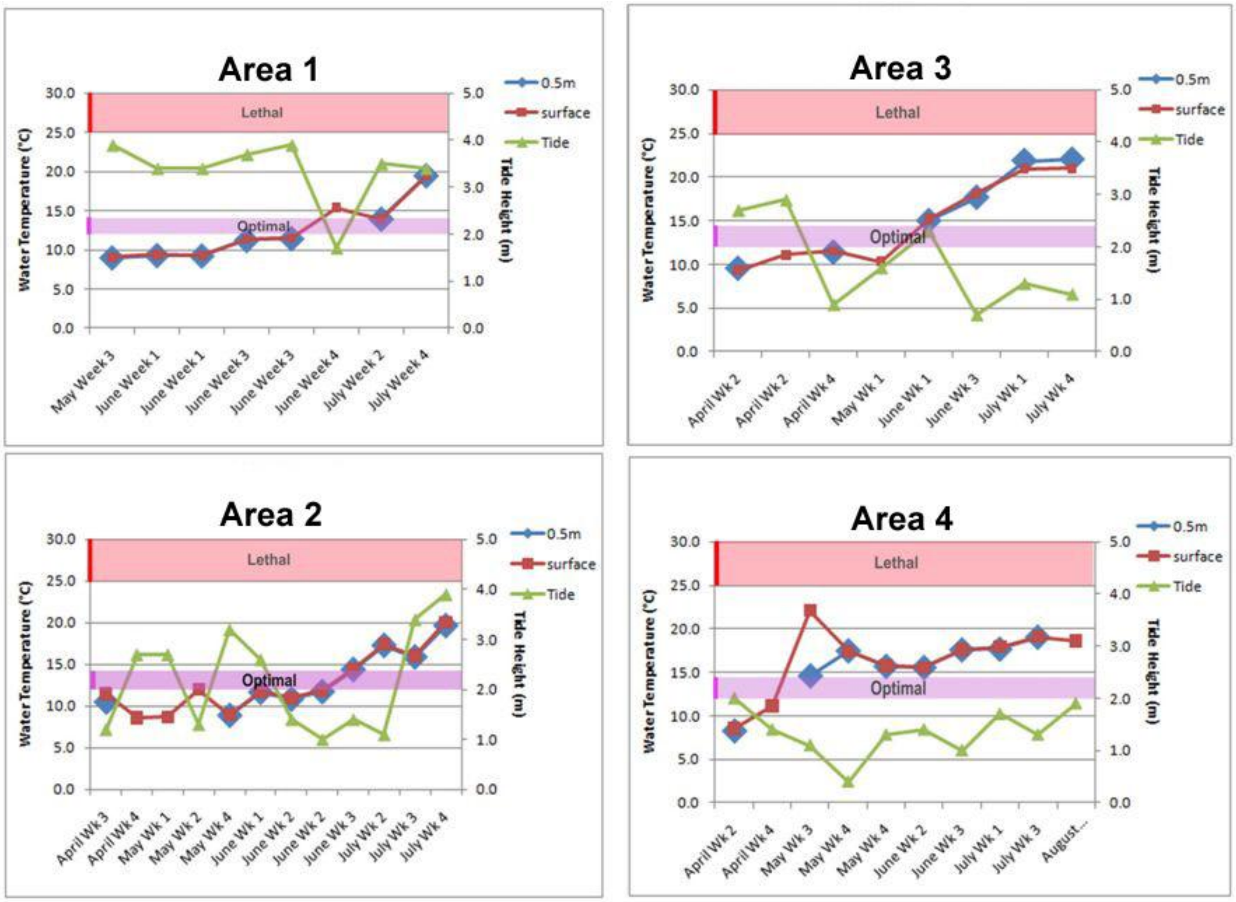


Figure 12: Comparison of 2001 and 2010 surface temperatures in Area 4. Tide ranges when temperatures were collected are provided in Table 4.

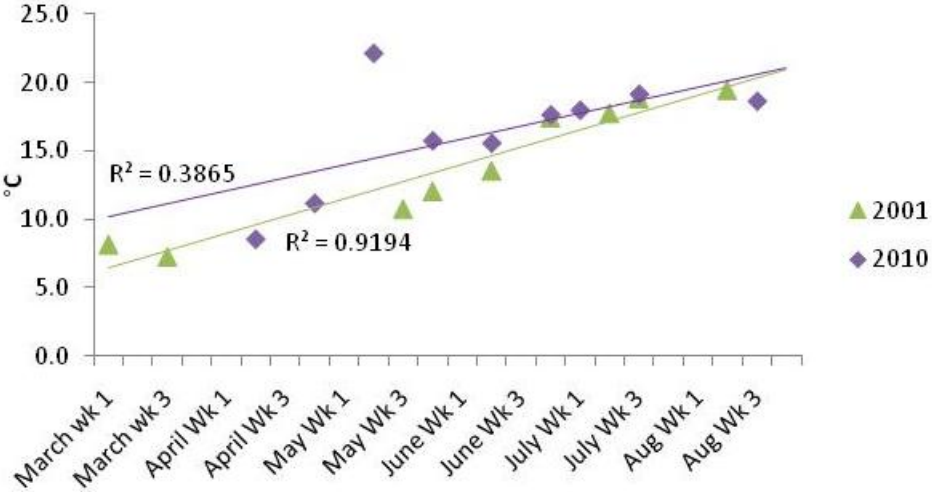


Figure 13: Comparison of 2001 and 2010 surface temperatures in Area 6. Tide ranges when temperatures were collected are provided in Table 4.

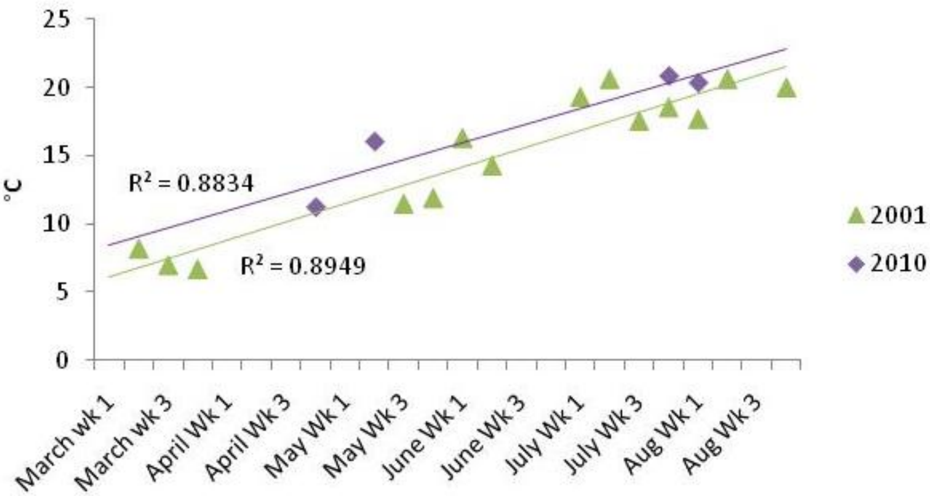


Figure 14: Chinook fry (cohort 2) growth rates for 2010 sampling by Area.

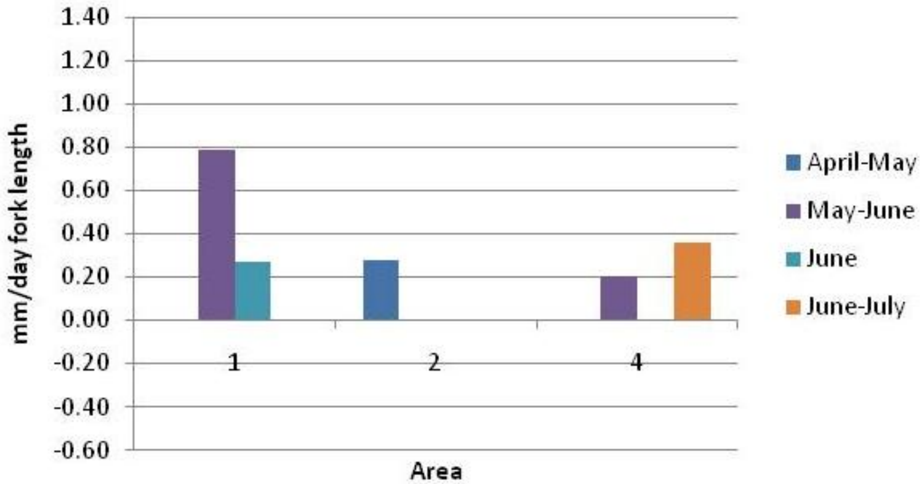


Figure 15: Coho fry (cohort 2) growth rates for 2010 sampling by Area.

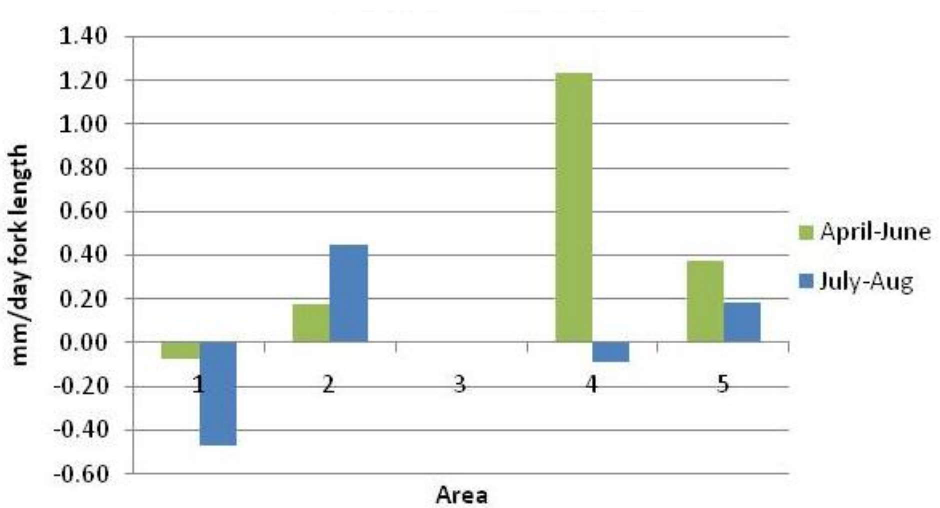


Figure 16: Comparison of between-site condition factors for chinook fry (cohort 2) in 2010 (site numbers = area numbers).

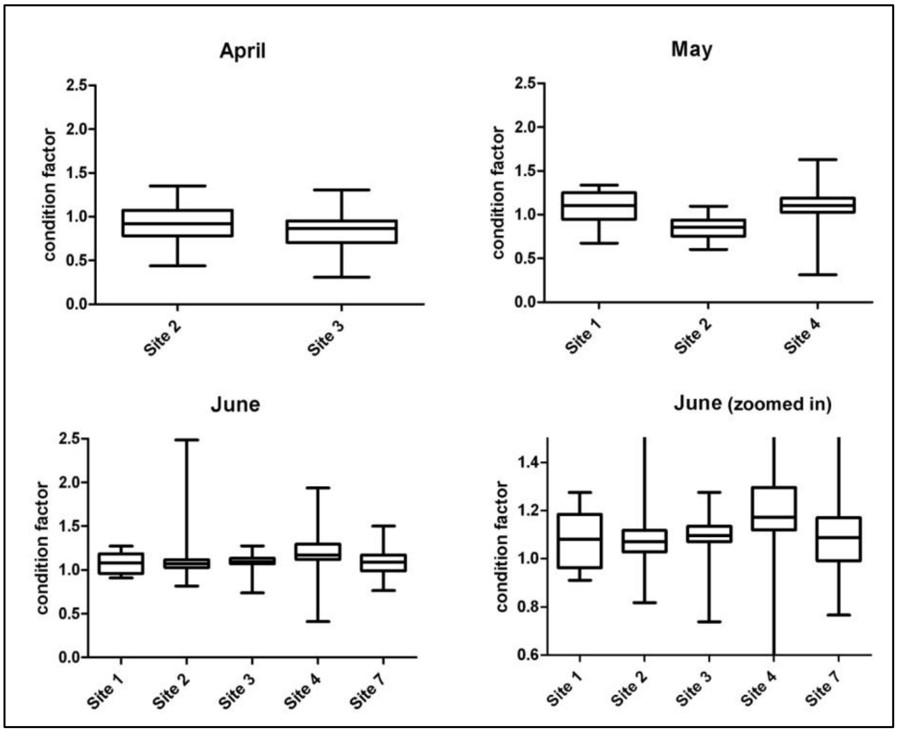


Figure 17: Comparison of between-site condition factors for coho fry (cohort 2) in 2010 (site numbers = area numbers).

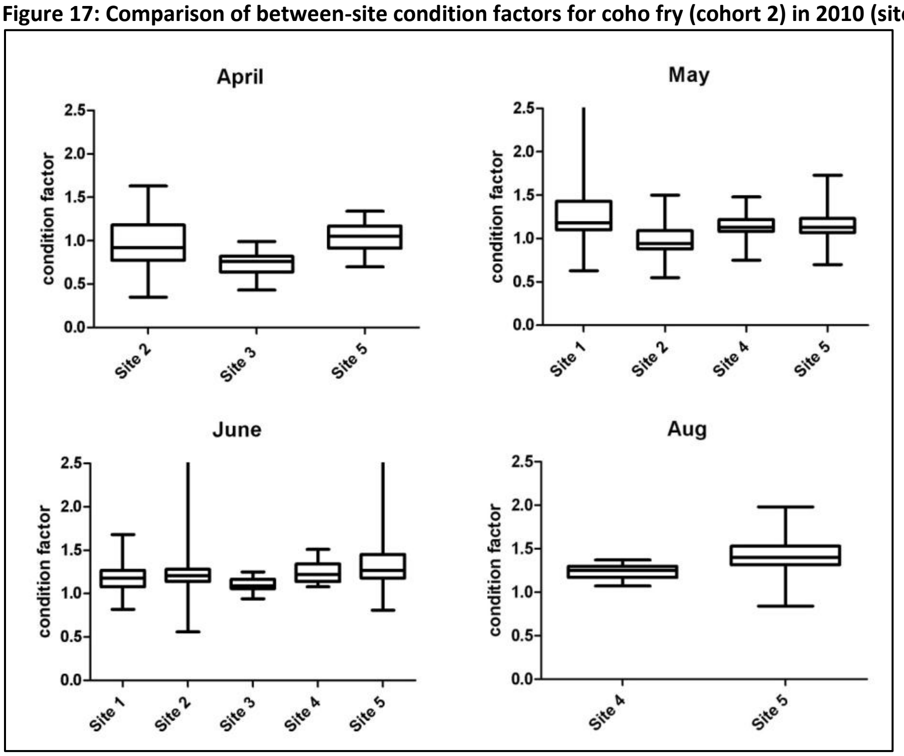


Figure 18: Comparison of mean fork lengths of coho fry captured in lower river (Condensory, Mallard and Glenn Urquhart) and estuary sites in July, 2010.

