A SURVEY OF OREGON COASTAL WETLAND RESTORATION AND CASE STUDY ON FISH MONITORING

by

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A THESIS

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A survey of three Oregon coastal wetland restoration projects is presented: Tillamook Bay, Salmon River, and Coos Bay. A conceptual framework was used to compare different human impacts on coastal wetlands, driving forces behind restoration, restoration strategies or methods, and post-restoration monitoring. An integrated watershed approach is likely to be more effective than piecemeal efforts. A case study on monitoring of coastal wetland restoration, at South Slough in Coos Bay, is presented. Initial results show that coastal wetland restoration is beneficial for fish. However, long-term monitoring is necessary to determine restoration success, and monitoring strategies need to be refined in the future.

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CHAPTER I

INTRODUCTION TO COASTAL WETLAND RESTORATION

This thesis presents a survey of three Oregon coastal wetland restoration projects: Tillamook Bay, Salmon River, and Coos Bay. A conceptual framework was used to compare different human impacts on coastal wetlands, driving forces behind restoration, restoration strategies or methods, and post-restoration monitoring. The comparison provides insight into how individual wetland restoration projects should be incorporated into a watershed scale management plan. In addition, short-term results from a case study on monitoring fish response to tidal marsh restoration at South Slough National Estuarine Research Reserve (NERR) offer initial insight into how coastal wetland restoration is benefiting fish populations. The long-term data collected at South Slough can be incorporated into a watershed scale assessment of ecosystem health in Coos Bay.

Coastal Wetland Structure and Composition

Coastal wetlands, also known as tidal salt marshes or tidelands, are extremely productive ecosystems due to nutrient input from tidal and fresh water influx and abundance of water (Mitsch and Gosselink 1993). Situated on shorelines and along estuaries, coastal wetlands experience a mixing of salt water from the ocean and fresh water from upstream runoff. Tidal flooding is crucial in obtaining a balance between salt and fresh water in coastal wetlands. Salt marshes exist over a wide salinity range, from the high intertidal zone to the nearly fresh water upstream tributaries of the estuary (Lewis 1994). Humans have developed these estuarine shorelines and have altered coastal wetlands over a broad tidal range.

The structure of estuarine marshes along the Pacific Northwest coast is unique and unlike those in California. Fresh water is a dominating factor in forming vegetation communities. Low marshes are regularly flooded by the tide and feature a wide variety of plant species, such as Lyngbye's sedge (*Carex lyngbyei*), tufted hairgrass (*Deschampsia caespitosa*), pickleweed (*Salicornia* spp.), rushes (*Juncus* spp.), and arrowgrass (*Triglochin* spp.) (Knutson and Woodhouse 1982). Flooding of high marshes does not occur regularly, and lack of tidal inundation and the evaporation of most standing water causes a high soil salinity concentration. Saltgrass (*Distichlis spicata*) is a common species in the high marsh (Knutson and Woodhouse 1982). Tidelands that become exposed at low tide and support no vegetation are called mudflats. These tidelands provide habitat for benthic (bottom-dwelling) organisms, such as oysters and flatfishes.

Coastal Wetland Function

From a human perspective, coastal wetlands have several key functions, including storm abatement, water quality enhancement, fish and wildlife habitat, recreational value, and scientific study (Mitsch and Gosselink 1993). Storm surges affecting the coast are buffered by wetland vegetation. Wave energy is dissipated thereby reducing shoreline erosion. Natural tidal marshes can shelter inland developed areas better than manmade seawalls or other storm protection devices (Mitsch and Gosselink 1993). Water quality can be enhanced by natural filtration through tidal salt marshes. Pollution and runoff from agricultural and industrial areas, such as sediment, heavy metals, toxic organics and nutrients, are trapped and absorbed by wetland vegetation (Coats and Williams 1990). Thus, coastal wetlands act as a natural, cost-effective water treatment system.

In addition to physical and chemical functions, coastal wetlands have many biological functions. Tidal marshes provide important habitat for many species of fish and wildlife. Benthic macroinvertebrates inhabit tidal salt marshes and feed upon detritus produced from wetland vegetation. Invertebrates including amphipods, copepods, and chironomids serve as prey species for juvenile salmonids. Marsh vegetation may provide fish with refuge from predation, as well as a food source (Levings et al. 1991). Certain species of juvenile salmon, such as fall chinook, require up to two months residence time in the estuary (Shreffler et al. 1990). Estuarine residence is necessary for juvenile salmon to biologically adapt to salt water, prior to their seaward migration. Therefore, tidal marshes provide cover and food for these juvenile fish, as well as off-channel shelter during periods of high flow. Commercial fish species may spend part of their life cycle in coastal wetlands. Commercial shellfish species are abundant and harvested to provide major economic income. Coastal wetlands provide food and shelter for waterfowl. Wading and marsh birds, such as herons and egrets, are permanent residents in coastal wetlands, searching for prey in tidal creeks, mudflats and other areas of shallow water (Zentner 1982).

Coastal wetlands have important recreational functions in addition to ecological functions. Clamming is a popular use of marshes. Recreational fishing and bird watching are also prevalent in wetlands. The abundance of waterfowl found near wetlands makes hunting another popular sport. Educational and research opportunities abound in tidal marshes. Wetlands also possess aesthetic value that is difficult to quantify.

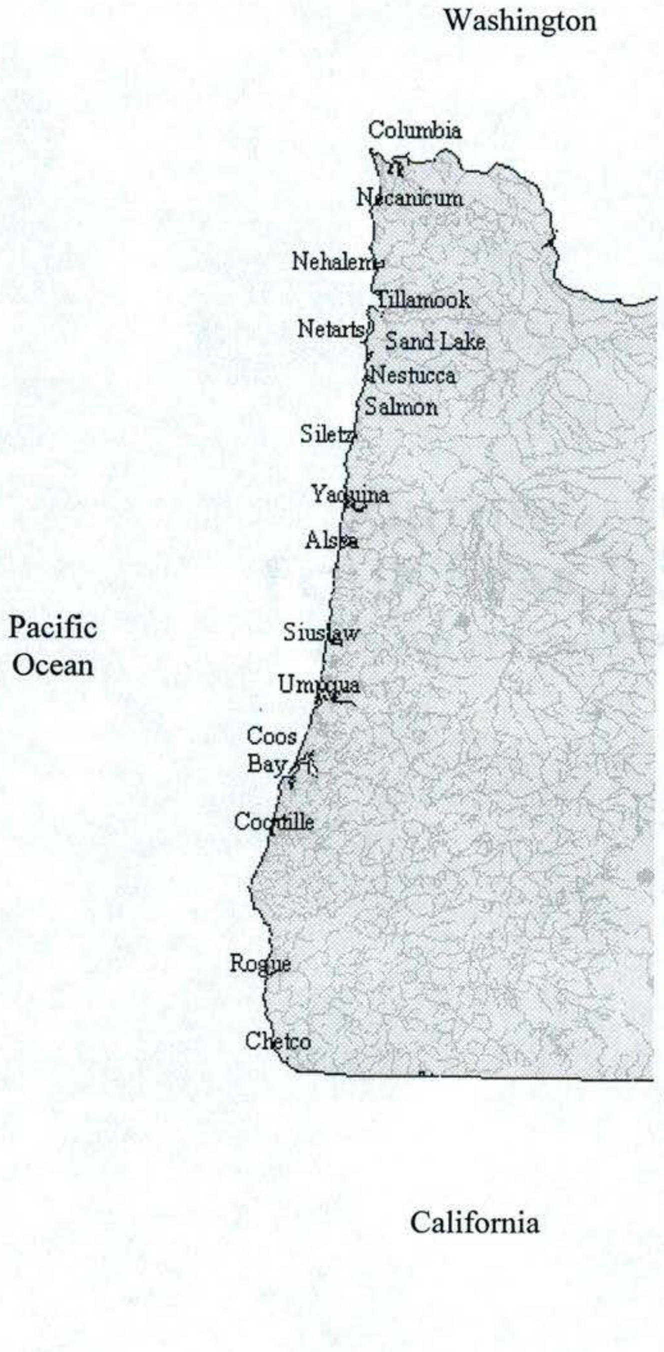
Mitigation or Restoration

In the past, wetland mitigation has been performed to compensate for losses due to development, according to the national "no net loss" policy. The policy was established at the request of the U.S. Environmental Protection Agency during a National Wetlands Policy Forum in 1987. Although there is no specific national wetland law per se, all federal agencies are responsible for ensuring no net loss of wetlands (Mitsch and Gosselink 1993). Recently however, state and federal government, as well as non-profit organizations, have begun performing coastal wetland restoration for ecological purposes rather than mitigation. The primary difference between mitigation and restoration is the driving force behind the activity. Several other differences will be illustrated and compared in Chapter II. One popular method of restoration is dike breaching; two examples of this type of restoration are presented in the survey of Salmon River in Chapter II and in the South Slough case study in Chapter III.