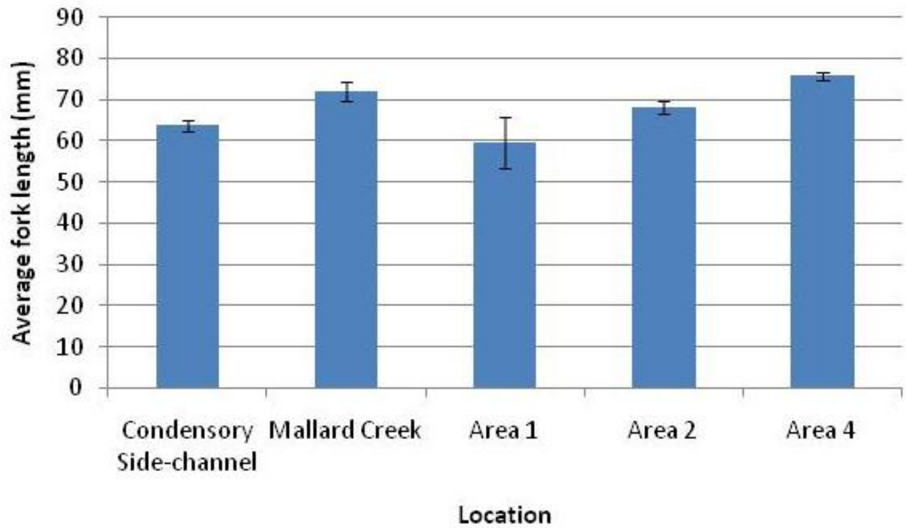


Figure 19: Comparison of mean fork lengths of coho fry captured in lower river (Condensory, Mallard and Glenn Urquhart) and estuary sites in August, 2010.

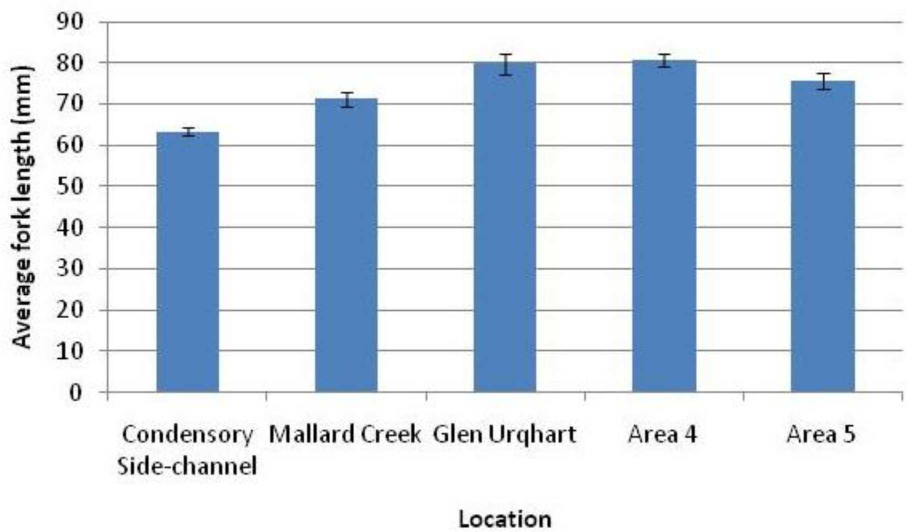


Figure 20: Salmon fry/smolt densities and trout densities estimated for the upper ecotone from snorkel observations in 2010.

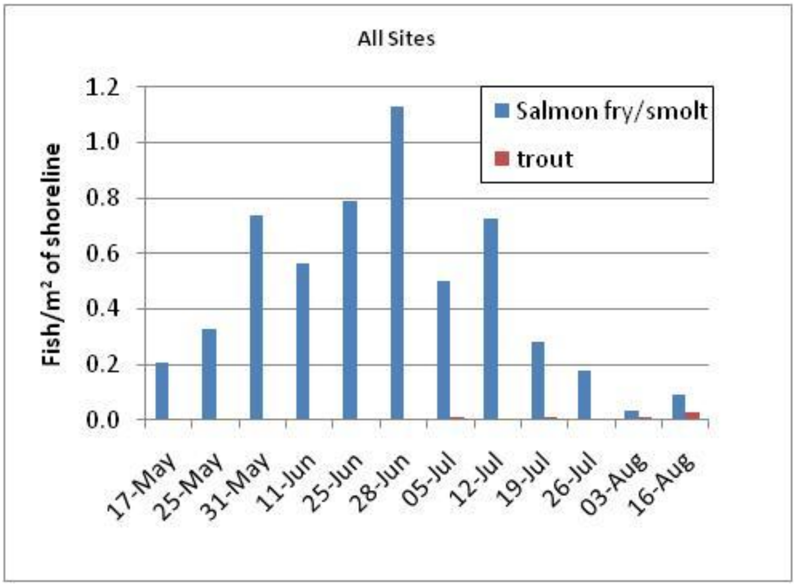


Figure 21: Site comparisons of vegetation found at seven sites mapped in August, 2010.

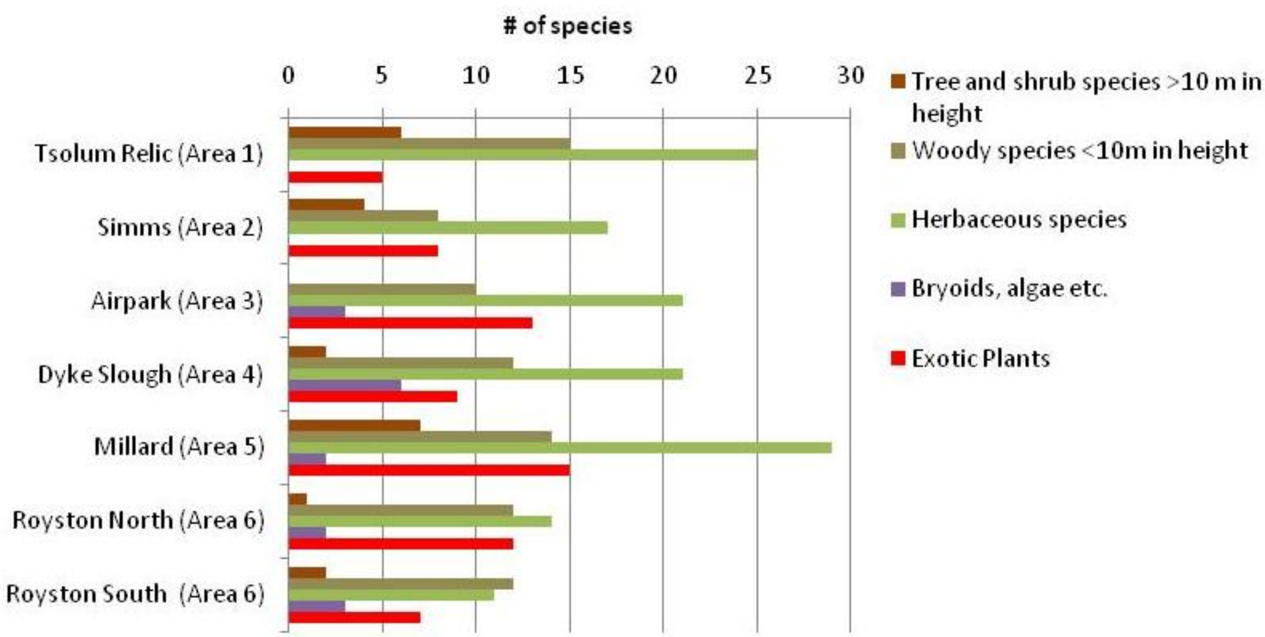


Figure 22: Concept Model for Restoration Options provided in Appendix 6.

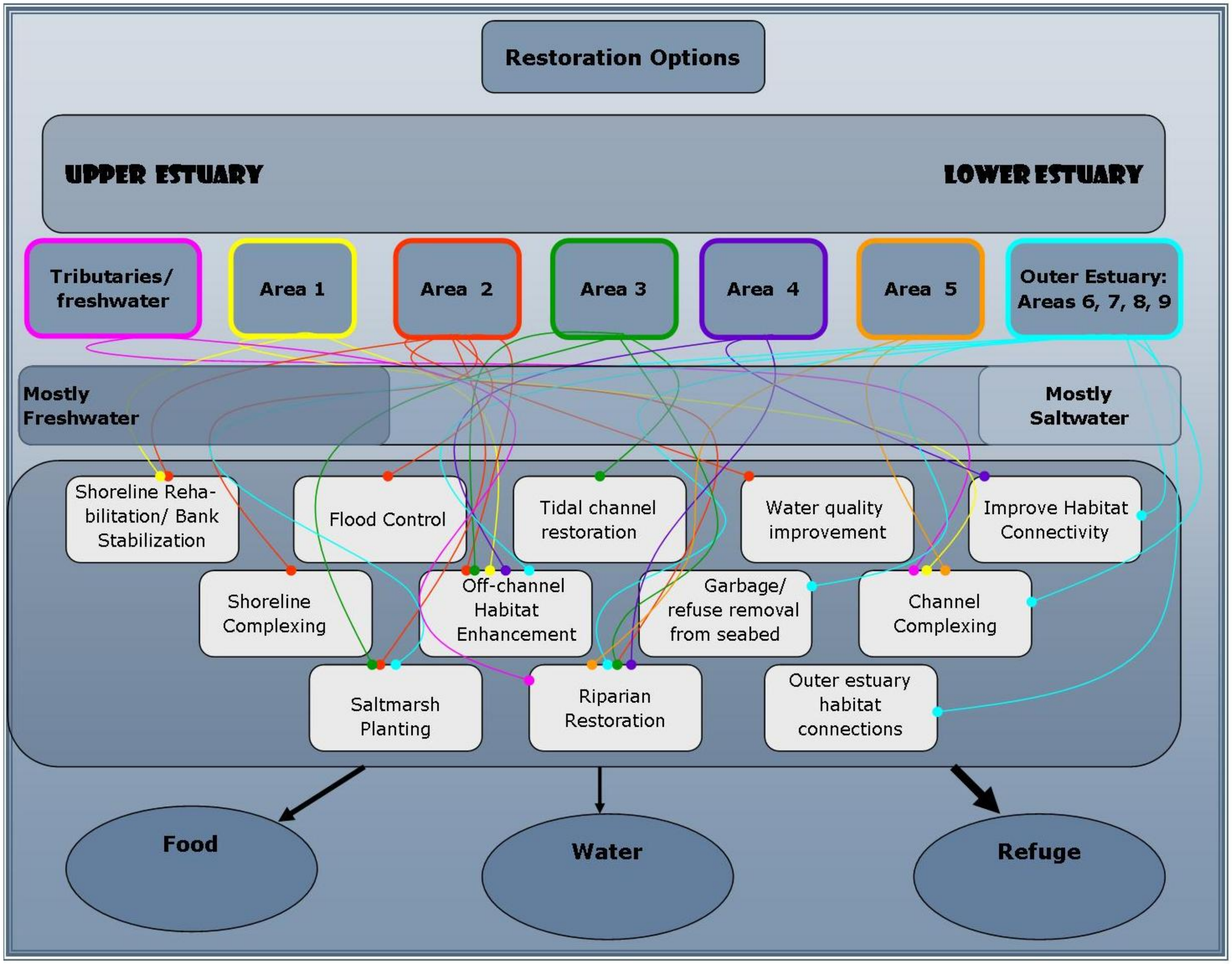
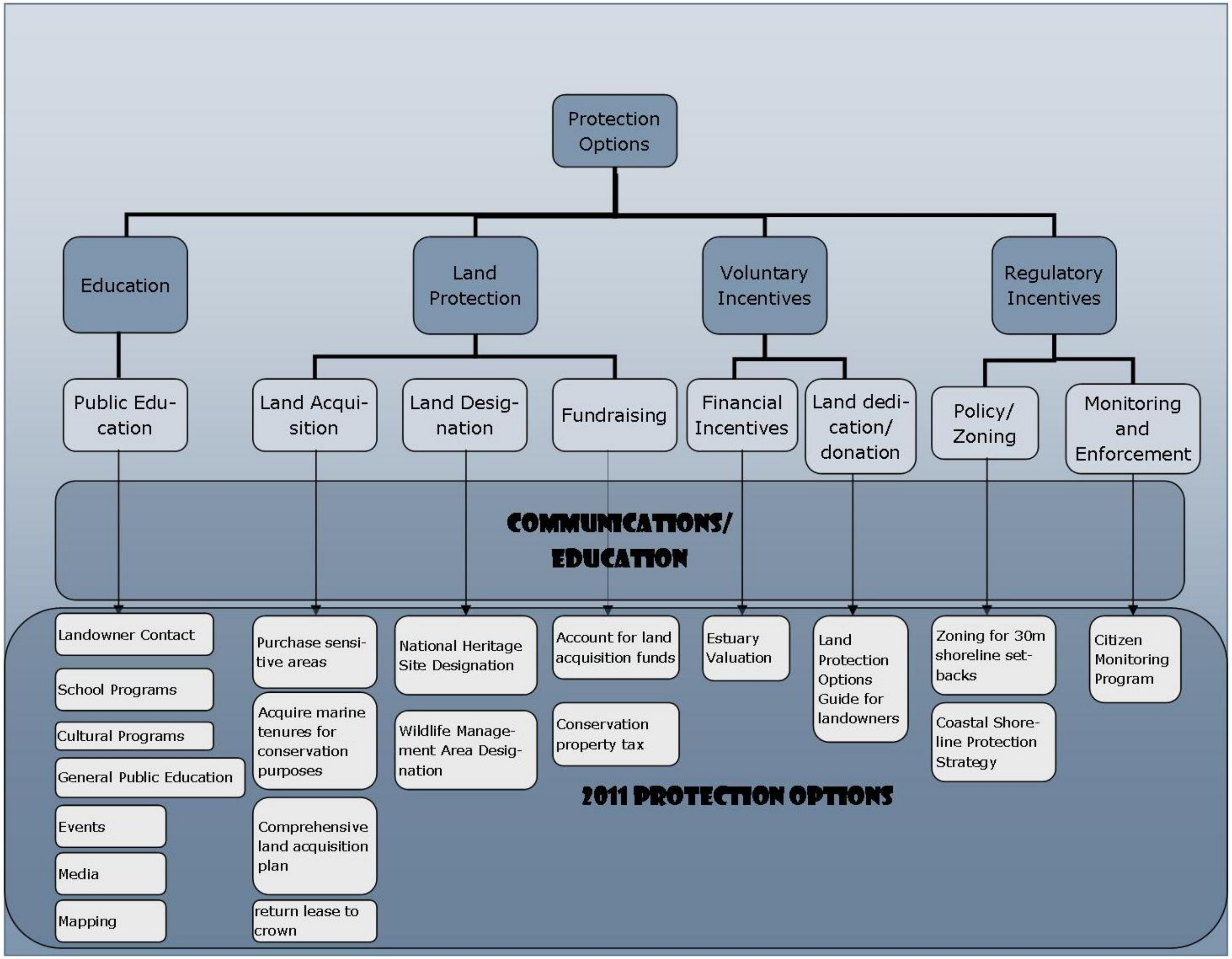


Figure 23: Concept Model for Protection Options provided in Appendix 7.



APPENDIX 3: TABLES

Table 1: Sites sampled and habitat notes for 2010 estuary sampling. Site locations can be found on Maps 2 and 3 of this report.

Area #	2010 site names	Site Description	Habitat Notes	Vegetation Map #
1	A	Tsolum/Puntledge Confluence	Sandy/gravel point bar immediately downstream of confluence. High usage in summer by recreational swimmers.	
1	1a	Tsolum Relic Channel near river mainstem	Shallow sand/mud habitat with riparian shrub and wet meadow. Complex habitat with LWD, alcoves, slow water next to swifter mainstem.	Map 4
2	1b	Lewis Bend	Concrete wall along shoreline, sparse riparian vegetation, cobble/sand substrate with relic pilings, immediately downstream of relic channel outflow. Location of dense fish observations during 2010 snorkel surveys	Map 4
2	1c	Courtenay River - d/s corner of central builders on right bank	near concrete bulkhead for Central Builders. Sparse riparian habitat, some sedges.	
2	2a	Courtenay Slough marina (Simms Park)	Shallow sloping shoreline, mostly mud. Heavy summer algae growth. Riparian vegetation, dock and pilings for marina. Freshwater seepage through gravel/mud substrate throughout length of slough. High captures of coho early in season, some chinook fry.	Map 5
2	2b	Simms Park Finger	Constructed channel with anchored LWD. Sparse sedge habitat along margins, deep slow moving water. Small numbers of coho captured near entrance to the river, mostly stickleback further up.	Map 5
2	2c	Simms pond	Constructed pond with anchored LWD. Sparse sedge habitat along margins. Isolated at low tides. Thick mud, noted infilling since original construction (2001). High numbers of coho captured here in December.	Map 5
2	2d	Simms at mouth of Slough	Moderately sloping thick wet meadow/sedge habitat. LWD clusters nearby. Near influence of main river.	Map 5
2	2e	Courtenay River - various locations between Simms Park and 17th sty. street bridge	High tide sampling along river margin in slow-water alcoves bordered with sedge benches and riparian vegetation.	
3	3	Lagoon	Deep water habitat with brackish sedge habitat along margins. Gravels and fines throughout most of lagoon. Tidal channel outflow with sand and cobbles.	(adjacent to Lagoon- Map 6)
4	4	Dyke Slough pool below tide gates.	Deep water habitat with eelgrass and brackish marsh habitats. Freshwater influence from above tide gates.	Map 7
4	4a	Dyke Slough tidal channel	Tidal channel with substrate of fines/mud bordered by brackish marsh habitat. Fish concentrated near scour pools created from LWD.	Map 7
5	5	Millard estuary. Includes ~240 m of tidal channel	Riffle/pool habitat along ecotone with gravels and fines with infrequent LWD. Large saltmarsh habitat along right bank, dense overhanging riparian along left bank. Deep pool at mouth before mudflats.	Map 8
6	10a	South side of Royston Pier (south-east of Roy Creek)	Gently sloping sandy/mud habitat over dense eelgrass.	Map 9 (north of this site on other side of wrecks- Map 10)
6	10b	Roy Creek estuary channel	fine sands and mud, sparse LWD.	Map 9
6	10c	Immediately south of Royston wrecks	Dense eelgrass at low tide over sandy/cobble habitat.	Map 9
7	7a	Beach with freshwater stream west of the Comox Marina	Sandy/gravel substrate over gentle slope. Small freshwater influence near tidal channel outflow at low tide. Eelgrass beds further offshore, but not directly at sample site.	
8	8	Mouth of river where it drops off south of Comox marina	eelgrass habitat along shallow sandy slope adjacent to mainstem Courtenay river where it enters the subtidal.	
9	9	Brooklynn Crk estuary tidal channel at low tide	Sandy, gently sloping habitat. Small freshwater influence near tidal channel outflow at low tide.	
Lower River	CSC	Condensory side-channel	margins of side-channel and small alcoves with small woody debris, sandy substrate and overhanging riparian vegetation	
Lower River	MC	Mallard Creek	Small Creek (~1-2m channel width) with scour pool habitat, dense riparian vegetation, and some open pond habitat.	
Lower River	GU	Glenn-Urquhart Creek	Wide constructed, low gradient open channel with muddy substrate. Little riparian vegetation: mostly grasses and Himalayan blackberry. Small section of creek with higher gradient downstream of Williams Rd., with gravel/cobble habitat and overhanging riparian vegetation.	

Table 2: Tag retention test at Puntledge Hatchery

Date Tagged	April-01-10
Time	12:30
Date recovered	April-09-10
Time	12:00
Species:	CN

Colour	# Tagged	# Recovered
Yellow	39	47
Red	47	53
Not tagged	50	39
morts	1	0
Totals	137	139

Table 3: Ecological assessment criteria and habitat attribute association used to characterize the habitat requirements of juvenile coho and chinook salmon in the Courtenay River estuary.

Survival success criteria	Measures	Habitat Association
Fish presence	CPUE (beach seine)	Opportunity
Life history composition	Cohort (size class) analysis	Opportunity
Proximately to migration routes	Distance from FW	Opportunity
Diet	Stomach content analysis	Capacity
	Diet overlap with invertebrate assemblage	Capacity
Water quality	optimal temperatures	Capacity
Growth	Growth rate	Realized Function
	Condition factor	Realized Function
Residence time	Mark/recaptures	Realized Function
Density	Snorkel counts	Realized Function

Table 4: Summary of tide ranges that occurred during sampling events when temperatures were collected to compare 2001 and 2010 seasonal trends (refer to Figure 12 and 13).

	Site 4		Site 6	
	2001	2010	2001	2010
Avg (m)	2.7	1.5	3.0	1.4
Max (m)	3.2	2.0	4.4	2.1
Min (m)	1.3	1.0	0.8	0.5
Std Dev (m)	0.7	0.3	1.1	0.7
N	10	9	19	4

Table 5: Summary of locations and dates where habitat mapping occurred. Details of exact locations provided in Table 1 , Map 3 and Map 4.

Location	Date Sampled
Tsolum Relic Channel	July 27th, 2010
Simms Park	July 27th, 2010
Courtenay Airpark	July 19 & 21, 2010
Dyke Slough below tide gates	July 23rd, 2010
Millard Creek estuary	July 21st, 2010
Royston Wrecks: north	July 23rd, 2010
Royston Wrecks: south	July 23rd, 2010

Table 6: Comparison of central tendencies of fork length (mm) for chinook salmon cohorts captured in Courtenay River estuary in 2001, compared to marked hatchery captures.

	June Cohort 2	June Cohort 1	June Hatchery CN
Number of values	52	91	17
Minimum	52	81	70
25% Percentile	62.5	86	98
Median	68.5	91	89
75% Percentile	75	95	83
Maximum	80	109	117
Mean	68.69	91.49	90.76
Std. Deviation	7.848	6.578	12.88
Lower 95% CI of mean	66.51	90.12	84.64
Upper 95% CI of mean	70.88	92.86	96.89

Table 7: Statistical summary of cohort fork length analysis for chinook (CN) and coho (CO) in 2001 indicating significant (P<0.05) differences in size classes.

						Mann-Whitney		Unpaired t-test	
Species/Month	Cohort A vs B	Test	P value	Are medians signif. different? (P < 0.05)	Are means signif. different? (P < 0.05)	Sum of ranks cohort A	Sum of ranks cohort B	t-ratio	DF
CN May	**1** vs **2**	Mann-Whitney	< 0.0001	Yes	-	2232	1596	-	-
CN June	**1** vs **2**	unpaired t-test	< 0.0001	-	yes	-	-	18.57	141
CN July	**1** vs **3**	Mann-Whitney	< 0.0001	Yes	-	189	406	-	-
CO May	**1** vs **2**	Mann-Whitney	< 0.0001	Yes	-	18250	3486	-	-
CO June	**1** vs **2**	Mann-Whitney	< 0.0001	Yes	-	635	1711	-	-

Table 8: Statistical summary of cohort fork length analysis for chinook (CN) and coho (CO) in 2010 indicating significant (P<0.05) differences in size classes.

						Mann-Whitney		Unpaired t-test	
Species/Month	Cohort A vs B	Test	P value	Are medians signif. different? (P < 0.05)	Are means signif. different? (P < 0.05)	Sum of ranks cohort A	Sum of ranks cohort B	t-ratio	DF
CN June	**1** vs **2**	unpaired t-test	< 0.0001	Yes	yes	-	-	18.57	141
CO April	**1** vs **2**	Mann-Whitney	< 0.0001	Yes	-	47945	5356	-	-
CO May	**1** vs **2**	Mann-Whitney	< 0.0001	Yes	-	5226	2775	-	-

Table 9: Description of Areas and associated sampling sites described in this report and depicted in Map 2.

Area #	Description	2010 Sampling Sites
1	Upper Ecotone	Tsolum Relic Channel, Tsolum/Puntledge Confluence
2	Mid Ecotone	Simms Park: slough and mouth, pond & finger, Main River channel, various locations
3	Lower Ecotone	Lagoon
4	Inner Estuary: North Shore (main river channel)	Dyke Slough channel and pool below gates
5	Inner Estuary: South Shore	~240 m of tidal channel and pool at mouth
6	Outer Estuary: South Shore	mouth of freshwater tidal channel, Eelgrass beds between Wrecks and Roy Creek tidal channel
7	Outer Estuary North Shore	mouth of freshwater tidal channel
8	Lower Estuary: Intertidal/subtidal Transition	Main river channel at bottom of mudflats
9	Goose Spit: Inside	mouth of freshwater tidal channel

Table 10: Dominant, sub-dominant, and other prominent food items found in the guts of fish sampled in the Courtenay River estuary during 2010 (CN=chinook, CM=chum, CO=coho, RT=rainbow trout, CT=cutthroat trout).

Place	Month	Species	Dominant food item	Sub dominant food item	Other
Dyke Slough	April	CN fry- April	Gammarid amphipods	copepods	shrimp, cumacea, larval fish
Dyke Slough	April	CM- April	copepods	Gammarid amphipods	euphasids, cumacea
Dyke Slough	May	CO smolt- May	Gammarid amphipods	Mysids	isopod
Dyke Slough	May	RT-May	Gammarid amphipods	Insects	mysids
Dyke Slough	May	CT-May	Isopods		Gammarid amphipods
Dyke Slough	May	CN-May-smolt	Gammarid amphipods		
Dyke Slough	May	CN-May-fry	Insects		Gammarid amphipods
Dyke Slough	May	CO- may cohort 2	Insects	Gammarid amphipods	
Dyke Slough	June	Co June	Insects	Gammarid amphipods	
Tsolum Relic	June	CN fry June	Insects		fish eggs
Simm's Slough	July	Co July	Insects		

Table 11: Estimated growth rates of chinook fry (cohort 2) during 2010 sampling period.

Area								
Area 1	Date:	19-May		02-Jun		17-Jun		
	Growth Rate (mm/day)		0.79		0.27			
Area 2	Date:	15-Apr		24-Apr		12-May		
	Growth Rate (mm/day)		0.00		0.28			
Area 4	Date:	14-May		27-May		22-Jun		20-Jul
	Growth Rate (mm/day)		-0.31		0.31		0.36	

Table 12: Estimated growth rates of coho fry (cohort 2) during 2010 sampling period.

Area														
Area 1	Date:	19-May		02-Jun		16-Jun		13-Jul		27-Jul				
	Growth Rate (mm/day)		-0.79		0.64		0.63		-1.57					
Area 2	Date:	15-Apr		24-Apr		05-May		12-May		03-Jun		24-Jun		14-Jul
	Growth Rate (mm/day)		-0.11		0.09		0.29		0.23		0.38		0.45	
Area 3	Date:	13-Apr		04-Jun										
	Growth Rate (mm/day)		0.00											
Area 4	Date:	27-May		22-Jun		06-Jul		20-Jul		17-Aug				
	Growth Rate (mm/day)		0.35		1.43		-0.50		0.32					
Area 5	Date:	23-Apr		06-May		15-Jun		19-Aug						
	Growth Rate (mm/day)		0.23		0.53		0.18							

Table 13: Statistical summary of chinook (CN) (cohort 2) condition factors in 2010.

Species/Month	Sites Analyzed	Test	P value	Are medians signif. different? (P < 0.05)	Are means signif. different? (P < 0.05)	Number of groups	Kruskal-Wallis Statistic	Unpaired t-test t-ratio	Unpaired t-test DF
CN April	2, 3	Unpaired t test	0.0425	-	yes	2		1.747	73
CN May	1, 2, 4	Kruskal-Wallis	< 0.0001	Yes	-	3	56.39	-	-
CN June	1, 2, 3, 4, 7	Kruskal-Wallis	< 0.0001	Yes	-	5	43.42	-	-

Table 14: Statistical summary of coho (CO) (cohort 2) condition factors in 2010.

Species/Month	Sites Analyzed	Test	P value	Are medians signif. different? (P < 0.05)	Are means signif. different? (P < 0.05)	Number of groups	Kruskal-Wallis Statistic	One-Way ANOVA F-ratio	One-Way ANOVA R square	Mann-Whitney Sum of ranks (one-tailed)
CO April	2, 3, 5	One-way analysis of variance	0.0008	-	Yes	3	-	7.61	0.1344	-
CO May	1, 2, 4, 5	Kruskal-Wallis	< 0.0001	Yes	-	4	33.62	-	-	-
CO June	1, 2, 3, 4, 5	Kruskal-Wallis	< 0.0001	Yes	-	5	56.46	-	-	-
CO Aug	4, 5	Mann Whitney test	< 0.0001	Yes	-	2	-	-	-	503 , 3413

Table 15: Estimated residence times in 2010 for chinook (CN) and coho (CO) fry recaptures in 2010.