The state of Oregon established the Land Conservation and Development Commission (LCDC) in 1973 for better land use planning. The LCDC adopted four goals specific to Oregon's coastal zone in 1977. The estuarine resource goal is to "maintain the integrity of the estuarine ecosystem by retaining the quantity and quality of estuary lands" (Jackson 1991). Figure 1 illustrates the geographic location of major estuaries on the Oregon coast. Oregon's estuaries are classified in one of two categories: "natural" and "development". The primary management goal of natural estuaries is protection and conservation of estuarine lands with insignificant alteration. Development estuaries are characterized by human structures such as dredged shipping channels and jetties. These estuaries are further broken down according to shipping potential, as either shallow draft or deep draft (Jackson 1991).

The federal "no-net-loss" of wetlands policy applies to both types of estuaries. In terms of development-class estuaries, any alteration of wetlands must be compensated through mitigation. Mitigation is loosely defined as the "creation, restoration, or enhancement of an estuarine area to maintain the functional characteristics and processes of the estuary, such as its natural biological productivity, habitat and species diversity, unique features and water quality" (Jackson 1991). The definition itself uses three terms that have different meanings: creation, restoration, and enhancement. Creation describes establishment of wetlands in an area previously devoid of them. Restoration involves improvement of degraded wetlands to yield better structure and function. Enhancement is the further improvement of functioning wetlands.

FIGURE 1. Location of major estuaries on the Oregon coast (Oregon Department of Land Conservation and Development 1999)



Mitigation has been criticized in recent years due to concern over failure of these types of compensatory projects. Successful mitigation can be defined as "providing a habitat that is functionally equivalent to the one that will be lost" (Zedler 1996). Unfortunately, most mitigation projects are not functionally equivalent to the impacted wetlands prior to development. Mitigation to replace different habitat requires greater compensation than a one-to-one ratio. To attempt to compensate for this reduced functionality, mitigation ratios are between 1:1 and 4:1; in other words, for every acre of wetland lost, between one and four acres of mitigation should occur. This increased ratio compels developers to attempt to replace the habitat that was impacted. If different habitat is to be created, then the mitigation site must follow the ratio and provide more wetland acreage than the impacted site.

Another concern is whether the mitigation site should attempt to duplicate the impacted wetland habitat it is meant to replace, or whether creating different marsh types in an alternate location is more appropriate. If the former is desired, natural reference sites in the vicinity of the mitigation projects are needed to judge wetland restoration progress, as historical information may be unsuitable or unreliable. Mitigation is currently interpreted as equal tradeoff in that historic wetlands can be filled and developed while creating new ones in a different location (Zedler and Powell 1993). Since mitigation sites can be scattered throughout a watershed, there is concern over how these projects function ecologically as a whole. A new approach to improve project success is mitigation banking, whereby new wetlands are created in a central location and must demonstrate functioning before historic wetlands are impacted (Zedler 1996). The development interest would purchase credits from the bank in exchange for compensatory mitigation. When the fill project is small in area (e.g. one acre), mitigation banking is a preferable alternative to in-kind mitigation. The first mitigation bank in Oregon was established in 1987 near Astoria. The Astoria mitigation bank is comprised of a 33.8-acre diked pasture that will eventually returned to functioning tidal marsh (Jackson 1991).

Mitigation is a type of restoration, but the impetus for these compensatory projects is development. Policy drives mitigation and requires developers to compensate for impacted wetlands. On the other hand, wetland restoration can be performed for the sole purpose of improving structure and function of the ecosystem.

Chapter II presents a survey and comparison of three Oregon coastal wetland restoration projects: Tillamook Bay, Salmon River, and Coos Bay. A conceptual framework was used to compare different human impacts on coastal wetlands, driving forces behind restoration, restoration strategies or methods, and post-restoration monitoring. The comparison provides insight into how individual wetland restoration projects should be incorporated into a watershed scale management plan. A case study on monitoring of coastal wetland restoration, at South Slough in Coos Bay, is presented in Chapter III. Initial results indicate that tidal marsh restoration is benefiting fish. Long-term data collected at South Slough can be incorporated into a watershed scale assessment of ecosystem health in Coos Bay.

CHAPTER II

A SURVEY OF OREGON COASTAL WETLAND RESTORATION

Introduction

This chapter presents a survey of three Oregon estuaries that have undergone coastal wetland restoration: Tillamook Bay, Salmon River, and Coos Bay. Each estuary represents a wide range of conditions in terms of geography, human impacts, and management. The survey is followed by a comparison of the three estuaries, and both combine to answer the following:

- How are various agencies or organizations involved with coastal wetland restoration?
- What are some typical management goals or methods for coastal wetland restoration?
- How are coastal wetland restoration projects funded?
- What monitoring projects have been implemented following restoration?

This comparative framework provides a basis for determining how Oregon is restoring coastal wetlands, how improvements can be made to existing projects, and how future restoration should be structured. Individual restoration projects need to be incorporated into a large scale management plan to ensure health of the entire watershed.

Tillamook Bay

Introduction

Tillamook Bay is the second largest estuary on the Oregon coast, with a total surface area of approximately 8,700 acres (Oregon Coastal Conservation and Development Commission (OCCDC) 1974). It is located in central Tillamook County approximately 50 miles south of the Columbia River (Figure 1). The three major towns in the area are Garibaldi, Bay City, and Tillamook. The Tillamook Bay basin has a drainage area of approximately 540 square miles (Seliskar and Gallagher 1983) and is fed by five main river drainages: the Miami, Kilchis, Trask, Wilson, and Tillamook rivers. These rivers deposit extensive amounts of sediment into the estuary, with an estimated annual river load of 135,000 tons (OCCDC 1974). Tillamook County derives the majority of its income from forest products and dairy farms. Severe impacts on the estuary have resulted from human activities such as dairy farming, logging, and filling, diking, and dredging of wetlands (Nehlsen 1997). Forty to fifty percent of the estuary is a mixture of different marsh types. Fifty to sixty percent of the estuary is tidelands, and oyster culture is a major economic activity; Tillamook Bay produces approximately 80 percent of Oregon's oysters (Akins 1973). Extensive sedimentation has filled in much of the estuary, creating expansive areas of shallow water. In 1994, it became one of the 28 sites of the U.S. Environmental Protection Agency's (EPA) National Estuary Program (NEP). The NEP was established in 1987 to identify, restore, and protect nationally significant estuaries of the United States. Although the EPA is the administrative body, the NEP is operated through interdisciplinary cooperation by citizens, local government officials, representatives from other federal agencies, academic institutions, and industry (U.S. EPA 1999).

Agency and Citizen Involvement in Restoration

The Tillamook Bay National Estuary Project (TBNEP) Management Committee is responsible for developing science-based, multidisciplinary management plans (TBNEP 1998). Since the TBNEP is relatively new, comprehensive project results were not available at the time of this publication. Members of the TBNEP Management Committee include representatives of local, state, and federal government, as well as non-governmental organizations. Tillamook County government members from Community Development, Health, and Coastal Planning Departments are involved in the planning process. Several Oregon state government agencies are participating as well, including the Oregon Department of Agriculture (ODA), Oregon Department of Environmental Quality (DEQ), Oregon Department of Fish and Wildlife (ODFW), Oregon Department of Forestry (ODF), Oregon Department of Land Conservation and Development (DLCD), Oregon Division of State Lands (DSL). The EPA and Natural Resource Conservation Service (NRCS) represent federal government interests in Tillamook Bay. Local communities and industries are represented in the TBNEP Management Committee by commercial fishing and shellfish interests, dairy representatives, and citizen action chairpersons. Finally, Oregon State University Extension Services in Tillamook County provide academic support. Each agency or organization has its own stake in the future of

Tillamook Bay and is therefore represented in the management process. These different goals may lead to conflicts over how restoration should proceed and what impacts it will have on various human groups. Issues such as dredging will continue to spark debate. However, the organizations involved with the planning process all share the common long-term goal of restoring Tillamook Bay (Bacon 1994).

The TBNEP Management Committee concluded its role as Tillamook Bay steward in December 1998 with the development of a Comprehensive Conservation and Management Plan (CCMP). Upon approval by the Governor of Oregon, the TBNEP will evolve into the Tillamook Performance Partnership. The CCMP will be administered by this local, state, and federal partnership.

The Oregon Plan seeks to "restore coastal salmon populations and fisheries to productive and sustainable levels that will provide substantial environmental, cultural, and economic benefits" through local efforts and voluntary cooperation between public citizens, private interests, local, state and federal government agencies, and academic. Interdisciplinary watershed councils are responsible for developing local action plans and monitoring programs. Although the Oregon Plan currently focuses on restoring endangered coho salmon in coastal river basins, it will be expanded to include all anadromous fish statewide (Oregon Plan 1999). The CCMP supports the Oregon Plan in terms of monitoring salmonid populations in freshwater habitat. The three restoration efforts discussed in this thesis started before the Oregon Plan was developed, but likely will be influenced by the plan in the future.

Management Goals

The CCMP identifies four major problems and an implementation strategy to achieve realistic solutions. Follow-up of implementation involves education and community development, project monitoring, and citizen involvement. The four areas of concern addressed in the CCMP are critical habitat, erosion and sedimentation, water quality, and flooding. Table 1 summarizes the targets and objectives of each goal.

Critical Habitat

The critical habitat goal targets the restoration of healthy stocks of salmonids, shellfish, and other aquatic species (TBNEP 1998). Several objectives are set forth to accomplish this goal. The objectives are intended to constitute an ecosystem approach to restoring aquatic life in Tillamook Bay and its watershed. For instance, protection and enhancement of riparian zones improves spawning habitat for adult salmonids. Estuarine improvement includes conservation and restoration of tidal wetlands and eelgrass beds.

Erosion and Sedimentation

Erosion and sedimentation goals also aim to improve salmonid habitat by reducing sediment input and achieving water quality standards. Forestry and associated activities are targeted as sources of sediment. Objectives include improvement and maintenance of forest roads on state and private lands, as well as decommissioning some roads. Timber harvest practices such as clearcuts and logging on steep slopes are to be

TABLE 1. Tillamook Bay CCMP goals and targets (TBNEP 1998)

Goal: Critical Habitat – restore healthy stocks of salmonids, shellfish, and other aquatic species

Targets:

- Enhance 200 miles of forested riparian habitat to meet TBNEP standards as defined for healthy riparian condition by 2010
- Manage 90% of upland riparian zones to meet state forest Habitat Conservation Plan (HCP) requirements
- Enhance 100 miles of upland instream habitat by 2010
- Enhance 500 miles of continuous riparian habitat in the 0 – 500 foot elevation band to healthy condition by 2010
- Upgrade 50% of all tidegates by 2010 to allow fish passage
- Conserve and restore 750 acres of tidal wetland by 2010
- No decline in eelgrass beds due to degradation or loss
- Achieve an improved climate for fisheries practices and regulatory actions
- Achieve wild fish production and spawner escapement goals set by ODFW for Tillamook Basin rivers

Goal: Erosion and Sediment – reduce sediments to meet salmonid habitat requirements and achieve water quality standards

Targets:

- Upgrade 1400 miles of forest roads by 2010 on state and private lands
- Decommission 50 miles of forest management road by 2010
- Conduct road maintenance activities on all 2000 miles of forest management roads annually
- Limit the amount of forested lands in clearcuts to no more than 1/8th of the total forest lands in the watershed
- Conduct a risk analysis on 95% of proposed high risk timber harvesting sites on slopes of 80% or greater
- Manage 67% of the watershed's privately-held, forested riparian areas under HCP standards
- Assess 90% of upland county and state roads, both paved and unpaved, for their sediment contribution by 2002
- Control erosion from all construction and development in urban areas by 2003

TABLE 1. (continued)

Goal: Water Quality – achieve water quality standards for fecal coliform bacteria (FCB) in the rivers and the Bay by 2010; achieve in-stream temperatures and suspended sediment concentrations that meet salmonid habitat requirements by 2010

Targets:

- Achieve at least a 25% reduction in FCB and sediment loads to rivers (Apparent decreasing trends by 2005. Statistically significant results by 2010)
- Achieve at least a 25% reduction every four years in the number of days that the rivers are not in compliance with water quality standards for FCB
- Achieve Senate Bill 1010 Plan compliance among 100% of livestock operations by 2010
- Achieve routine annual inspections of 100% of the CAFOs (confined animal feedlot operations) by 2004
- Achieve total compliance with National Pollution Discharge Elimination System (NPDES) permits for wastewater treatment facilities by 2002
- Reevaluate commercial shellfish harvest area classifications and closure criteria annually

Goal: Flood Mitigation and Management

Targets:

- Develop a hydrologic model by year 2000
- Complete 20 projects within two years from hydrologic model development which:
    - Reduce runoff rate in the watershed's uplands
    - Alleviate drainage problems in the watershed's lowlands
    - Increase floodplain storage capacity in the watershed's lowlands
    - Improve the natural environment's capacity to withstand or benefit from flood events
- Raise at least 55 houses to a level at least 3 feet above the 100-year flood elevation by year 2010
- Construct 18 cow pads in flood prone areas to protect livestock during major floods by 2000
- Increase percentage of compensated damages from flood events

curtailed and reassessed. Erosion from urban construction and development is to be controlled as well.

Water Quality

Water quality improvement requires compliance from several groups. The goals set for 2010 are to achieve water quality standards for fecal coliform bacteria (FCB) in rivers and Tillamook Bay and to meet salmonid habitat requirements in terms of stream temperature and suspended sediment (TBNEP 1998). The major polluters of Tillamook Bay targeted by the CCMP are livestock and dairy operators, commercial shellfishers, and wastewater treatment facilities. Better management of waste from farms and confined animal feedlot operations (CAFOs) are central to improving water quality.

Flooding

Flood mitigation and management is the fourth goal of the CCMP. Although this goal directly benefits humans economically compared to the other three, it is still valuable in terms of increasing floodplain storage capacity and habitat restoration. The primary objective is to develop a hydrologic model by 2000. After the model is developed, several projects are planned to restore the natural flood capacity of the Tillamook Bay watershed. Furthermore, improvements to existing structures will provide safer conditions during floods, such as elevating or relocating flood-prone structures and constructing cow pads.

Project Funding

The majority of funding for the Tillamook Bay National Estuary Project comes from federal sources. The Natural Resource Conservation Service (NRCS), formerly known as the Soil Conservation Service, was created in 1935 in conjunction with the Soil Conservation Act. This law put NRCS in charge of providing conservation assistance to farmers, ranchers, and other private landowners. The agency is committed to helping private land owners care for their property by helping them understand the importance of conservation and through voluntary stewardship. These goals are accomplished by providing natural resource inventories and planning and technical assistance (TBNEP 1998a).

The NRCS administers the U.S. Department of Agriculture (USDA) Farm Bill programs for the North Oregon Coast Basin through Tillamook. Two Farm Bills have been introduced within the past two decades. The 1985 Farm Bill established federal farm program benefits for private land owners participating in voluntary stewardship. Activities include soil and wetland conservation, and the NRCS provides assistance in terms of delineating wetlands on private lands. The 1996 Farm Bill created new voluntary, incentive-driven conservation programs.

Six Farm Bill programs are providing funding for the Tillamook Bay National Estuary Project. The Environmental Quality Incentives Program offers planning, technical and financial assistance for water quality projects. Farm owners must provide NRCS with a comprehensive farm plan prior to the awarding of funds. NRCS awards approximately $200,000 per year to landowners, and the funding provides for improving practices such as manure management (TBNEP 1998a).

The Wetland Reserve Program was created with “no net loss of wetlands” as its primary objective. The program provides financial assistance through 100% cost-sharing for permanent easements, 75% for 30-year easements, 50% for restoration cost-share agreements, plus a percentage of the agricultural value of the land (TBNEP 1998a). By offering private landowners financial incentives, permanent and long-term conservation easements on private wetlands will have a better chance of being eventually restored. However, limited funding has made the program very competitive. The conditions for the program are the applicant must own land for at least one year, and wetlands must be impacted and not naturally functioning (TBNEP 1998a).

The Wildlife Habitat Incentive Program provides cost-sharing for private landowners. The objective is to develop habitat for upland and wetland wildlife, endangered species, and fisheries. The Forest Incentives Program assists landowners with private timber land management. The program pays up to 65% of the costs of tree planting, sustainable forest practices, and stand improvements on non-industrial private lands (TBNEP 1998a). This will provide a sustainable yield of timber while allowing for conservation of soil and protection of water quality, as well as improved wildlife habitat.

The Conservation Reserve Program provides financial incentives to farmers and ranchers. The program encourages farmers and ranchers to plant vegetation, such as native grasses, trees, and riparian buffers, on open fields and areas prone to erosion. NRCS pays farmers an annual rental payment for the term of a multi-year contract, usually 10 to 15 years. The program also provides cost sharing to assist with vegetative cover practices (TBNEP 1998a). Farmers must identify marginal pasture lands that can be converted to riparian buffer zones in order to qualify for the program. Incentives to convert cropland to riparian or native vegetation allow farmers to promote conservation on their property while giving up minimal farmland. The Conservation Reserve Enhancement Program (CREP) would increase the rental rate of farmland through additional USDA funds. These funds would go directly to the State of Oregon, and higher rental rates would increase the incentive for farmers to join the Conservation Reserve Program (TBNEP 1998a).