Species	Source	Destination	Recovery Date	Potential tagging dates	Residence time range (days)
CO	Area 2 (Courtenay Slough)	Area 2 (Courtenay Slough)	12-May	15-Apr, 24-Apr, 5-May	8-28
CO	Area 2 (Courtenay Slough)	Area 2 (Courtenay Slough)	12-May	15-Apr, 24-Apr, 5-May	8-28
CO	Area 2 (Courtenay Slough)	Area 2 (Courtenay Slough)	03-Jun	15-Apr, 24-Apr, 5-May, 12-May	23-50
CO	Area 2 (Courtenay Slough)	Area 2 (Courtenay Slough)	03-Jun	15-Apr, 24-Apr, 5-May, 12-May	23-50
CN	Area 2 (Courtenay Slough)	Area 4 (Dyke Slough)	22-Jun	5-May, 12-May, 3-June	20-82
CO	Area 3 (Airpark Lagoon)	Area 4 (Dyke Slough)	07-Oct	13-Apr, 29-Apr, 4-June	125-177
CO	Area 4 (Dyke Slough)	Area 4 (Dyke Slough)	06-Jul	27-May	41
CO	Area 5 (Millard)	Area 5 (Millard)	06-May	23-Apr	14
CO	Area 5 (Millard)	Area 5 (Millard)	19-Aug	23-Apr, 6-May, 29-May, 15-June	66-118

Table 16: General observations from the snorkel surveys conducted during the in 2010. "T" refers to the transect snorkel sites, u/s and d/s refer to upstream and downstream, respectively.

Date	Location	Observation
25-May	between powerlines d/s to 17th st bridge	200 juvenile salmon observed
31-May	~50m u/s snorkel T5	40CNS observed around some LWD
31-May	immediately u/s 17th st bridge	70 CNS observed along RB
11-Jun	between T1 and T2	observations of ~1500+ fry, large CT (12"), 1 adult CN
25-Jun	between T2 and T3	~300+ fish seen in riprap at Lewis Park side of river
28-Jun	on pUN upstream Puntledge/Tsolum confluence	1 adult CN with contusions
28-Jun	between T2 and T3	~500 observations
05-Jul	between T2 and T3	~1500 juvenile salmon observed
19-Jul	T1	1 jack (sp UK) observed
03-Aug	T6	1 adult pink observed
16-Aug	T1	Many tubers/swimmers near site 1
16-Aug	T1	1 pink adult observed
16-Aug	T5	300 perch observed

Table 17: Tsolum Relic Channel plant list.

Tree and shrub species >10 m in height	Woody species <10m	Herbaceous species	Bryoids, algae etc.	Exotic Plants
bigleaf maple	bigleaf maple	American speedwell		European mountain-ash
black cottonwood	black hawthorn	American water-plantain		common St. John's-wort
Cherry	coastal red elderberry	bur-reed		Himalayan blackberry
Garry oak	common snowberry	common silverweed		orchard-grass
Pacific willow	hardhack	cow-parsnip		reed canarygrass
red alder	Pacific ninebark	dock		
	Pacific willow	false bugbane		
	red alder	false lily-of-the-valley		
	red-osier dogwood	mannagrass		
	salmonberry	Pacific bleeding heart		
	Scouler's willow	purple-leaved willowherb		
	Sitka willow	reedgrass		
	thimbleberry	rushes		
	western flowering dogwood	sedges		
	willows	Sitka sedge		
		skunk cabbage		
		slough sedge		
		small-flowered bulrush		
		small-flowered forget-me-not		
		spike-rush		
		springbank clover		
		sweet-scented bedstraw		
		water lobelia		
		water-starwort		
		yellow monkey-flower		

Table 18: Simms Park plant list.

Tree and shrub species >10 m in height	Woody species <10m in height	Herbaceous species	Bryoids, algae etc.	Exotic Plants
Acer macrophyllum	Alnus rubra	Alisma triviale		Fallopia x bohemica
Alnus rubra	Physocarpus capitatus	Athyrium filix-femina		Rubus armeniacus
Populus balsamifera ssp. trichoca	Rosa nutkana	Callitriche sp.		Convolvulus arvensis
Prunus sp.	Rubus parviflorus	Carex spp.		Geranium robertianum
	Rubus spectabilis	Epilobium angustifolium		Hypochaeris radicata
	Sambucus racemosa var. arbores	Equisetum arvense		Mycelis muralis
	Spiraea douglasii ssp. douglasii	Glyceria sp.		Phalaris arundinacea
	Taxus brevifolia	Lysichiton americanus		
		Mimulus guttatus		
		other grasses		
		Polystichum munitum		
		Potentilla anserina		
		Rumex sp.		
		Schoenoplectus tabernaemontani		
		Scirpus microcarpus		
		Stachys chamissonis		

Table 19: Courtenay Airpark plant list.

Tree and shrub species >10 m in height	Woody species <10m	Herbaceous species	Bryoids, algae etc.	Exotic Plants
Populus balsamifera ssp. trichoca	Acer macrophyllum	Ambrosia chamissonis	Enteromorpha sp.	Rubus armeniacus
	Alnus rubra	Carex lyngbyei	Ulva sp.	Cytisus scoparius
	Crataegus douglasii	Deschampsia cespitosa	Fucus sp.	Rubus armeniacus
	Physocarpus capitatus	Distichlis spicata		Phalaris arundinacea
	Populus balsamifera ssp. trichocai	Eleocharis sp.		Atriplex patula
	Rosa nutkana	Glaux maritima		Cirsium vulgare
	Rosa sp.	Grindelia integrifolia		Convolvulus arvensis
	Rubus spectabilis	Juncus breweri		Dactylis glomerata
	Sorbus sitchensis	Juncus sp.		Daucus carota
	Symphoricarpos albus	Lathyrus japonicus		Lotus corniculatus
		Leymus mollis		Melilotus alba
		Mimulus moschatus		Phalaris arundinacea
		Plantago maritima		Symphytum officinale
		Potentilla anserina		
		Rumex sp.		
		Schoenoplectus pungens		
		Schoenoplectus tabernaemontani		
		Sidalcea hendersonii		
		Trifolium spp.		
		Trifolium wormskioldii		
		Triglochin maritima		

Table 20: Dyke Slough Plant list.

Tree and shrub species >10 m in height	Woody species <10m	Herbaceous species	Bryoids, algae etc.	Exotic Plants
Alnus rubra	Crataegus douglasii	Carex lyngbyei	Enteromorpha sp.	Rubus armeniacus
Populus balsamifera ssp. trichoca	Alnus rubra	Deschampsia cespitosa	Brown algae	Rubus laciniatus
	Crataegus douglasii	Eleocharis sp.	Eleocharis sp.	Dactylis glomerata
	Lonicera involucrata	Equisetum arvense	Enteromorpha sp.	Cirsium arvense
	Malus fusca	Glaux maritima	Green algae	Convolvulus arvensis
	Physocarpus capitatus	Grindelia integrifolia	Ulva sp.	Lythrum salicaria
	Prunus emarginata	Hordeum brachyantherum		Melilotus alba
	Ribes divaricatum	Juncus spp.		Phalaris arundinacea
	Rubus spectabilis	Leymus mollis		Rubus armeniacus
	Rubus ursinus	Phleum sp.		Sonchus asper
	Salix lucida ssp. lasiandra	Plantago maritima		
	Symphoricarpos albus	Potentilla anserina		
		Rumex sp.		
		Ruppia maritima		
		Schoenoplectus pungens		
		Sidalcea hendersonii		
		Trifolium wormskioldii		
		Triglochin maritima		
		Typha latifolia		
		Zostera marina		

Table 21: Millard Creek estuary plant list.

Tree and shrub species >10 m in height	Woody species <10m	Herbaceous species	Bryoids, algae etc.	Exotic Plants
Alnus rubra	Abies grandis	Bolboschoenus maritimus	Enteromorpha sp.	Rubus armeniacus
Abies grandis	Acer glabrum	Calamagrostis sp.	Ulva sp.	Hedera helix
Acer macrophyllum	Cornus stolonifera	Carex lyngbyei		Rubus armeniacus
Alnus rubra	Crataegus douglasii	Deschampsia cespitosa		Convolvulus arvensis
Picea sitchensis	Ilex aquifolium	Distichlis spicata		Agropyron sp.
Prunus sp.	Mahonia nervosa	Eleocharis sp.		Atriplex patula
Pseudotsuga menziesii var. menzi	Malus fusca	Epilobium angustifolium		Convolvulus arvensis
	Picea sitchensis	Galium triflorum		Cotula coronopifolia
	Prunus sp.	Glaux maritima		Geranium robertianum
	Rhamnus purshiana	Grass species		Lotus corniculatus
	Rosa nutkana	Grindelia integrifolia		Phalaris arundinacea
	Rubus spectabilis	Hordeum brachyantherum		Plantago major
	Rubus ursinus	Juncus breweri		Sonchus asper
	Symphoricarpos albus	Juncus spp.		Spartina patens
		Lathyrus japonicus		Spergularia salina
		Leymus mollis		
		Myosotis laxa		
		other grasses		
		Plantago maritima		
		Poa sp.		
		Polystichum munitum		
		Potentilla anserina		
		Rumex sp.		
		Schoenoplectus pungens		
		Schoenoplectus tabernaemontani		
		Sidalcea hendersonii		
		Symphyotrichum subspicatum		
		Trifolium wormskioldii		
		Triglochin maritima		

Table 22: Royston Wrecks: north plant list.

Tree and shrub species >10 m in height	Woody species <10m in height	Herbaceous species	Bryoids, algae etc.	Invasive Plants
Pseudotsuga menziesii var. menzi	Acer glabrum	Achillea millefolium	Fucus sp.	Atriplex patula
	Acer macrophyllum	Carex lyngbyei	Brown algae	Cirsium vulgare
	Crataegus douglasii	Distichlis spicata		Cytisus scoparius
	Mahonia nervosa	Eleocharis sp.		Dactylis glomerata
	Malus fusca	Glaux maritima		Daucus carota
	Physocarpus capitatus	Grindelia integrifolia		Hedera helix
	Pseudotsuga menziesii var. menzi	Juncus spp.		Hypericum perforatum
	Rhamnus purshiana	Leymus mollis		Leucanthemum vulgare
	Rosa nutkana	other grasses		Malus pumila
	Rubus parviflorus	Plantago maritima		Phalaris arundinacea
	Rubus spectabilis	Potentilla anserina		Rubus armeniacus
	Sambucus racemosa var. arbores	Salicornia virginica		Spergularia salina
		Triglochin maritima		
		Typha latifolia		

Table 23: Royston Wrecks: south plant list.

Tree and shrub species >10 m in height	Woody species <10m in height	Herbaceous species	Bryoids, algae etc.	Exotic Plants
Pseudotsuga menziesii var. menzi	Acer macrophyllum	Ambrosia chamissonis	Ulva sp.	Atriplex patula
Abies grandis	Amelanchier alnifolia	Epilobium angustifolium	Brown Algae	Cirsium arvense
	Amelanchier alnifolia	Glaux maritima	Fucus sp.	Convolvulus arvensis
	Holodiscus discolor	Grindelia integrifolia		Cytisus scoparius
	Mahonia nervosa	Leymus mollis		Hypochaeris radicata
	Pseudotsuga menziesii var. menzi	other grasses		Rubus armeniacus
	Rosa nutkana	Plantago maritima		Tanacetum vulgare
	Rubus parviflorus	Polystichum munitum		
	Salix sp.	Rumex sp.		
	Sambucus racemosa var. arboresc	Salicornia virginica		
	Sorbus sitchensis	Triglochin maritima		
	Symphoricarpos albus			

APPENDIX 4: INTERVIEWS

Interview #1

Stakeholder Interview #1 with Ron Wantanabe (1st Vice President, Courtenay and District Fish and Game Protective Association) conducted by Lora Tryon on January 24th, 2011.

Interview #1 was conducted with Ron Watanabe of the Courtenay and District Fish and Game Protective Association (CDFGPA). The purpose of this interview was to identify the potential role of the CDFGPA in the planning and implementation of restoration projects in the estuary. After a review and discussion of the proposed project restoration options Lora (LT) explained the rationale for prioritizing the identified restoration options in the Courtenay River Estuary (CRE). LT and Ron (RW) discussed examples of how the CDFGPA has been involved in past restoration projects, and the potential for their involvement in future projects. As a follow up to the interview (after RW had some time to review the restoration options spreadsheet on his own), he provided a letter outlining the potential capacity of the CDFGPA to be involved in the future and an estimate of their level of future involvement. A summary of both or these communication events are provided below.

Prioritization of Restoration Options
The face-to-face interview began with LT giving an overview of the restoration options identified in her study. As an aid in this interview, LT provided a print-out of the restoration option matrix spreadsheet along with a map of the corresponding sites in the CRE.

Given the many restoration options identified in this study, RW suggested prioritizing to one single, most important option so that he (and other CDFGPA members) could focus on a single issue in detail, to improve the likelihood of improving important fish habitat in the estuary. LT responded that the lower river (and estuary) is a corridor for migration through which fish encounter many hazards that are effectively preventing functional refuge and feeding, and that a single project will not remediate this larger issue within the corridor. As an alternative, LT proposed a system of prioritization that identified one priority option for each segment or reach of the corridor, so that habitat connectivity throughout the rearing and migration phases of young salmonids can be more effectively addressed. She emphasized the relative importance of each segment of an estuary/river interface during advanced juvenile phases of development for saltwater adaption, as well as the necessity for interconnection between feeding areas and areas of refuge from predators.

RW responded that it would make sense (from the perspective of juvenile anadromous fish) to tackle such restoration projects in an upstream to downstream direction, given that the transition from freshwater to saltwater appears to be the largest bottleneck in their survival.

Past CDFGPA Protection and Restoration Projects

The discussion turned towards what the traditional capacity of the CPFGPA has been with regards to habitat restoration. RW provided examples of members involvement in hatchery programs, members volunteering in fish studies (including previous work in the data collection stage of this project), the organization donating money to other groups for restoration works, and an annual program where volunteers transported chum carcasses to the upper Puntledge watershed for nutrient enrichment. As well, RW mentioned that the CPFGPA have been active in writing letters to lobby specific issues, or provide support for particular projects.

Future Involvement of the CPFGPA in CRE Restoration Projects
LT asked RW what level of involvement CPFGPA would take in future restoration work in the CRE? RW responded by saying that he wanted more time to review and digest the options being proposed. A couple days after this meeting, RW responded further with the following comments:

"I believe that there are multiple opportunities for the Courtenay and District Fish and Game Protective Association to assist in varying degrees in all of the projects listed. All that is needed are formal requests for volunteers to do the physical work, letters of support, financial contributions, participating in meetings with government officials and other NGO's, are all activities that are doable by members of my Association." (Watanabe, email communication).

In Summary
RW stressed that his group would likely support 'in principle' any enhancement or restoration projects for juvenile salmonids as long as they are supported by strong scientific evidence.

Interview #2

Stakeholder Interview #2 (by phone) with Cynthia Durance of Precision Identification (Seagrass Restoration Specialist) conducted by Lora Tryon on January 26th, 2011.