There are six other funding opportunities currently being pursued by the TBNEP, and other funding sources may arise in the future. The federal government is also the major source of funding besides the NRCS Farm Bill programs. This is perhaps due to the fact that the EPA oversees all National Estuary Project sites. Tillamook County Soil and Water Conservation District (SWCD) received an EPA grant of $425,000 for the Methane Energy and Agriculture Development (MEAD) project. This SWCD Revolving Loan Fund provides money to participants in the MEAD project. The "revolving" aspect of the loan means that once the MEAD loans are paid back, the grant funds will be available to landowners for water quality related projects (TBNEP 1998a). The Transportation Equity Act for the 21st Century (TEA-21) provides nationwide funding for improvements in transportation infrastructure, economic growth, and environmental protection. Over $200 billion is allocated to improve air and water quality, restore wetlands and native habitat, and improve urban areas through transportation redevelopment. In terms of water quality, specific improvements possible under TEA-21 include road maintenance and upgrades, and watershed enhancement projects in critical road areas. Finally, the U.S. Army Corps of Engineers funds flood control and habitat restoration projects through a program known as Challenge 21 (TBNEP 1998a).

State and local funding is also being pursued by TBNEP. Project Impact provided $250,000 seed money to develop Tillamook County into a Disaster Resistant Community. The project provided startup funds for the flood hazard mitigation projects detailed earlier. TBNEP is currently pursuing Governor's Watershed Enhancement Board (GWEB) grants. These grants provide funding to establish and staff watershed councils as well as develop specific watershed assessments, action plans, and restoration projects. The Northwest Oregon Economic Alliance (NOEA) represents a partnership between Tillamook, Clatsop and Columbia Counties in northwest Oregon. These rural communities have joined together to develop an economic strategy focused on forest products, environmental services, and tourism. The Alliance, as part of the state's Regional Strategies and Rural Investment Fund program, will allocate money for job creation in rural communities, thus leading to improvements in the local economy (TBNEP 1998a).

Monitoring

The TBNEP has established two levels of monitoring: implementation and effectiveness. Implementation monitoring essentially takes note of the status of actions outlined in the CCMP. Thus, it could also be referred to as administrative monitoring, in the sense that accountability for specific actions can be documented and tracked. Organizations responsible for executing CCMP directives are “monitored” through the implementation system. This accountability will be made available to the public and government agencies via the World Wide Web and a Geographical Information System (GIS).

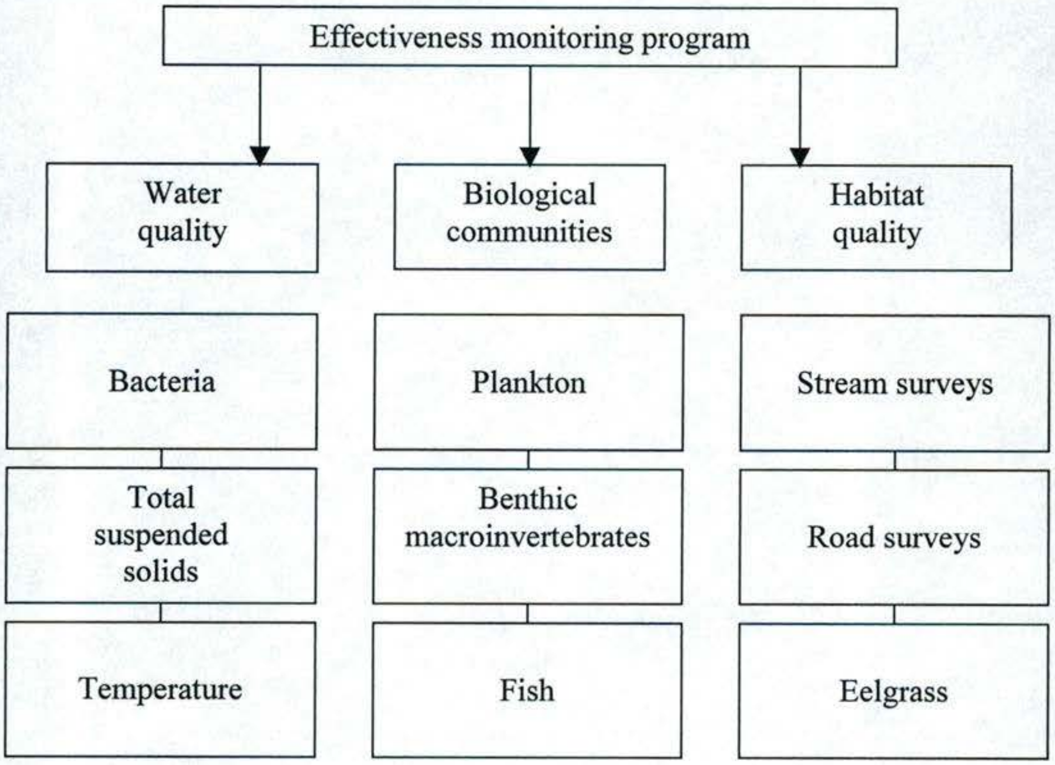
Effectiveness monitoring seeks to answer questions regarding the ecological status of Tillamook Bay. It is a multi-tiered system that will indicate whether the environment is changing, and whether it is improving or declining. Thus, effectiveness monitoring will gauge the success of implemented CCMP measures. The effectiveness monitoring program is incorporating strategies from the Oregon Plan for Salmon and Watersheds, the North West Oregon State Forests Management Plan, the establishment of total maximum daily loads, Senate Bill 1010, and the Shellfish Management Plan (TBNEP 1998b).

The TBNEP effectiveness monitoring program tracks three main issues: water quality, sedimentation, and critical habitat (using salmonids as an indicator species). The program monitors a set of individual parameters that collectively represent the ecosystem. These include: water quality (fecal coliform bacteria, total suspended solids, temperature), biological communities (plankton, benthic macroinvertebrates, fish), and habitat quality (stream surveys, road surveys, and eelgrass). Figure 2 illustrates the hierarchy of the monitoring program. Besides ecosystem-wide monitoring, the program will investigate fine scale problem areas, such as low dissolved oxygen in sloughs (TBNEP 1998b).

Water Quality

Under Section 303(d) of the Clean Water Act, DEQ is responsible for identifying those bodies of water that are quality impaired. In the Tillamook Bay basin, several rivers are listed as "impaired" for bacterial contamination and/or temperature; some other water bodies are listed as "being of concern" for aquatic habitat, flow modification, and sediment (TBNEP 1998b). ODA is responsible for monitoring pathogen concentrations in Tillamook Bay as part of the shellfish harvest plan. High input of bacteria from

FIGURE 2. Effectiveness monitoring program hierarchy.



agriculture can lead to the closure of shellfish harvesting; therefore ODA is pressured by shellfishers to accurately measure pathogen concentrations.

Storm monitoring is crucial for determining seasonal trends in pathogen concentration, since bacterial input into streams occurs mainly during storms. Upstream from the bay in the Tillamook watershed, continuous monitoring data for precipitation and discharge are collected. ODF collects hourly precipitation data, while the US Geological Service (USGS) and Oregon Water Resources Department (WRD) measure stage height on each of the 5 major rivers. Streamflow during two storms per season will be sampled for pathogens, with two to three samples at the forest/agricultural interface and six to eight samples at the lower primary riverine site. In order to determine trends in fecal coliform bacteria (FCB) input, flow-weighted averages for concentration will be plotted over time (number of bacteria per volume of river water). Sampling at 5 to 15 different locations in the watershed during storms will be used to identify land use types as potential sources of FCB. Another type of FCB monitoring involves compliance with standard concentration levels. Weekly, fixed station compliance monitoring will occur at the forest/agricultural interface and the lower primary river site to track the number of days that the 126 *E. coli*/100 mls (recreational contact and shellfish harvesting standard) is met (TBNEP 1998b).

Sediment input into streams from erosion is detrimental to the quality of aquatic habitat. Erosional inputs can stem from forest roads, mass wasting and landslides, and bank erosion. Monitoring of suspended sediments focuses on three critical regions: salmonid spawning and rearing habitat, the lower reaches of the five major rivers, and

Tillamook Bay. Since sediment input is greatest during peak precipitation events, sampling will be performed during storms. These samples will be collected during storm event monitoring for bacteria and other pathogens and will be analyzed for total suspended solids. Annual estimates of total suspended solids (TSS) load per river can be calculated from stream discharge (TBNEP 1998b).