The purpose of this interview was to discuss the past, present and future conditions of eelgrass habitats in the Courtenay River Estuary (CRE). Lora Tryon (LT) initiated the discussion by giving a brief overview of the condition of eelgrass beds she has encountered in the CRE through field investigations for this and other recent projects. She then asked Cynthia (CD) to describe any past assessment or restorative work she was aware of in the CRE, as well as opportunities for restoration in the near future.

Historical Restoration on CRE

CD began by reviewing a restoration project that took place approximately 20 years ago. She described an unsuccessful effort to transplant eelgrass into a degraded habitat area adjacent to the Comox Marina. She explained that the initial lack of success of this transplant effort was likely due to unfavourable conditions (chemical or physical) within the site locale. She further explained that this site restored itself approximately 10 years after the initial transplant effort was made, indicating that it is possible that some eelgrass shoots torn from the sediment by boats were able re-establish without being washed away by currents and tides. CD indicated that this incidence is an interesting anomaly because eelgrass beds in this region usually expand through vegetative means (which is a very slow process at approximately 0.5m/year).

Potential Restoration of CRE

CD mentioned that (at the time of the interview) she was in the process of preparing to deliver an eelgrass restoration workshop in the CRE (hosted by the Comox Valley Project Watershed Society). This workshop would introduce volunteer stewards to habitat identification, transplant and monitoring techniques. She followed by saying that the next step was to find a suitable location for a pilot eelgrass transplant project in the estuary.

Present and Future Threats to Restoration of CRE

LT asked CD to identify the greatest adverse impact to eelgrass beds in an estuary environment (such as that found in the CRE). CD said that recreational boat use in shallow water is likely the most adverse. She said that prop wash often breaks or dislodges eelgrass vegetation and rhizomes in shallow habitats. It was suggested that public education in the form of signage, and/or creating 'no go' zones for boaters near shore (i.e., use buoys and floats to delineate newly restored areas) may be effective ways of preventing this kind of degradation in the CRE in the future. Recreational boaters are likely to respond positively if they are informed of potential impact to the ecosystem, and that public response to travel restrictions will be based on effective modes of education and voluntary compliance.

CD identified that point and non-point source water pollution were also important threats to consider, as they can contribute to eelgrass bed degradation. She mentioned that this is a much more difficult issue to tackle - but important to identify and mitigate wherever possible.

Restoration Techniques

LT asked whether bed restoration through transplantation or seed broadcast would have a higher success rate in an environment like CRE? CD responded that seed collection and broadcast is the most cost-effective method (as long as restoration work is done by trained professionals), however the success of this method has been poor in past endeavours. She said that though transplanting is more labour intensive it can be cost effective (as long as experts are used to do the work), and there is greater chance for success than seeding. She went on to explain that many seeds will germinate but few can grow roots fast enough to avoid being washed away by tides and currents (a situation that is very different in the Atlantic where many populations of eelgrass have developed an annual lifecycle).

CD mentioned that she has developed a transplant technology that has met with very high success in most of the pilot study areas where she has done restorative work. In her experience with transplanting, a lack of success is usually related to planting in areas of excessive erosion and poor water quality. She said that it is important to cluster the plants together in patches of 10 or more to protect the centre of the patch long enough to allow good rhizome establishment. She also recommended that steel washers be used to anchor plants (1 per shoot). The steel is known also to assist in sediment remediation by chelating excess sulfide molecules that are often found in estuarine sediments.

CD went on to say that if seed collection and broadcast is going to be used, seeds are easy to harvest without adversely impacting parent stock, and broadcast technique(s) are inexpensive. She suggested that if a seeding project were undertaken locally, it should be done on a pilot project basis, and at a site with minimal influence from tides and waves. Seeding projects have not met with high success on the Pacific Coast as they have on the Atlantic Coast, and that there are reproductive differences between east and west coast eelgrass beds. She emphasized that since local eelgrass beds typically reproduce through the slow process of vegetative branching, leaving nature to expand on existing eelgrass beds without intervention can take a very long time.

Remedial Potential of Eelgrass in Estuaries

CD explained that eelgrass has an incredible physiology because it can derive nutrients either from the water column or from sediment depending on the optimal source. As well, eelgrass will sequester oxygen from the water column and pump it into sediment through its rhizomes. This introduction of oxygen into the sediment will often have a remedial effect on buried toxins. CD mentioned that there are possibly areas within the CRE where toxic 'hotspots' may be a limiting factor for eelgrass bed survival, but eelgrass is quite tolerant of many toxins including heavy metals. Toxic hotspots therefore might be good candidates for restoration as the eelgrass could potentially remediate the sediment now that many of the impacting industries (e.g., log storage) have been phased out within the CRE.

Interview #3

Stakeholder Interview #3 with Nancy Hofer, Environmental Planner, City of Courtenay conducted by Lora Tryon on February 10th, 2011.

The purpose of this interview was to identify opportunities within the governance structure of City of Courtenay to implement and support estuarine protection and restoration programs on the Courtenay River Estuary (CRE). Lora (LT) started by giving a brief overview of the BCRP study to-date and a review of the relationship(s) between the various groups involved in local estuary stewardship.

LT began by asking what (if any) current initiatives or policy exist to support estuary protection and/or restoration within the City of Courtenay? Nancy (NH) responded that there is interest internally to acquire lands (i.e., protection interest) along the estuary shoreline (e.g., the Field Sawmill site), but this will require partnership(s) to secure funding as no funds currently available within City budget. LT inquired whether there were changes being made within the OCP to increase shoreline protection? NH showed a recent map illustrating protective buffers along the CRE shoreline (i.e., riparian areas protection), and explained that she is in the process of working with senior staff to flag sensitive habitats such as these within Environmental Development Permit Areas. LT emphasized the sensitive and complex nature of such estuarine shoreline habitats and the resulting problems that can arise when defining high water marks in a tidal environment. NH agreed and mentioned that she has been working to update the definition(s) of sensitive areas within the OCP (and using the recently published Nature Without Borders document extensively, along with provincial Riparian Areas Regulation literature and the past work on a Sensitive Ecosystem Inventory by the CVRD).

LT continued by asking what (if any) opportunities exist to create a sustained dialogue between city staff and groups with expertise, knowledge and active involvement in estuary protection? NH responded that since she started this position with the City (6 months prior to this interview), she has been given the opportunity to attend meetings amongst local conservation groups so she could learn more about local environmental issues and network with the people involved with these issues in the community. NH emphasized that her position as a municipal Environmental Planner requires that she does not form political alliances, however. She said that there are already systems in place for the planning staff to make referrals to local stewardship groups in the Development Permit process. She mentioned that the City recently hosted a meeting with the local development community to help applicants streamline their applications by addressing the necessary environmental protection measures during the design phase of their development proposal.

LT asked about the level of importance that public recognition plays when staff and/or council implement environmental protection measures? NH responded that she is not aware of any obvious drive by staff or council to gain community recognition for environmental initiatives. She said that there are incentives, however, from the province to gain future municipal resources through implementing innovative environmental initiatives.

LT asked whether the system of applying dollar values to Ecosystem Goods and Services (EGS) is an effective way of educating staff, council and the public about the necessity of investing in a new environmental initiative? NH confirmed that she felt this has the potential to be an effective strategy as the single message of 'protecting because it's valuable' doesn't connect to everyone. Economics of a decision grab a larger audience. She gave the example of the local Cycling Task Force that is working to change the perception that the development of a bike lane network around the city is expensive. She said that over the long term such investments actually save money by reducing car infrastructure costs, and reducing health care costs as people have low-cost opportunities to exercise more. There are also growing costs associated with global warming that are not being accounted for within a fossil fuel based economy, of which transportation is a central issue. LT asked whether the Estuary Working Group (a committee of the Comox Valley Project Watershed Society) could help bridge the information gap regarding such issues? NH affirmed that the language that is used is very important. She said that accurate economic evaluation of ecosystem services would likely be key to bridging the communication gap between municipal government and those working to protect the natural environment. LT asked if there was any particular style of communication that should be avoided when proposing such initiatives to staff and council? NH indicated that the current council is very practical and would likely respond positively to proposals for environmental protection if a valid case was made showing a benefit to the local taxpayers.

LT asked how committed the City is to idea of land protection either through opportunities for direct acquisition, a legislated designation (such as a National Historic Site or a Wildlife Management Area), or through a land conservation type property tax? NH reiterated that the City is interested in acquiring land(s) but requires financial partnership(s) to do so because there is currently no budget for such purchasing. NH expressed hesitation about the City aligning themselves with land protection initiatives that are based on external designations such as those suggested by LT, possibly because she doesn't know enough about them and some sound quite onerous to obtain. She followed by saying public pressure reaches staff through council sensitivity to a public issue. In regards to the idea of implementing a land conservation property tax (similar to the one described by LT that was recently implemented in the Regional District of East Kootenay), NH said that the intent would likely have to appeal to 'parks and recreation' and 'quality of life' interests as well as for land conservation in order to get enough public support

LT asked what regulatory incentives exist within the City for estuary shoreline protection? More specifically, LT asked what level of involvement or interest the City has for the current Courtenay River Estuary Management Plan (CREMP) initiative? NH replied that she thinks staff and council are tentative about getting involved with such a multi-jurisdictional issue. LT mentioned that she had obtained feedback from one of the original participants in the CREMP process, who felt that the City may have not supported it due to it being highly controlled by the federal government, leaving little room for collaboration. LT went on to say that her source had told her that the current atmosphere within this second round with CREMP is one of collaboration. NH replied that she was given the most recent CREMP version and plans to review it and sit in on a future CREMP meeting but will likely stay non-committal, due to the uncertainty among city staff of the CREMP outcomes. LT asked if the Estuary Working Group took time to inform staff and council of the recent developments within the CREMP process, could this result in increased involvement by CoC in this process? NH replied that it is possible.

LT asked what voluntary incentives exist for the City to protect the estuary, such as carbon offsets, etc.? NH responded that the BC Climate Action Charter involves complex accounting that deals with large-scale, internationally based offsets. Blue carbon offsets such as those potentially found in the CRE are an emerging field that do not seem to be accounted for by the Pacific Carbon Trust. Until the province recognizes such initiatives, there is not a financial incentive for the CoC to pursue this particular avenue to help protect the estuary.

Regarding restoration projects on municipal lands, LT asked what level of involvement could be expected from the City for the restoration of shorelines along the Courtenay River? LT provided an example of a problem shoreline along the old Field Sawmill site where the corrugations in the sheet metal pilings are used by seals to trap fish. LT then went on to inform NH that the $5,000 requested for investigation of fish habitat enhancement opportunities at the City's Simms Park was conditionally approved, and asked if the City would be interested in future involvement in similar restoration or enhancement projects? NH replied that the City would likely support similar restoration work on municipal lands as long as the appropriate level of planning has taken place. LT inquired what level of involvement the City might have in the necessary removal and naturalizing hardened shorelines such as that mentioned at the old Field Sawmill site? NH responded that a floodplain study is being planned by the City for the Lewis Park area to determine constraints on present and future use, and that there may be more support for shoreline "softening" projects once this is complete. For example, it may be decided that some City buildings that are on the existing floodplain may be inappropriately placed, and their removal may facilitate other opportunities for shoreline restoration in the area. LT asked about municipal support for invasive plant removal in riparian areas along the CRE? NH said that if there were money available from the province for invasive plant removal the City would likely support such an initiative financially. Otherwise, support will likely only be verbal and in the form of access to municipal lands.

APPENDIX 5: MARCH 17TH, 2011 PRESENTATION DISCUSSION

Project Presentation at the Courtenay & District Museum on March 17, 2011

“Investigation of Restoration and Protection Options for Juvenile Salmonids in the Courtenay Estuary – A Study by Lora Tryon, R.P.Bio.”

Question & Answer Period(s) Summary

1. Methodologies Q & A:

Ensalmo Q: Why were upstream areas determined to have priority over downstream areas as indicated by the Areas 1-9 labelling for the study area?

Lora Tryon A: The criteria used in this study were habitat condition(s) for juvenile Chinook and Coho. This includes food and refuge requirements during outmigration, which were determined to be the more critical at higher reaches of the system where the physiology of anadromous fish must change from freshwater to saltwater dwelling. This priority ranking is not meant to discount other priority areas downstream – it is just one way of categorizing the importance of restoration and protection on this system.

2. Restoration and Protection Options Q & A:

Brett Knight Q: Why are invasive plants in riparian areas a problem in terms of fish habitat?

Lora Tryon A: Some of the key functions of riparian area vegetation for fish habitat are what’s called the “insect drop” and “litter fall”. Native plant species evolved through time with native species of fish, and the fish rely on the insects and detritus inputs provided by specific types of plants in the riparian zone. Non-native species of plants often won’t recruit the same kinds of insect larvae and may not provide the same sorts of litter fall into a stream – which will negatively impact the fish in that habitat.

Shane Johnson Q: Was a Large Woody Debris (LWD) inventory a part of this estuary study?

Lora Tryon A: LWD complexing is important to fish habitat in the estuary, and LWD at particular habitats were mapped, but an detailed inventory was not done. LWD is limited to the lower estuary as a result of tidal inputs. Some LWD comes downstream, but logging and dams are limiting factors in this system.

Wayne White Comment: The Tsolum and lower Puntledge do provide a significant amount of LWD to the estuary that is constantly being buried in soft sediments. This is important in terms of carbon sequestration.

Unknown Person Q: Why was there no mention of Pink salmon juveniles in your study results?

Lora Tryon A: There were a handful of Pink juveniles sampled, but these were not included because so few. Most of the pinks out-migrated before the sample period.

Unknown Person Q: Did you compare the temperature data from this study to historical data for this system?

LoraTryon A: There was no comparison made but it would be interesting to compare current average air temperatures to those of the past as a way to monitor climate change. The challenge with water temperature comparisons in an estuarine system is replicating tidal influx and discharge within a specific period in a season.

Wendy Kotilla Comment: Studies from the Carnation Creek research area have shown a clear correlation between increasing instream temperatures and logging within the riparian areas upstream within a watershed.

Ensalmo Comment: Another factor that results in increased water temperatures in any system is dropping summer flows. This is compounded in systems with poor shoreline habitat complexity such as the Courtenay River Estuary.

Ensalmo Q: How would you rate the overall health of the Courtenay River Estuary – stable, increasing or decreasing?

Lora Tryon A: If salmonid species are indicators of this, then I would say that the estuary and the watershed as a whole are in decline. For salmon, the overall decrease in stream habitat complexity in this watershed is clearly a factor.

Wayne White Comment: I believe the health of the estuary is actually slowly increasing. If you consider that the old dredged channel in the lower river is slowly infilling and most of the old industries that were a source of toxins in the river system are now gone – these factors can only be an overall benefit to the ecology of this system!