Water temperature is another key aspect of the monitoring program. Salmonids and other aquatic organisms have tolerance limits for temperature. If the water temperature exceeds the maximum tolerance level, it can prove lethal for these organisms. For example, the published value of upper incipient lethal temperature for steelhead (anadromous rainbow trout *Oncorhynchus mykiss*) is about 26°C in streams (Li et al. 1994). Oregon DEQ is responsible for monitoring 60 locations throughout the Tillamook Bay estuary and watershed. Summer temperature monitoring will continue, and winter temperature monitoring will be initiated at critical areas of poor riparian and salmon habitat or low aquatic diversity.

Another monitoring concern involves nutrient increases that could lead to low dissolved oxygen levels in the water. Although present nutrient concentrations in Tillamook Bay and the upper watershed are not high, precautionary alert measures are being taken if nutrient input increases. Therefore, bimonthly sampling on the lower Wilson and Trask rivers will be implemented. These two rivers carry the largest loads of nitrogen and phosphorus, according to previous studies. Low dissolved oxygen concentrations have been measured in some of the smaller streams and sloughs. Special studies are planned to address these specific concerns of high nutrient concentration or low dissolved oxygen (TBNEP 1998b).

Biological Communities

The biotic web of aquatic organisms provides good indication of the health of an ecosystem (Karr et al. 1986). These organisms incorporate biological, chemical, and physical attributes of their surroundings and are excellent indicators of environmental quality. Tillamook Bay has implemented a three tiered biological monitoring system: plankton, benthic macroinvertebrates, and fish. This multi-level system allows scientists to identify problems that stem from several ecological interactions (TBNEP 1998b).

Plankton are classified as either zooplankton (free floating animals) or phytoplankton (free floating plants). Phytoplankton serve as a food source for zooplankton. Zooplankton are consumed by fish and other estuarine organisms. Long term monitoring of planktonic communities is beneficial for several reasons. During a certain season or under specific environmental conditions, different species or communities of plankton will become predominant. These environmental conditions will cause a change in plankton communities, and these changes can serve as a warning sign or indicator of changing ecosystem health. Variables measured in the plankton monitoring system include biovolume, relative abundance, and species identification. The monitoring system was adapted from a similar program in Willapa Bay, Washington. A local oyster grower collects weekly plankton samples at four stations in Tillamook Bay, with each station representing a different water column habitat (TBNEP 1998b).

Benthic macroinvertebrates are bottom-dwelling organisms that are visible to the human eye. These include larval and adult forms of insects and worms. The sampling of macroinvertebrate communities and assemblages in order to assess ecosystem health has been used for approximately 20 years. Some macroinvertebrate taxa are sensitive to ecological disturbances, and their absence may serve as an early indicator of environmental problems long before being noticed in fish populations. They do exhibit sufficient stability in assemblage structure to be used for long-term monitoring despite being sensitive to aquatic conditions (Richards and Host 1994).

Oregon DEQ reported poor benthic community structure in several small freshwater tributaries and streams in the Tillamook Bay watershed. Oregon Trout, a non-profit organization to save wild anadromous fish, started a community-based macroinvertebrate monitoring program in the Kilchis sub-basin. Oregon State University will commence additional benthic community sampling beginning summer 1999 in the Kilchis and Tillamook sub-basins (TBNEP 1998b). In the summer of 1996, ODFW surveyed the Tillamook Bay estuary and wetlands for benthic invertebrates. Grab samples were collected around the bay, and the data revealed absences of important prey species for juvenile salmonids, as well as changes in clam community structure as compared to previous studies (TBNEP 1998b).

Fish monitoring is used to monitor stock size and assess changes in water quality and aquatic habitat. There is increasing interest in using fish assemblages as indicators of ecosystem health, especially in estuaries. The estuary serves as a rich feeding and spawning area for adult fish and as a feeding or rearing area for juvenile fish. The abundance and high diversity of fish in estuarine environments are due to nutrient-rich waters, as well as aquatic vegetation that provides cover for young fish and a suitable chemical environment (Deegan et al. 1997). Anadromous fish experience a vast geographic range during their life cycle and incorporate the effects of water quality and habitat alterations throughout the watershed.

Fish monitoring is occurring in both freshwater and estuarine habitats. The freshwater program operated by TBNEP in conjunction with ODF and ODFW counted outmigrating salmonid smolts. This was accomplished by installing traps on the Kilchis and Wilson rivers. ODFW is also responsible for conducting spawning, resting pool, and creel surveys in the upper watershed (TBNEP 1998b). The ODFW estuarine fish monitoring program is seeking to establish long-term data on changes in habitat conditions within estuaries. Sampling of fish in salt marsh habitat will be the primary focus, since salt marshes will most likely be affected by future habitat restoration programs, such as dike breaching. Fish sampling will be integrated with monitoring of other biological, physical, and chemical parameters within the estuary (TBNEP 1998b).

Habitat Quality

The third component of the effectiveness monitoring program is habitat monitoring. Stream channel and habitat surveys are conducted by ODFW to track in-stream and riparian conditions. The range of spawning and rearing salmonids in the Tillamook watershed is extensive, with over 300 miles of stream surveyed between 1995 and 1998. By surveying streams and riparian habitats, critical segments can be identified and prioritized for restoration and protection (TBNEP 1998b).

Road surveys are another component of the habitat monitoring program. Since the majority of sedimentation input is due to logging roads, it is important to identify these problem areas. ODF is inventorying approximately 900 miles of roads within the Tillamook Forest. This inventory will allow ODF to monitor sediment input on a watershed level and identify necessary road upgrade projects. The road surveys will focus on drainage structures and search for failed culverts that increase sediment input into streams (TBNEP 1998b).

A physical inventory of tide gates in the Tillamook watershed was recently accomplished, and a dike breach assessment was completed to determine where breaching would be a viable restoration method. Three tide gates were replaced with a design that allowed fish passage. No fish were found upstream of the old tide gates, according to baseline surveys. Future surveys will determine whether the new tide gates allow fish access to upstream waters.

Eelgrass (*Zostera marina*) contributes to estuarine water quality and provides habitat for many aquatic organisms, including juvenile salmonids. In fact, juvenile salmon utilize eelgrass beds because of their detritus trapping characteristics, as well as for shelter from predators. Eelgrass carbon contributes significantly to the detritus based food web that supports salmonids (Healey 1982). Eelgrass beds throughout Tillamook Bay were mapped using an airborne imaging system to establish a baseline of bed density and distribution. On-the-ground surveys verified the accuracy of the airborne survey.

Routine eelgrass monitoring should occur every three to five years using this technique since eelgrass beds change distribution over time. Density and area of eelgrass beds are decreasing due to channel dredging and sedimentation. Eelgrass monitoring should incorporate other environmental factors to determine how bed abundance and distribution is being affected throughout the estuary (TBNEP 1998b).

Salmon River

Introduction

The Salmon River estuary is second smallest on the Oregon coast and lies approximately 85 miles south of the Columbia River (Percy, Sutterlin et al. 1974). The mouth of the estuary lies in Lincoln County, just south of the border with Tillamook County. The estuary and wetlands of the Salmon River are part of the Cascade Head Scenic-Research Area (CHSRA), managed by the U.S. Department of Agriculture Forest Service (Mitchell 1981). Approximately 270 acres in area, the Salmon River estuary is quite small compared to the other Oregon estuaries (Wilsey and Ham 1974). The Salmon River basin drains about 75 square miles (Seliskar and Gallagher 1983).

Primary human impacts on the estuary include recreation and agriculture. Human population in the area is light, with centers located in the towns of Three Rocks, Otis, and Rose Lodge. The Salmon River deposits a relatively small amount of sediment in the estuary, estimated at 14,000 tons per year (Percy, Sutterlin et al. 1974). By 1978, about 75% of the Salmon River's 552 acres of tidal salt marsh had been diked for conversion to pasture (Frenkel and Morlan 1991). The remainder of the tidal marsh is mature high marsh. Grazing and cutting of marsh hay are traditional uses of the estuary, along with some filling for residential homes despite the threat of flooding (Akins 1973). Shellfish are recreationally harvested as opposed to Tillamook Bay, which has a strong economic input from commercial harvesting. Overall, human impacts on the Salmon River estuary are light compared to the industrial development in Tillamook Bay and Coos Bay. The comparison of human impacts between the three estuaries is discussed further at the end of this chapter.