Kathryn Clousten Q: Your study has identified the Dyke Slough as great refuge habitat for juvenile salmonids migrating out to the estuary. Have you found other sites that have potential to provide a similar level of quality refuge and possibly feeding habitat for outmigrating salmonids?

Lora Tryon A: The Airpark Lagoon has a lot of potential. In it's current state, there is not much freshwater input. This could be mitigated by creating a high (tide) water breach between the Courtenay River and the lagoon through a culvert under the pedestrian walkway. This modification will presumably also enhance the downstream tidal flat as increased flows result in increased channel braiding. Channels in estuarine tidal flats provide critical summer refuge for salmonids. It is important to note that is some concern still for the potential release of toxins from this lagoon with increased flows as it used to serve as a sewage lagoon.

Wayne White Comment: There is record of excavation within the lagoon to remove contaminated sediments, so this may not be an issue.

Wayne White Comment: The current strategy at the hatchery is to release the Chinook smolts in the high pulse flows of spring in an effort to essentially blow them past the hungry seals waiting downstream. This is known to be hard on the fish as they don't have much time to acclimatize to the saline conditions. It is critical that shoreline refuge habitats be restored to allow these fish safe holding habitat out of reach of seals.

Lora Tryon Q: How many property owners in the audience today would be willing to pay a kind of conservation tax levied to restore and/or protect the estuary?

Audience response: Approximately 8 of the 30 odd participants put up their hands. One person commented that he would be more willing if this levy wasn't called a "tax".

Lora Tryon Q: Of the municipal staff present, how many would be willing to try to convince their respective Council members to enact such a levy?

Response: 1 of the 2 Municipal Planners present put up her hand.

Janine Bond Q: How is this study tied to the current CREMP process?

Lora Tryon A: The ecosystem based management structure of this study model should make it easy for such a group to integrate components of the study from areas applicable to the work they are doing.

Janine Bond Q: I guess I'm wondering if this study is already part of a larger, comprehensive management plan for the estuary?

Don Castledon A: An emphasis of this recent version of CREMP has been to develop a more inclusive consultation process that integrates a wider range of information and values.

Wayne White Comment: The current CREMP process is not necessarily taking a site specific approach. There will be overarching goals such as reducing shoreline hardening that will overlap directly with this study – but not site specific objectives within CREMP.

Brett Knight Q: You mentioned a priority restoration project as the removal of hardened shoreline structures along Lewis Park. Is this feasible?

Lora Tryon A: There have been similar studies implemented in the US that have been successful. The risks associated with potential loss of private land are difficult to manage, however. There are substantial resource and capacity hurtles to overcome to implement such a project (e.g., engineering requirements, public support, long-term management, etc.).

Brett Knight Comment: Shoreline softening in public areas such as Lewis Park could actually add value in terms of beach creation, increased biodiversity and natural habitats that many people appreciate.

APPENDIX 6: RESTORATION OPTIONS

(attached separately)

APPENDIX 7: PROTECTION OPTIONS

(attached separately)

Reed Canary Grass Control and Management Plan

Prepared for: Fish and Wildlife Compensation Program

Prepared by: Beatrice Proudfoot and Jennifer Sutherst (Comox Valley Project Watershed Society)

Prepared with financial support of:
Fish and Wildlife Compensation Program on behalf of its program partners BC Hydro, the Province of BC, Fisheries and Oceans Canada, First Nations and public stakeholders.
December 2019

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Executive Summary

This report outlines the Comox Valley Project Watershed Society's (CVPWS) plan for controlling the spread of invasive reed canary grass (RCG) in the K'ómoks Estuary. The overarching objective of the plan is to provide recommendations and advice that can guide the CVPWS's RCG control and management activities over the next 5 or more years.

Reed Canary Grass is a perennial cool season grass that can grow up to two meters tall and expands by creeping rhizomes, vegetative fragments and seeds. RCG out competes other native vegetation due to its effective dispersal mechanisms, lack of dormancy requirements, and ability to shade out slower growing native species. RCG provides little value for native wildlife, few species will eat it, and it grows too thickly for mammals or waterfowl to use for cover/nesting. Foraging juvenile salmonids have feeding opportunities reduced in areas dominated by RCG, and it constricts waterways thus preventing salmon from reaching spawning habitats.

During the spring of 2019, the CVPWS inventoried and mapped the extent of RCG in three priority areas in the K'ómoks Estuary: Hollyhock Marsh Conservation Area, Dyke Slough and the lower reaches of Mallard Creek. These areas were then targeted for eradication trials. The following seven treatments were trialed: mowing; mowing and shading; mowing and mulching; mowing, mulching and shading; manual excavation by hand; machine excavation; and machine excavation and live staking with native species. The effectiveness of these treatments are currently being documented and monitored, and results will be incorporated into updated versions of this control management plan. An adaptive management process will be used to continually update this control plan based on the results of the various treatments.

Unfortunately there is no quick way to convert an RCG infestation into a native plant community. However, even highly infested areas can be restored to more desirable and diverse plant communities and much can be accomplished within 2-3 years. It was determined that removal and local eradication of existing RCG plants and their rhizomes in high priority areas, such as areas along streams, should be the focus in the first 1-2 years. Continued monitoring and follow up treatments will be required for up to 5 years in order to prevent re-infestation and decrease the seedbank.

This control management plan covers the Hollyhock Marsh Provincial Conservation Area, the lower reaches of the Mallard Creek and Dyke Slough – all of which are contained within the K'ómoks Estuary in the Comox Valley, B.C.

Contents

Figures

Tables

Introduction

The overarching goal of this project is to control and manage the spread of invasive reed canary grass (RCG) in the K'ómoks Estuary and its concomitant impacts to fish, wildlife and plant communities. While full eradication is an ambitious and challenging goal, a variety of management approaches can be used to at help shift RCG infestations towards more desirable vegetation communities, and slowly work toward containing and reducing infestations.

An adaptive management approach is required, particularly at the initial stages of control and management when variety of treatment methods are trialed to determine the most efficient and effective way to move forward. As such, this control management plan will be regularly updated as lessons are learned about controlling and managing RCG in the K'òmoks Estuary.

Reed Canary Grass

Reed Canary Grass (RCG; Fig. 1) is a perennial cool season grass that can grow up to two meters tall and expands by creeping rhizomes, vegetative fragments and seeds. It is thought that the invasive subspecies of Reed Canary grass (RCG) in B.C. is an escaped Eurasian cultivar. Several Eurasian cultivars have been repeatedly introduced since the early 1800s as forage for livestock. RCG cultivars and subspecies have either escaped cultivation or hybridized to become invasive in much of North America. RCG out competes other native vegetation due to its effective dispersal mechanisms, lack of dormancy requirements, and ability to shade out slower growing native species. In areas where it has been introduced it typically will dominate 50-100% of the site (Lavergne and Molofsky, 2004). It can out compete native grasses within 5 to 6 months of introduction, which leads to a reduction in native plant diversity. This can lead to changes in habitat and concomitant changes in wildlife populations that rely on native wetland and riparian plant species for food and shelter. RCG effectively out competes native plant species for space and nutrients. RCG provides little value for native wildlife, few species will eat it, and it grows too thickly for mammals or waterfowl to use for cover/nesting. Foraging juvenile salmonids have feeding opportunities reduced in areas dominated by RCG, and it constricts waterways thus preventing salmon from reaching spawning habitats. It supports less diversity of insect life and results in reduced foraging opportunities for juvenile salmon that feed on insect that drop from riparian and wetland vegetation. It also does not provide shade to streams, which can increase water temperature in streams and reduce habitat quality for salmon and trout.

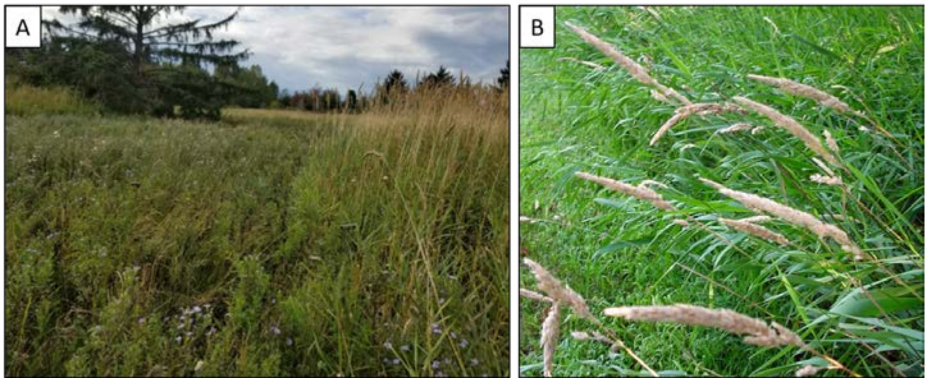

Figure 1: Reed canary grass encroaching on native vegetation (A) and reed canary grass inflorescence (B). Photo credit Ernie Sellentin (A) and Invasive Species Council of BC (B)

RCG prefers moist to wet soil, and is most often found in wetlands, along riverbanks, or in wet ditches. It spreads quickly and can have many negative impacts on the wetland or riverine ecosystems that it invades. In addition to reducing plant and animal diversity in the areas it grows, it also alters the geomorphology of streams by impeding water flow, trapping silt and constricting waterways, thus preventing salmon from reaching their spawning habitats.

In the summer of 2018 a local invasive species expert, Ernest Sellentin, requested to present to the CVPWS's Estuary Working Group (EWG). Mr. Sellentin has been working on the control and management of invasive species in the province of BC for over 30 years. For many years, he worked with the BC Invasive Species Council and he is now the President of Sellentin's Habitat Restoration and Invasive Species Consulting Ltd. He has had direct experience managing invasive species in the Estuary and he expressed his concern to the EWG about the expansion of RCG he has observed in the Estuary. He indicated that, by his estimation, RCG is now established in approximately half if the Estuary and it has tripled in extent since 2004 (CVPWS 2018). He reports that there is effectively a RCG monoculture in large parts of the Estuary, which is outcompeting native grasses. He finished by suggesting that an inventory of RCG in the estuary should be done and that control measures should to be undertaken sooner rather than later. Based on his input the EWG decided to move forward with a project to inventory the extent of RCG in the Estuary and develop a control management plan for dealing with this invasive species. In the fall of 2018, Project Watershed submitted an application to the Fish and Wildlife Compensation Program to undertake this work and funding was secured early in 2019.

Study Areas

Reed canary grass is spreading within the Courtenay River (K'ómoks) Estuary and dense stands are starting to form, especially in Hollyhock Marsh, Dyke Slough and the lower reaches of Mallard Creek. Based on local expert feedback via the CVPWS's EWG and Technical Committee, it was determined that the control/management plan should cover the high priority areas of Hollyhock Marsh Provincial Conservation Area, the lower reaches of the Mallard Creek and Dyke Slough all of which are contained within the K'ómoks Estuary. Specific treatment areas were prioritized based on feedback from tenant farmers, landowners, and local naturalists. For the first year of the project, the goal was to make the best use of limited resources to trial several different control methods. The results of the treatment trials will be used to scale up the project and expand RCG control and management activities into new areas.

Komok's Estuary

The K'ómoks (Courtenay River) Estuary is one of the most important estuaries on Vancouver Island, and one of only eight that are ranked as Class 1 estuaries in B.C. (WWF 2013). It is a special and unique feature of the Comox Valley and supports 145 bird species (recognized as an internationally important bird area), 218 plant species, 29 fish species (including all 5 species of Pacific salmon), and a plethora of intertidal life. The Puntledge and Tsolum Rivers merge to form the Courtenay River which is the freshwater body that feeds the Estuary. Another reason the K'ómoks Estuary is unique is the abundance of well-preserved wooden stakes – archeological remnants of a large-scale ancient First Nations fish trap complex.

The broader Baynes Sound region that encompasses the K'ómoks Estuary has been identified by Fisheries and Oceans Canada (DFO) as an Ecologically and Biologically Significant Area (EBSA; DFO 2014). The region includes a component of the highest ranked cumulative Pacific herring spawning and rearing area in BC (DFO 2014). The annual herring spawn supports >10,000 birds, including Brant and Harlequin ducks (DFO 2014). The thermally stratified waters and soft substrates in Baynes Sound support a high biomass of associated benthos including a high density of butter clams (*Saxidoimus gigantea*). The area is also important for pinnipeds such as Harbour Seals (*Phoca vitulina Richardsi*) and Stellar sea lions (*Eumetopias jubatus*) by providing key foraging areas and haul out sites (DFO 2014).

A portion of the K'ómoks Important Bird Area (IBA) is located in K'ómoks Estuary. The K'ómoks IBA was designated due to the significance of area for birds during the Pacific herring (*Clupea pallasii*) spawn. The region supports continentally significant numbers of waterbirds each year. The IBA also supports important numbers of three species designated as Threatened or of Special Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). These species include: Great Blue Heron (Special Concern), Marbled Murrelet (Threatened) and Peregrine Falcon (Special Concern; Important Bird Area Canada 2012).

RCG is spreading within the Courtenay River (K'ómoks) Estuary and dense stands are starting to form, especially in Hollyhock Marsh and the lower reaches of Mallard Creek.

Hollyhock Marsh Conservation Area

The Hollyhock Marsh Conservation Area (Fig .2), was deemed a high priority as it contains many rare plant communities that are at risk of being taken over by RCG. Additionally, the area has been shown to have some of the highest concentrations of juvenile trout and salmon over the summer months indicating that this is a key habitat area. As such, improving fish habitat quality of this area has been identified as a restoration priority (CVPWS 2019). Furthermore, the CVPWS has to restore the adjacent Kus Kus Sum (KKS; CVPWS 2018) site, there are concerns that the RCG present at Hollyhock, could easily spread into the newly restored site. Currently, the KKS site is almost completely covered by pavement and concrete. As part of the restoration the hard surfacing will be removed, the site will be regraded and wetland channels will be created. The area will then be planted with native wetland and terrestrial plant species. However, until these plants can become well established, the bare earth at the site will likely provide fertile ground for RCG colonization.

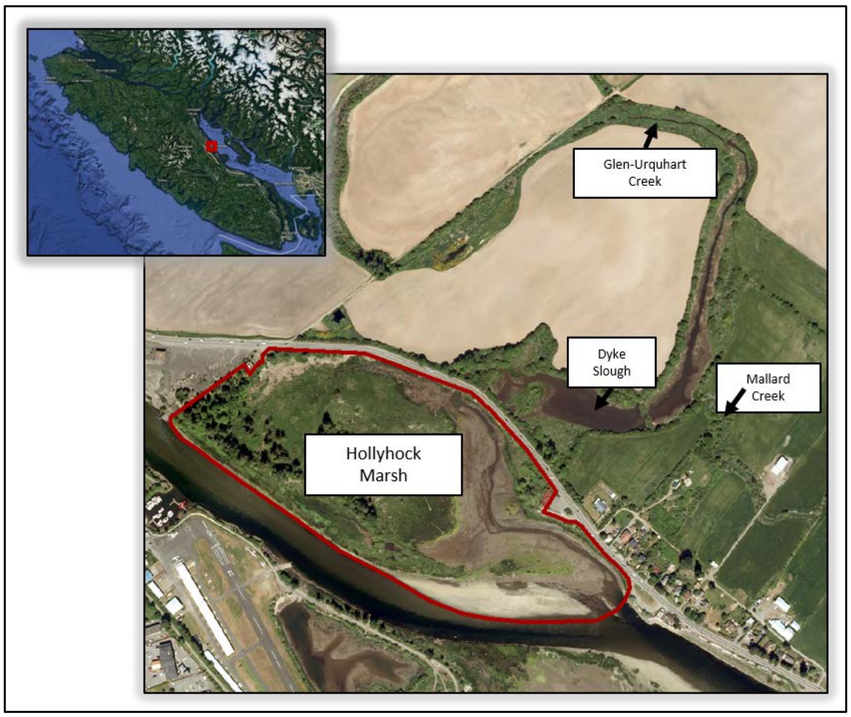

Figure 2: Dyke Slough, Hollyhock Marsh and parts of Mallard and Glen-Urquhart Creeks that are the focus of reed canary grass control and management

Mallard Creek and Dyke Slough

The areas along Dyke Slough and Mallard Creek have also been shown to have high habitat values. Mallard Creek (Fig. 2) is a hot spot for RCG and also supports Coho, Chinook and Chum salmon as well as Cutthroat Trout, however available spawning and rearing habitat is already limited due to intensive agricultural activities and the creek is being further constricted due to RCG growth. Mallard Creek originates from groundwater sources in East Courtenay, and is one of the most heavily degraded salmonid streams in the Comox Valley. Impacts stem from upstream urban development and downstream agricultural activities. Despite the fact that their habitat has been compromised by human activity, Mallard Creek still manages to sustain salmonids. Mallard Creek once supported spawning coho, however it is unknown if this is still the case. Mallard Creek is utilized by juvenile coho for overwintering habitat (Bond 2010; CVPWS 2017) and a study that assessed juvenile fish usage in Dyke Slough, among other parameters, noted that the highest number of coho juveniles were captured in February, and the majority of these were caught in Mallard Creek (Guimond 2010). In addition to coho juveniles, cutthroat trout fry have also been found in Mallard Creek (Bond 2010).

Finally, the areas along Dyke Slough and Mallard Creek have landowners who are engaged and supportive of conservation solutions including Ducks Unlimited Canada (Mallard Creek) the Nature Trust of BC (Dyke Slough) as well as private landowners. Specifically, Ducks Unlimited Canada has a new tenant farmer leasing land adjacent to Mallard Creek and Dyke Slough who is very open to the CVPWS's conservation initiatives in the area.

Management Objectives and Indicators

The overarching objective of the Control Management Plan for RCG is to provide guidance on controlling, reducing and preventing the spread of RCG in the K'ómoks Estuary.

The following objectives have been identified to support the control and management of RCG in the study area:

Objectives

1. Reduce the spread of RCG in the study area its impact on invasive species

2. Work toward eradicating reed canary grass in the study area (lower reaches of the Mallard Creek, Dyke Slough and Hollyhock Conservation Area).

3. Reestablish native plant communities in study area that are currently dominated by reed canary grass.

4. Raise awareness and educate the general public about the reed canary grass and its potential impacts

Indicators

1. Reduction in the extent and density (m^2) of reed canary grass in the study area (Objectives 1 and 2)
2. Increase in the abundance and diversity of native species in the study area (Objective 3)
3. Increased public engagement in reed canary grass removal and control initiatives undertaken by Project Watershed (Objective 4).

Current Extent of RCG

Since 2004, it is estimated that the amount of RCG in the K'ómoks Estuary has tripled. To work toward achieving the management objectives, an inventory of RCG in the study area was done using aerial photography and a supervised classification approach to produce a map of RCG in the study area. Using the mapped outputs of the current distribution of RCG in the estuary, the CVPWS produced a plan for removal, replanting and subsequent monitoring.

Mapping Methodology

A supervised classification approach was used to map RCG the priority areas. Supervised classification approaches are commonly used to inventory and map vegetation using aerial and satellite imagery, and is an effective way to produce vegetation maps over large areas (Richards 2013). The approach requires ground truthed data that identifies the location of the vegetation of interest. The ground truthed data are then used to calculate the spectral signature of the vegetation from the aerial imagery. Once the spectral signature of the vegetation of interest is determined, the imagery is then classified based on the signature, producing polygons of the vegetation of interest.

For this project, ground truthed training data of RCG was collected using a Wide Area Augmentation System (WAAS)-enabled Garmin GPSMap 78s GPS (Fig. 3). With the GPS set to track-mode, the perimeter of multiple RCG patches was mapped and patches were classified into one of the following classes based on the level of dominance of reed canary grass in the polygon:

- Dominant – RCG comprises 80% or more of the patch
- Co-Dominant – RCG comprises 50-79% of the patch
- Sub- Dominant – RCG comprises less than 50% of the patch
- Sparse – RCG comprises less than 10% of the patch

Figure 3: Ground truthing reed canary grass to support inventory and mapping

Aerial imagery with near-infrared band (0.3 m spatial resolution) was purchased from Aeroquest Mapcon (Coquitlam, BC) and used for the classification. Despite the temporal difference between imagery and ground-truthed data acquisition, the resulting mapping is still appropriate and useful due to the persistent nature of RCG. Additionally, local knowledge regarding RCG infestation in the study area has confirmed that RCG has been present in certain areas for many years (Ernie Sellentin, *personal communication*). Acquiring aerial imagery is also quite costly, so the ability to use a single image for multiple mapping projects is beneficial, as the 2016 imagery was used for a previous nearshore habitat mapping project undertaken by PW.

ArcGIS 10.5 was used for data processing and image classification. The ground-truthed polygons (n=29) were overlain on the 2016 aerial photography, evaluated, deemed representative of the desired RCG classifications and used to create the spectral signature file. To classify the image, the Maximum Likelihood Classification tool was used. The tool is based on maximum likelihood probability – which assigns each pixel to a class based on the means and variances of the class signatures (this information is stored in the signature file). The output of the maximum likelihood tool is a classified map.

It is possible that the maximum likelihood classification process can misclassify pixels, creating random noise that may not represent RCG. To remedy these possible misclassifications, post classification filtering and smoothing tools were applied to smooth classification boundaries and remove small, isolated regions. The resulting RCG polygons can then be used for further analyses and control/management activities.

Mapping Results

The following map shows the results of the supervised classification of RCG in the study area.

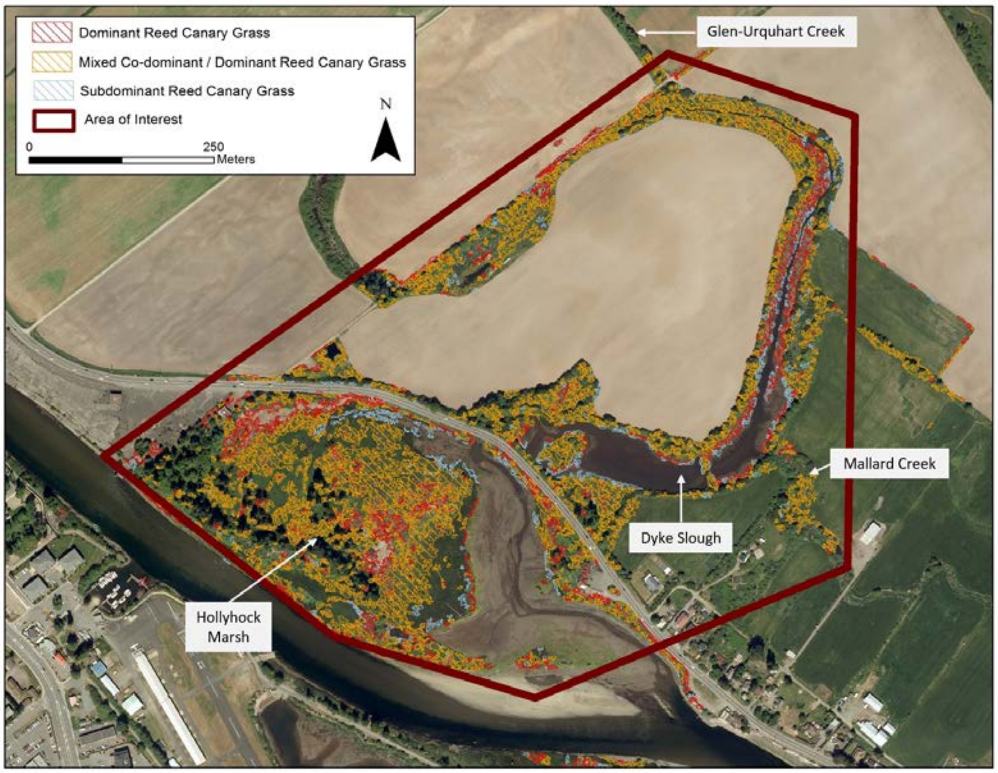

Figure 4: Distribution of Reed Canary Grass throughout the area of interest

Review of Management Tools for Controlling Reed Canary Grass in the K'ómoks Estuary

A review of management approaches for controlling the spread of RCG was undertaken to determine treatment options. A variety of treatments are outlined in Table 1. Pros, cons, considerations and recommendations for each treatment approach are also included. The results of the review (i.e. Table 1) was used to guide to selection of treatment options and develop recommendations for future RCG control/management activities. The type of infestation (dominant, co-dominant, subdominant) was also considered.

Table 1: Treatment options and considerations for controlling and managing reed canary grass

Treatment	Details	Pros	Cons	Time Window	Considerations	Commitment required to control (years)	Recommended (Yes/No)
Excavation using large equipment	• Use backhoe and other excavators to remove RCG, underground rhizomes and seedbank in soil. • Excavated material needs to be appropriately disposed of.	• Removes rhizomes and seedbank • Can be used in large areas and monoculture stands	• Removes sediment and nutrients which can alter hydrology. • Potential for disturbing native species present. • More appropriate for monoculture stands. • Costs associated with equipment and operators. • May be challenging to move material off-site	• When sites are dry to minimize soil compaction.	• Need to remove excavated soil and associated seed bank off site. • Should be avoided if there are native species communities in the area. • Use caution when disposing of material as RCG will rapidly colonize disposed soil. • Permits may be required for excavation and disposal. • Permits and surveys may be required for archaeologically sensitive areas.	• Post excavation, areas should be replanted with native species. • Monitoring for regrowth from seedbank is necessary. • Additional control may be required.	• Yes – should be used in areas where RCG forms a monoculture.
Manual excavation	• Use hand tools to dig out plants, roots and rhizomes. • Excavated material needs to be appropriately disposed of.	• Can effectively remove small patches and isolated plants. • Volunteer and community members can be recruited to assist in removal.	• Not feasible for larger patches and monoculture stands. • RCG will quickly colonize disposed soil.	• Ideally in spring, prior to seed germination. • Removal is easiest when soil is moist however moist soil is vulnerable to compaction	• Appropriate disposal of excavated material is required. • Permits and surveys may be required for archaeologically sensitive areas.	• Post excavation, areas should be replanted with native species. • Monitoring for regrowth from seedbank is necessary. • Additional control may be required.	• Yes – should be used in conjunction with shading and/or planting native species.
Mowing	• Remove stems, leaves and seeds before maturation. • Promotes the establishment of native species by increasing available light.	• Reduces RCG height, providing an opportunity for native species to establish and shade out RCG	• Depending on density of remaining mat of vegetation, native species may have a difficult time establishing. • Does not remove rhizomes.	• Mowing should be done twice annually • Initial mow should be done prior to seed maturity	• Mowing should be done before seed heads appear (spring/early summer). • Surveys may be required to minimize impacts to birds that may be nesting in RCG.	• Mowing should occur a minimum of two times per year for several years • Monitoring for regrowth and expansion via	• Yes – should be used in conjunction with shading and/or planting native species

Treatment	Details	Pros	Cons	Time Window	Considerations	Commitment required to control (years)	Recommended (Yes/No)
		• Minimal soil disturbance • Relatively cost effective		(spring/early summer)		rhizome is required.	
Shading	• Cover with commercially available shade cloth, plastic or cardboard	• Kills RCG rhizome • Kills adult plants	• Non-selective. • Potential for native species to be shaded out and killed. • Not ideal when native species are mixed in with RCG. • Not appropriate for large areas. • May have adverse impacts on soil microorganism and soil chemistry.	• Shading should be done prior to seed maturity • Shading should be left in place for a minimum of one growing season	• Determine whether native species are present prior to shading and attempt to transplant them.	• 1-3 consecutive years • Edges of shade material should be regularly monitored for shoots from lateral rhizome growth	• Yes – should be used in conjunction with mowing and/or excavation. • Can facilitate planting and establishment of native species.
Revegetate with Native Species (e.g. live staking, planting sizeable shrubs, trees)	• Plant competitive shade producing native species to shade out RCG	• Using native species to shade out RCG is the best long term control strategy • Promotes native biodiversity	• Likely needs to be coupled with other types of treatment (e.g., excavation, mowing, shading)	• Plant native species in early spring to allow ample time for establishment	• Plants used for revegetation must be highly competitive and be ability to thrive at the site. • RCG will recover/re-invade in conditions with insufficient shade	• Monitoring and spot control of reinvasion may be required for several years	• Yes – Should be used in conjunction with mowing, excavation and or/shading.
Grazing	• Allow domesticated animals (e.g. cattle, goats) to graze on RCG in spring, prior to seed germination	• Adds nutrients to the system • Grazing can reduce the height of RCG, allowing native species to establish by increasing available light • Effective as a suppressant, but unlikely to	• If grazing occurs while seeds are mature, grazing can actually promote the spread of RCG • Trampling and compaction can damage soil • Desirable species may be inadvertently grazed • Does not remove rhizomes	• Grazing should occur prior to seed maturation	• Grazing is not appropriate if high quality native plant communities are in the vicinity, as animals may indiscriminately graze on all vegetation in the area.	• Grazing should occur over several growing seasons	• Possible –only if done prior to seed maturation. May be more cost effective than mowing (no fuel required).