Agency Involvement in Restoration

The Cascade Head Scenic-Research Area (CHRSA) was established as the first Scenic-Research Area in 1974 by Congress. The purpose of the dedication was to set aside public lands for human use and enjoyment, as well as scientific research. Six zoned subareas of the CHRSA were established with primary management objectives for each (U.S.D.A. Forest Service 1982). In the Estuary and Associated Wetlands subarea, the long-term goal was rehabilitation of the Salmon River estuary and tidal wetlands and removal of human influences. Functioning of these wetlands was eliminated by agricultural diking. In order to achieve this goal and uphold the "no net loss" policy, the U.S. Forest Service planned and executed a large-scale dike breaching project to restore salt marsh in 1978 (Frenkel and Morlan 1990). The project provided evidence that diked pastureland along the Oregon coast could be returned to fully functioning tidal marsh. Two additional Forest Service dike breaches occurred in 1987 and 1996, and a fourth is being planned for the summer of 1999 (Robert E. Frenkel, pers. comm., 14 Apr. 1999). Restoration of the estuary was an ecologically motivated and deliberate action; the Salmon River estuary was not targeted for mitigation and is not a mitigation bank (Jackson 1991).

Restoration Methods

The objective of the Forest Service was simple and straightforward. Restoration of the estuary was to occur through dike breaching. The Forest Service acquired two diked pastures totaling 22 hectares (approximately 54.4 acres) in 1978. Permanent sampling plots were established on the diked study site to gather baseline data on plant community type and location. Environmental characteristics such as vegetation, soils, and elevation of the diked marsh were compared with those of intact Salmon River marshes, in order to gain pre-breaching baseline data (Mitchell 1981). Bulldozers were used to remove half of the 1550 meter outer dike in the late summer of 1978 (Frenkel and Morlan 1990). Removed dike material was deposited into the inner ditch created when the dike was constructed. A tractor-type backhoe was used to excavate material from tidal creeks that had filled in since diking. This excavation recreated a tidal connection between the formerly diked marsh and the river channel (Mitchell 1981).

Funding

The U.S. Forest Service fully funded the actual breaching and restoration of the Salmon River salt marshes. The Forest Service also funded Diane L. Mitchell, an Oregon State University Ph.D. student "to evaluate the potential for natural salt marsh reestablishment after dike breaching" (Frenkel and Morlan 1990).

The U.S. Environmental Protection Agency (EPA) provided funding for a follow-up study by Frenkel and Morlan in 1990. The objectives of the EPA were "to more fully document the Salmon River salt marsh restoration, more than a decade after initiation, and to develop recommendations for future coastal salt marsh restoration projects in the Pacific Northwest" (Frenkel and Morlan 1990).

Monitoring

Monitoring of the Salmon River estuary restoration has been quite intensive. In 1978-1979, Mitchell (1981) established several transects perpendicular to the river on the north shore. Along these transects, she established permanent plots for long-term monitoring of biological, chemical and physical attributes. Frenkel and Morlan revisited Mitchell's plots a decade later in 1988. Following the second U.S. Forest Service dike breaching in 1987, they established more permanent plots and transects to monitor the reconnected marsh on the south shore.

Extensive data were gathered in the permanent study plots. Four attributes were monitored in the control plots and analyzed for comparison to the study plots. Data gathered for control and study in the north shore plots are summarized in Table 2 below. Note that Frenkel and Morlan did not conduct as detailed a study of soil chemistry as did Mitchell during her earlier work.

During the 1988 south shore monitoring, Frenkel and Morlan performed a more rapid baseline survey due to dike breaching time constraints. Considerably fewer transects and permanent plots were established. The monitoring system was aimed at detecting vegetation trends rather than measure precise numbers.

TABLE 2. Monitoring data collected in study and control plots on north shore of Salmon River (Frenkel and Morlan 1990)

Data collected	Study plots	Control plots
Percent cover of all vascular plant species	✓	✓
Above-ground biomass sorted by species	✓	✓
Color slide photo of vegetation cover plot	✓	
Interstitial soil-water salinity	✓	
Interstitial soil-water pH (Mitchell only)	✓	
Soil texture	✓	
Organic content of soil	✓	
Accretion above 1978 sand-tagged surface (Frenkel and Morlan only)	✓	
Location within transit survey network	✓	✓
Elevation	✓	✓

A nested frequency method was used to assess change in species composition. Random sampling along transects allowed each station to be used as a statistical sample for the entire area. Only species presence or absence was recorded; no estimates of cover were made. Three nested plot sizes, including 0.01 m^2, 0.25 m^2, and 1.00 m^2 were used. Elevation was also measured to assess subsidence and recovery, before and after dike removal (Frenkel and Morlan 1990).

Mitchell (1981) concluded that the Salmon River salt marsh restoration was successful in the sense of establishing good vegetative cover. Furthermore, the previously isolated wetlands have been reconnected with tidal influence. It is apparent that the restored salt marsh will be compositionally and functionally different than the pre-diking salt marsh (Mitchell 1981). Frenkel and Morlan revisited the Salmon River site in 1988 to determine restoration progress. They concluded that "the restored marsh was a functioning part of the estuarine system, largely free from human influence" (Frenkel and Morlan 1990). In addition to the tidal reconnection observed by Mitchell, accretion of riverine and marine sediments was occurring. Natural salt marsh vegetation was established, and marsh birds, mammals, and juvenile fish were observed in the restoration area. However, Frenkel and Morlan determined that restoration was not successful in that it did not meet the Forest Service criteria of "rehabilitation to its condition prior to the existing diking and agricultural use" (Frenkel and Morlan 1990). A return to "pristine conditions" is difficult due to lack of historical data regarding pre-human use of the wetland.

Coos Bay

Introduction

Coos Bay is the largest estuary entirely located in Oregon and is situated on the southwestern coast (the Columbia River estuary is larger yet on the border of Oregon and Washington). The Coos Bay estuary consists of 12,380 acres, of which 6200 acres are in tidelands and 6180 acres are in permanently submerged lands. Over the past 114 years, 5891 of the 6200 acres of tidelands have been deeded to private landowners by the State Land Board. Located mainly in Coos County with a small portion in Douglas County, the Coos Bay watershed drains a total area of 729 square miles (Towner and Emerson 1973). The bay's watershed is drained by four major rivers—the Coos, Millicoma, North Slough, South Slough—as well as by many small streams.

Although the two major cities of Coos Bay and North Bend support only a combined population of approximately 25,100, both are heavily developed and industrialized. Mining was the first major industry established in Coos Bay. In the late 1800's, between 40,000 to 75,000 tons of coal were mined per year (Hoffnagle and Olson 1974). Coal barging was also a historical use of the Coos Bay estuary. Eventually, timber superseded coal as the principal resource in the region. Coos Bay is the second largest port in Oregon and is first in production and shipment of timber products, including pulp, chips, lumber, and logs. Commercial fishing is another major industry in Coos Bay.

Historic losses of wetlands in Coos Bay are high. It is estimated that about 90% of tidelands have been lost throughout the estuary to many different uses, including agriculture, industry, recreation, and residences. Dredge spoils were placed on wetlands both for convenience and to reclaim tidelands for industrial and residential development (Hoffnagle and Olson 1974). Losses due to dredge fill total approximately 1260 acres of wetlands in the Coos Bay estuary. About 155 acres of the filled wetlands are state-owned lands, with the remainder in private ownership. The first landfilling occurred in the late 1800's near Eastside, Oregon, and continued for the next 100 years. The majority of the filling of wetlands that occurred was the depositing of dredged material from Coos Bay; the estuary had to be dredged regularly to maintain the port of Coos Bay. Present use of all filled wetlands is mainly for industrial and residential development, rather than spoils from channel dredging for navigation (Towner and Emerson 1973).

Another common practice was diking and draining of tidal salt marshes for agricultural use. With the marsh cut off from tidal inundation, nutrients became trapped behind the dike and provided for incredibly productive farm land (Hoffnagle and Olson 1974). Many diked pasturelands still remain throughout the Coos Bay watershed, although some of them are no longer being used. This will be discussed further in the South Slough case study presented in Chapter III.

Agency Involvement and Management of Mitigation

Unlike Tillamook Bay and Salmon River, there is no single watershed plan or restoration project for Coos Bay. Rather, management consists of a conglomeration of mitigation projects under several jurisdictions. Under state law, Oregon Division of State Lands (DSL) is the local agency responsible for authorizing remove-fill permits for development projects; the Oregon Land Conservation and Development Commission (LCDC) provides additional input for projects involving dredge and fill (Muretta and Price 1982). Under Oregon's Removal-Fill Law, DSL requires a development interest to obtain one of three types of permit, depending on the wetland impact: remove, fill, or remove-fill. Developers must choose a mitigation site nearby the project site with generally similar ecological attributes. If such a site is not feasible, then mitigation efforts should concentrate on restoring heavily degraded areas or resources found in scarcity compared to historical abundance and distribution (Muretta and Price 1982). In Oregon, mitigation must meet the "no net loss of estuarine values" requirement. Mitigation is defined as "the creation, restoration or enhancement of an estuarine area to maintain the functional characteristics and processes of the estuary, such as its natural biological productivity, habitats and species diversity, unique features and water quality" (Muretta and Price 1982).

The Coos Bay estuary has been heavily developed for commercial, industrial and public uses. Coastal wetland restoration in Coos Bay has been primarily mitigation of lost wetlands, as opposed to restoration for the purpose of reestablishing ecological functioning. Mitigation is driven by development and compliance with regulations whereas the impetus for wetland restoration is recovery of ecological functioning and habitat. This classic conflict between economic development and environmental value is well illustrated in Coos Bay. A case study of restoration for ecological purposes at South

Slough National Estuarine Reserve Reserve is presented in Chapter III. This is currently the sole restoration project in Coos Bay that is not for mitigation. A plan is being discussed in which South Slough staff would perform wetland restoration outside of the Reserve's boundaries, beginning in summer 1999 (Craig Cornu, pers. comm. 11 Apr. 1999). The Coos Watershed Association is another entity that is planning restoration for solely ecological purposes. Although the Coos Watershed Association assists in ecological restoration, it cannot replace governmental management of the watershed (Anne Donnelly, pers. comm., 27 May 1999). A watershed scale management plan for Coos Bay was developed and finalized by the Bureau of Land Management (BLM) in 1994. However, the BLM plan addresses mainly the need for balance between the timber industry and healthy forests (Bureau of Land Management 1999). Although wetland restoration is mentioned in the plan, it is not a primary goal and not the expertise of the BLM.

The work of Shaffer (1999) who researched wetland compensatory mitigation in the Coos Bay estuary provides the bulk of information for the following discussion of mitigation projects in Coos Bay. Timber industries such as Weyerhauser West Coast, Inc. and Diamond Wood Products have applied for DSL permits to develop on wetlands. State and local government agencies, including Oregon Department of Transportation (ODOT) and the Cities of Coos Bay and North Bend, have also mitigated wetlands for transportation-related development projects. Shipping facilities such as Port of Coos Bay and Sause Brothers Ocean Towing require permits and mitigation for filling and development of wetlands to build docks and ports. Even private citizens and organizations like the Coos Country Club have applied for development permits and are required to mitigate for lost wetlands (Shaffer 1999).

Shaffer's research identified 36 DSL permitted wetland mitigation sites in Coos Bay. The majority of these sites involved wetland creation, enhancement, or a combination of the two. Only three sites involved restoration of degraded wetlands, and a few sites involved a combination of restoration and enhancement. Depending on the project site and severity of degradation, creation or enhancement may be easier and more cost effective than restoration of wetlands. Thus, developers may choose to mitigate by creating new wetlands or enhancing existing ones.

In the case of private development, funding to perform compensatory wetland mitigation is primarily provided by the interest itself. However for publicly financed projects, additional sources of funding exist. Under the Water Resource Development Act of 1976, the U.S. Army Corps of Engineers receives funds to support some mitigation projects associated with water dependent development. Federal navigation projects, such as channel dredging, require compensatory mitigation as well. Section III of the Rivers and Harbors Act amendments of 1968 provides funding for mitigation of such projects (Muretta and Price 1982).

Monitoring

The duties of monitoring and maintenance of mitigation projects fall on the local government agency (Muretta and Price 1982). DSL is responsible for monitoring its permitted mitigation projects in Coos Bay. Over 50 percent of the DSL permitted mitigation sites investigated by Shaffer did not have a monitoring plan established. Table 3 summarizes the criteria used by Shaffer to determine WCM (wetland compensatory mitigation) site long-term viability and watershed function success. Approximately 85 percent of the sites were fully or partially functioning as wetlands (Shaffer 1999). Unfortunately, the developer is more likely to complete a mitigation project merely to comply with regulations. Monitoring to determine mitigation success is expensive and time consuming and not considered as part of the mitigation process. Up to five years is required to assess several attributes of the mitigation, including wildlife usage, vegetation, water quality, and tidal circulation (Coats and Williams 1990).

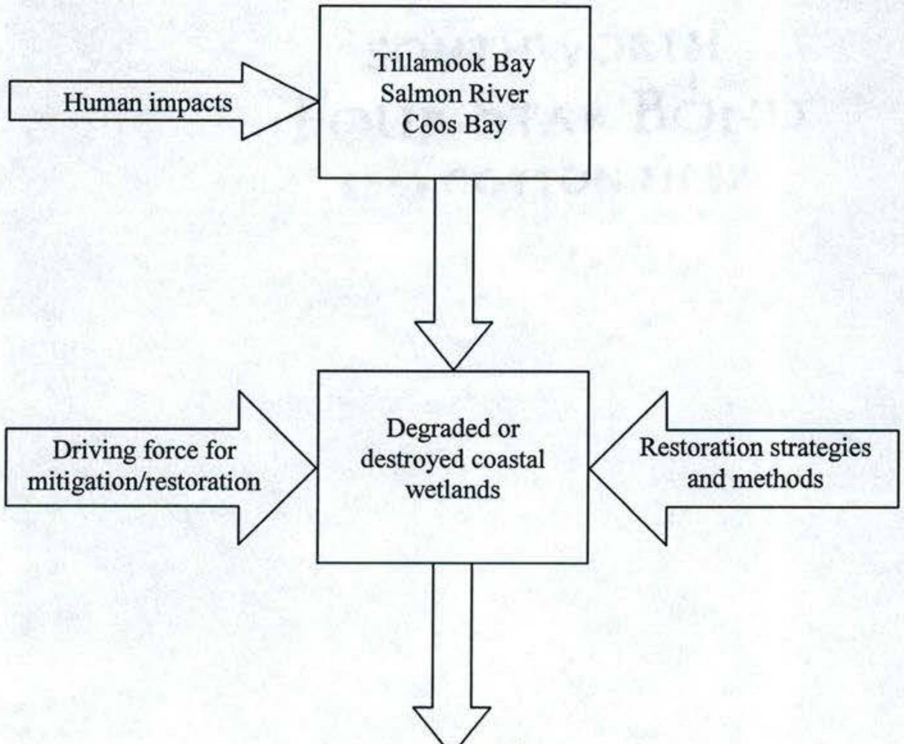
TABLE 3. Criteria used to determine WCM site long-term viability and watershed function success (Shaffer 1999).

- Permit compliance – was the mitigation site in compliance with the DSL permit?
- Within same watershed – were the WCM and impact sites in the same subbasin?
- On-site – was the WCM located on the same site as the impact?
- Proximity to natural sites – was the WCM near natural or developed areas?
- Proximity to other sites – was the WCM within 0.25 miles of another WCM site?
- Equal habitat exchange – was the WCM exchanged for the same habitat impacted?
- Acreage exchange – difference between actual gained acres and proposed lost acres
- Site site > 1 acre – was the WCM project greater than 1 acre in size?
- WCM ratio met – was the acreage and type of WCM (creation, enhancement, restoration, etc.) at the required ratio?
- Functioning as wetland – was the WCM functioning using short-term success assessment?
- Monitoring plan – was a monitoring plan mentioned or currently in place?
- Invasive species – was the number of invasive species: 0, 1-7, or 8-15?
- Protective zoning – is the WCM site surrounded by natural/rural zoning or other?
- WCM type – was the site a creation, enhancement, restoration, or combination of methods?

Comparison of Oregon Coastal Wetland Restoration

A comparison of coastal wetland restoration in Tillamook Bay, Salmon River, and Coos Bay is presented in this section. Figure 3 illustrates the comparative framework used to analyze the three estuaries.

FIGURE 3. Conceptual framework for comparing coastal wetland restoration.



Project Scale and Structure

The three estuaries surveyed represent a wide range of geographic scale on the Oregon coast. Most of the estuaries on the Oregon coast are drowned-river valleys, created by rising sea levels due to glacial melting and flooding of the former river valleys, including the three sites described here (Seliskar and Gallagher 1983). Coos Bay is the largest of the three estuaries, with Tillamook Bay being second largest and the Salmon River estuary being smallest. Table 4 summarizes site acreage.

TABLE 4. Physical areas of the three Oregon estuaries surveyed.