Treatment	Details	Pros	Cons	Time Window	Considerations	Commitment required to control (years)	Recommended (Yes/No)
		lead to long term control and eradication.					
Hydrology alterations	• Modify hydrology to produce wetter conditions that kill RCG rhizomes, adult plants and prevent seed germination	• Can promote the growth of native cattail and bulrush • In areas where RCG has choked out creeks and streams, modifying hydrology can assist in returning the site to conditions prior to RCG invasion	• High water levels can promote growth of other invasive species that may thrive in wetter conditions • Alterations might disrupt or alter other ecosystem functions	• Outside fish windows	• Modified water depth must be greater than 12inches and maintained through the growing season • Permits may be required • All potential impacts and effects of altering hydrology must be considered and weighted.	• Once hydrological alterations are implemented, monitoring for adequate water levels and RCG reinvasion is required	Possible –Would require substantial planning to ensure that any hydrological alterations to not negatively impact other species and ecological processes

Treatments

A comparison of seven different control and management treatments was done in the Summer/Fall of 2019. The results of the various treatments were compared and used to guide the development of recommendations for future control and management activities. Details of the seven treatments are outlined in Table 2. The treatments should continue to be monitored to better understand the long term effects and appropriateness of each treatment.

A brief description of the treatments are described below:

- Mowing (Fig. 5A): Reed canary grass is mowed down with brush cutters during the height of growing season in order to provide native plants an opportunity to grow without being constrained by the shade produced by the tall RCG. Mowing must be done prior to seed head development.
- Mulching (Fig. 5B): Mulching is a variation of mowing where mowed material is broken down into small pieces and left to decompose.
- Shading (Fig. 5C): After mowing, large sheets of cardboard are installed over sections of the mowed area. The cardboard can be staked down using coat hangers. Cardboard is a good alternative to more expensive weed cloth/geotextile fabric because it can be obtained at zero cost. Additionally, cardboard is recommended as it is biodegradable and will break down over time.
- Manual Excavation (Fig. 5D & E): Discrete patches of RCG can be manually excavated by hand using shovels and mattocks. Plants should be properly disposed of to ensure that rhizomes don't reestablish.
- Machine Excavation (Fig. 5F): A small excavator can be used to flip large monoculture mats of RCG, both in open areas and along stream banks such as Mallard Creek. The RCG rhizomes become exposed, and the leaves and stems become smothered. This is an effective way of removing large patches of RCG and preparing them for further treatment (e.g. live staking).
- Live Staking (Fig. 5G): Live staking is the use of living cuttings from pioneering woody vegetation species (e.g. willow, red osier dogwood etc.) to revegetate areas targeted for restoration. In the case of RCG control, the goal is that the stakes will shade out the RCG and prevent it from establishing and spreading (Polster 2017). An additional benefit of live staking along stream banks/riparian areas is that the stakes, once established, provide the streams with shade and increase habitat quality for fish.

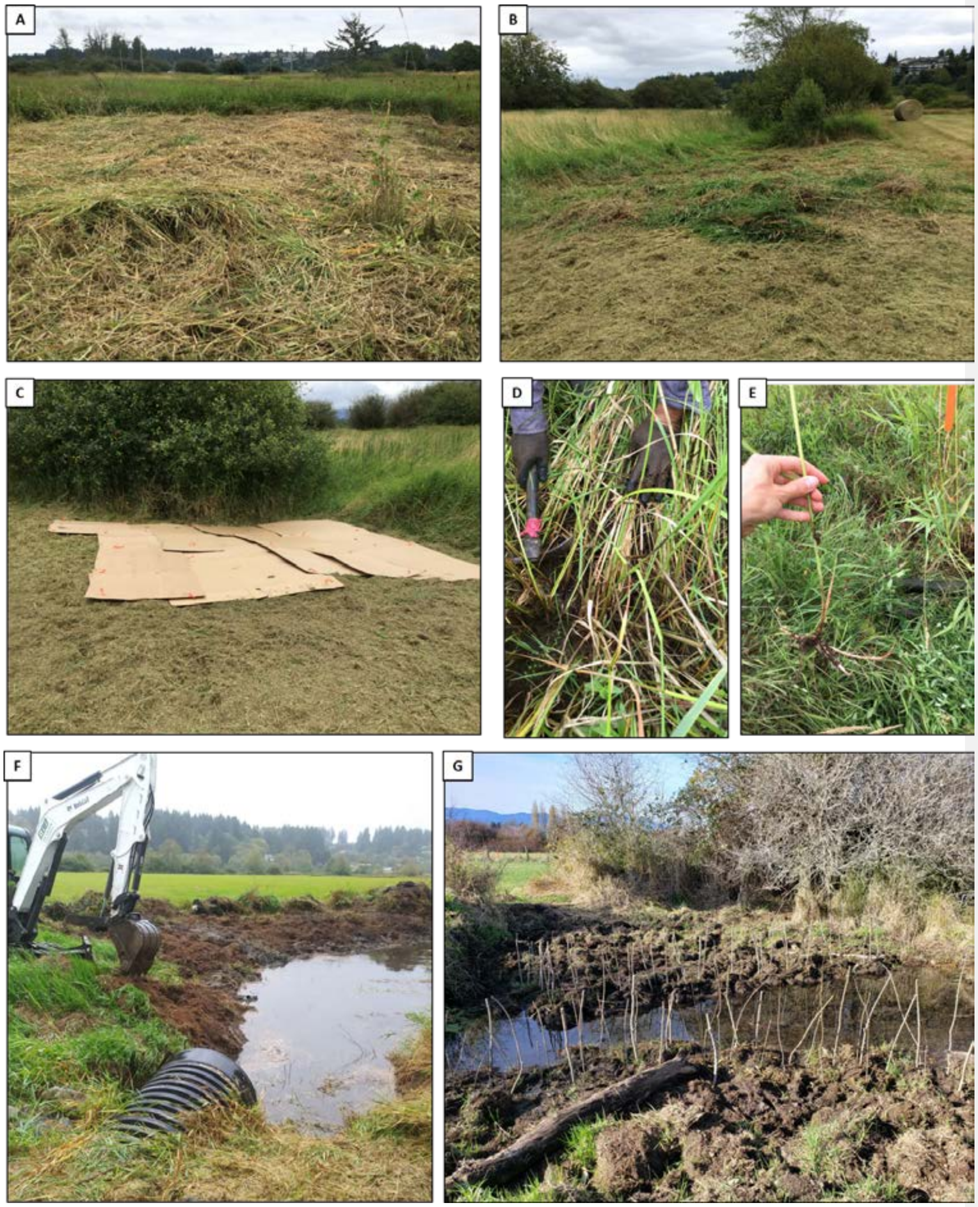

Figure 5: Treatments tested to control and manage the spread of invasive reed canary grass in the K'ómoks Estuary)

Table 2: Details of reed canary grass treatments trialed in the summer and fall of 2019

Treatment	Date	Location(s)	Observed Pros	Observed Cons
Mowing	June/July 2019	Sections of Hollyhock Marsh, Dyke Slough, Mallard Creek	Potentially effective if mowing occurs prior to seed development	Time consuming. Only relatively small patches can be mowed at a time. Coupled shading/ live staking likely required.
Mowing + shading with cardboard	June/July 2019	Sections of Hollyhock Marsh, Mallard Creek and Dyke Slough	Cardboard can be easily obtained and is biodegradable.	Time consuming. Only effective for relatively small patches. Pins/ stakes must be removed as cardboard decomposes.
Mowing + mulching	July 2019	Sections of Mallard Creek	Potentially if mowing/mulching occurs prior to seed development	Mulching is more time consuming than mowing. Only relatively small patches can be mowed at a time. Mowing/mulching can be difficult around stream banks due to uneven terrain. Coupled shading/ live staking likely required.
Mowing + mulching + shading	July 2019	Sections of Mallard Creek	Potentially if mowing/mulching occurs prior to seed development	Mowing/mulching can be difficult around stream banks due to uneven terrain.
Manual excavation (test patches)	July 2019	Sections of Hollyhock Marsh	Deep rhizomes can be fully removed; can effectively remove discrete patches of RCG within native plant areas. Useful for early detection and removal.	Tedious, time consuming. High effort required to remove small patches. Rhizomes often break during excavation.
Machine excavation – flipping over RCG to shade it out	Sept. 2019	Sections of Mallard Creek	Can excavate relatively large areas in a short period of time in open areas and along stream banks.	Machine time can be costly
Machine excavation – flipping over RCG and staking with live willows	Sept/Oct 2019	Sections of Mallard Creek	Can excavate relatively large areas in a short period of time; Staking known to be effective; High volunteer recruitment potential	Machine time can be costly; additional time/resources required to harvest live stakes

Challenges and Recommendations for Control and Management

In order to successfully shift RCG infested areas towards native plant communities, control measures that involve both RCG removal and native species establishment should be carried out annually for at least 3-5 years. An adaptive management process is also recommended that involves updating this control/management plan based on the results of the management and monitoring actions recommended below.

Controlling and managing the spread of RCG is complex and requires a variety of methods and long-term monitoring. The patch size, location and the nature of the surrounding plant community should inform the management approach needed in each area. Determining the appropriate treatment requires a consideration of the following:

- The type of infestation (i.e., monoculture, co-dominant patches, subdominant patches)
- Whether infestation is along a streambank (e.g., Mallard Creek)
- The size of the infestation
- The accessibility of the area
- Whether landowners are co-operative and supportive
- Availability of funds
- Desired plant community

Control and Management of RCG Monocultures

Ideally, large monoculture RCG infestations (i.e., when RCG comprises 80% or more of the patch), particularly those along stream banks should be treated by machine excavation. Depending on the site characteristics, live staking with willow may also be appropriate. Whether or not live staking is used depends on the nature of the desired plant community once the RCG is removed (i.e., live staking with willows is only recommended if establishing native trees and shrubs is the goal). Cardboard panels can also be installed and staked with the willow stakes as an additional measure to eradicate RCG.

Large monocultures are heavily dominated by RCG and therefore few (if any) native species need to be avoided, making excavation an appropriate treatment. Care must be taken to ensure that no harm is done to fish, wildlife and their habitats. This means that all riparian and in-stream work should be done in appropriate timing windows. Timing windows are typically site specific and vary depending on which species may be present and the sensitivity of the habitat.

It's recommended that moderately sized to small patches of RCG monoculture are mowed before plants produce seeds and then shaded with cardboard panels. Small monoculture patches can also be dug out by hand and subsequently shaded. Manual excavation is easiest when the soil is moist.

Control and Management of Co-dominant RCG

Co-dominant RCG infestations (i.e., when RCG comprises 50-79% of the patch) should be mowed during the height of growing season and prior to seed head development. This provides the opportunity for co-occurring native plants to grow without being constrained by the shade produced by the tall RCG. An important goal with co-dominant RCG infestations is to avoid removing or damaging co-occurring native species. As with monoculture infestations, smaller patches an individual plants can be removed manually. Proper disposal is required (see below) to ensure that rhizomes do not re-establish.

Control and Management of Sub-dominant RCG

Subdominant RCG infestations (i.e., when RCG comprises less than 10% of the patch) can also be mowed during the height of growing season. Individual plants should be manually excavated before rhizomatous mats develop. Manual excavation is easiest when soil is moist. As with co-dominant infestations, care should be taken to avoid removing or damaging co-occurring native species.

Subdominant RCG infestations should be prioritized for control and management. Early detection and prevention is critical to controlling the spread of RCG and subdominant patches can indicate RCG encroachment. Once established, RCG monocultures and co-dominant patches are difficult to control and eradicate. It is therefore pertinent that minor infestations and newly established RCG plants be removed as soon as they are detected.

Volunteer Support

As a small not-for-profit environmental stewardship society, the CVPWS relies on individual volunteers and volunteer stewardship groups to assist during various stages of habitat restoration projects. Controlling and managing RCG is a time consuming and labour intensive process and may not possible without volunteer labour and support. It's recommended that volunteer support be solicited for the following activities:

- Mowing and mulching
- Acquiring, preparing and installing cardboard shading
- Harvesting, preparing and planting live stakes
- Manual excavation of individual plants and small patches

Additional Considerations

Disposal

RCG is a hearty and vigorous plant. Rhizomes and stems can develop new roots if they remain in contact with moist ground. To avoid this, plant material that has been manually excavated should be removed from the site and properly disposed of. In terms of larger scale excavations (e.g., excavation of large monocultures), offsite disposal is likely not feasible, however adequately shading exposed plant material will reduce the likelihood of the plants reestablishing.

Early detection and prevention

As mentioned above, early detection and prevention is critical to controlling and managing the spread of RCG. Early detection and prevention should involve updating the RCG inventory for the K'ómoks Estuary and highlighting new infestations and areas where RCG is encroaching. Special attention should be paid to areas where RCG is encroaching onto sensitive plant communities, such as the south east portion of Hollyhock Marsh).

Archeological considerations

Prior to any manual and machine excavation activities, an archaeologist should be consulted as to whether archeological oversite is needed in areas that might have cultural values and the potential to unearth cultural artifacts. Onsite archaeological monitors may be required.

Upstream infestations

The most common vector for RCG seeds and rhizome fragments is water (Tu 2004). If RCG infestations upstream of areas where control and management activities are occurring are left unchecked and unmanaged, seeds and rhizome fragments could travel downstream and reestablish. Therefore it is important to consider any impacts that upstream RCG infestations may have on downstream control and management activities.

Desired plant community

The nature of the desired plant community is another key consideration when deciding on a control/management approach. For example, if the natural plant community (i.e., the plant community that existed prior to RCG infestation) was a mix of native grass, sedge and rush species, live staking with willow would not be an appropriate technique because the willow stakes reduce the ability for the native species to reestablish. Mowing and shading would be more appropriate techniques. Alternatively, if establishing desirable trees and shrubs is the long term goal, then excavation and live staking would be an appropriate management action.

Monitoring

On-going monitoring is required throughout all stages of control and management activities. It's recommended that areas where RCG treatment has occurred should be resurveyed once a year in the spring to determine how well the treatments area working and if any follow up treatment is required. Monitoring should involve photo documentation (see Photo station monitoring below), and vegetation classification based on the level of RCG dominance (i.e., monoculture, co-dominant, subdominant). On-going monitoring efforts are needed until the seed bank is depleted.

Photo station monitoring

Photo Station Monitoring is recommended for monitoring the success of RCG control and management activities Photo station monitoring involves taking repeat oblique photographs of the whole site from the same azimuth (compass bearing) and easily described photo-station. The goal is for each photo to capture exact same image each year (i.e. same location, same azimuth). Mike Wright, from M.C. Wright and Associates Ltd. generously provides the CVPWS with their custom NCompas Photo Station Monitoring App. The App allows the user to collect photos from a mobile device, associated specific data (including comments) with each photo and sync collected photos and data directly into a database. Photo station should be established prior to any treatment so that the before/after images can be compared.

Unfortunately there is no quick way to convert an RCG infestation into a native plant community. However, if control and management activities are undertaken and consistently applied, even highly infested areas can be restored to more desirable and diverse plant communities and much can be accomplished within 2-3 years.

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Commented [OA1]: Do you have any info on the EWG meeting that Ernie presented at? I couldn't find anything in the minutes/agendas