Estuary	Total area covered (acres)	Drainage area (mi^2)
Coos Bay	12,380	729
Tillamook Bay	8,700	540
Salmon River	270	75

The Coos Bay area is also the most industrialized and populated of the three estuaries. However, it lacks the comprehensive management plan that Tillamook Bay and the NEP have adopted. The restoration that is occurring in Coos Bay is primarily mitigation for wetland losses due to development, with the exception of South Slough which will be discussed in Chapter III (Cornu, pers. comm. 11 Apr. 1999). The TBNEP has taken a watershed management approach which takes steps to curb environmental degradation throughout the landscape, as opposed to isolated point source problems. For example, water quality standards for Tillamook Bay have been established that require decreasing aquatic inputs of pollution, agricultural runoff and sediment.

The Salmon River scenario is different from Coos Bay and Tillamook Bay. Geographic scale is an important factor in determining methods of restoration. The Salmon River estuary is quite small and constrained in comparison to the other two bays. It is simpler to perform restoration on a small area such as the Salmon River. Monitoring a few sites is cheaper and more efficient than maintaining several sites throughout the watershed. The multiple dike breaches performed by the Forest Service were simple yet effective methods of wetland restoration accomplished on a small scale. Since the predominant form of human degradation in the Salmon River is diking of wetlands, breaching of these dikes is an appropriate restoration method. Compared to the watershed approach of Tillamook Bay and the mitigation sites of Coos Bay, the Salmon River restoration is simple and straightforward.

Human Impacts

Tillamook Bay and Coos Bay are heavily industrialized and developed, and all three estuaries are heavily diked for agriculture. Table 5 summarizes the principal human impacts on the three estuaries. The Coos Bay estuary channel is deeply dredged to allow access to oceangoing freighters. Spoils from dredging operations are deposited on tidelands, essentially destroying ecological functioning of those wetlands. Commercial and industrial interests proceed to develop on these filled wetlands. The timber industry generates considerable economic profit in Tillamook Bay and Coos Bay. In Coos Bay, the basis for wetland mitigation is destruction of existing functioning wetlands through

TABLE 5. Principal human impacts on Tillamook Bay, Salmon River, and Coos Bay.

Estuary	Human impacts
Tillamook Bay	Dairy farming Diking of wetlands for agriculture Dredging/filling of wetlands for shipping Livestock farming Logging Oyster culture Residential development Timber products
Salmon River	Diking of wetlands for agriculture Recreation Residential development
Coos Bay	Coal mining (historical) Commercial fishing Diking of wetlands for agriculture Dredging/filling of wetlands for shipping Logging Residential development Timber products

development. Therefore, the purpose of mitigation in Coos Bay is to replace lost wetland acreage in accordance with federal no net loss policy and state law.

The shipping industry has also impacted wetland ecosystems in Coos Bay. At 8:28 A.M. on February 4, 1999, an empty wood products freighter named the *New Carissa* ran aground north of the mouth of Coos Bay. Nearly 400,000 tons of heavy fuel were ignited and burned to prevent oil seepage. Despite the burning, the freighter leaked approximately 50,000 tons of heavy fuel (Hunsberger 1999). It is difficult to predict the long term impact of the oil spill on the Coos Bay environment, as well as the economic repercussions on those people who make a living off natural resources in the region.

Agriculture and dairy farming have a greater impact on Tillamook Bay than Coos Bay and make up a considerable percentage of the Tillamook Bay economy. However, the TBNEP is prepared to confront the environmental problems generated by agriculture, as well as other human activities in the area. The Tillamook Bay CCMP is a comprehensive strategy that addresses environmental concerns at various spatial and temporal scales. In other words, it seeks to reduce environmental degradation at specific locations and across the watershed simultaneously. Some restoration activities require more time than others due to gradual changes in policy and technology, such as reduction of agricultural runoff.

The comparison between Tillamook Bay and Coos Bay illustrates the need for comprehensive watershed management in large developed areas. Wetland mitigation at various sites throughout Coos Bay may replace lost wetland acreage but does not yield a functioning ecosystem as a whole. The comprehensive Tillamook Bay plan integrates all aspects of the ecosystem and addresses the watershed's concerns as a whole rather than piecemeal.

The Salmon River estuary was historically diked for agricultural use. Diked and drained tidelands may be ecologically damaged but not destroyed as in the case of filling and development. Dike breaching and reconnection with tidal influence is an ecologically motivated action, although this method of restoration could be part of a mitigation plan as well. Since human impacts on the Salmon River are relatively minor and somewhat reversible compared to industrialization in the other two estuaries, restoration can proceed with less hindrance. There is less conflict between economics and environment than in industrialized areas.

One concern that arises from analysis of these three distinctly different estuaries is how to accomplish environmental goals while minimizing economic disruption. In the case of the Salmon River estuary, economic interests are limited to recreation and pasture farming. Estuarine restoration is able to coincide with these interests although sacrifices of diked tidelands may have to be made. The Coos Bay estuary is heavily industrialized with economic income supplied by logging, timber and shipping industries. Furthermore, these industries possess heavy political influence and are traditional sources of income in Oregon. The problem is persuading these industries to perform mitigation not only for compensation but for environmental reasons. Mitigation of individual sites throughout the Coos Bay estuary does not provide cohesiveness. In other words, present mitigation policies will not improve the overall environmental health of Coos Bay. Mitigation banking may solve the problem of piecemeal restoration but only if a bank is located in the Coos Bay estuary.

Involvement and Funding

The spatial and temporal scale of each estuary's wetland management scheme is reflected in the amount of involvement and funding. Tillamook Bay has a combined effort involving organizations, agencies, and citizens that have a stake in the health of the watershed. The level of involvement and funding for implementation of the CCMP is much higher than that of the Salmon River or Coos Bay restoration projects. The TBNEP recognizes that a healthy environment is the basis for a robust economy. Although Tillamook Bay is not the largest estuary, the scope of involvement and funding is the greatest.

Since the U.S. Forest Service operates the Cascade Head Scenic-Research Area, it has accepted the role of restoring the Salmon River estuary. The Forest Service will continue with stewardship of the Salmon River through dike breaching projects. There are benefits and drawbacks to a single organization restoration effort. One benefit is efficiency in establishing a restoration plan and executing it. Multi-agency cooperation may not be beneficial if timely consensus cannot be reached on restoration or management schemes. However, multi-agency involvement usually implies additional funding, expertise and points of view. The Forest Service is not limited to its own knowledge or capabilities and can solicit assistance from outside sources.

Management in Coos Bay is limited to local and state government agencies like DSL overseeing many mitigation projects. DSL is a regulatory agency; it is the responsibility of the development interest to carry out actual mitigation. This situation is inefficient since the number of mitigation sites in Coos Bay is large, and DSL has limited resources to manage all of them. Additional management is necessary and should involve private development interests and local and state agencies in planning, executing, and monitoring mitigation projects. A cooperative effort working toward the common goal of restoring Coos Bay tidal marshes is more effective than creating disjointed mitigation sites throughout the estuary. The Oregon Plan represents the cohesive, watershed scale approach needed to deal with the multitude of environmental problems facing Coos Bay and other watersheds throughout Oregon. A management plan for the entire Coos Bay watershed has not yet been prepared under the Oregon Plan, although the Coos Watershed Association is getting local communities involved in restoration (Anne Donnelly, pers. comm., 27 May 1999).

Management Goals

Tillamook Bay has a comprehensive management framework that addresses four areas of concern: critical habitat, erosion and sedimentation, water quality and flooding. This framework integrates various levels of government, industry, academia, and public citizenry in achieving set goals. Although economic considerations are included in the CCMP, they are not the focus of the plan. For example, targets in the flood control plan call for additional floodplain storage and ability to withstand flood events. By creating an environment that is able to contain floods, private property will be less prone to damage from rising waters. The Tillamook Bay CCMP is an ecologically based plan with economically driven incentives.

On the other hand, Coos Bay is a major industrial port. Economic considerations are primary in Coos Bay decision-making, and environmental concerns are secondary. The majority of wetland restoration projects in the estuary are for compensatory mitigation to replace marsh lost through development. Mitigation is occurring only to comply with regulations that require lost wetlands be replaced. Prior to compensatory regulations, hundreds of acres of coastal wetlands were destroyed for industrial or agricultural use. Management of tidal marshes is to ensure a “no net loss of wetlands” in the Coos Bay estuary. More non-compensatory restoration projects need to be established throughout the Coos Bay watershed to improve ecological functioning of the entire estuary.

The U.S. Forest Service is restoring ecological functioning in the Salmon River estuary. Three dike breaches in the estuary have reintroduced tidal circulation into former pastureland. Management of the Salmon River tidal marshes is attempting to reverse human impacts of diking and draining for agricultural purposes. Restoration is ecologically driven and non-compensatory. Most of the pastureland is no longer in use and is not maintained. If the land is unused by farmers, it is environmentally and economically wise to return the diked marshes to functioning wetlands rather than let the land remain unutilized.

Monitoring Results and Future Considerations

Monitoring results from 1978 and 1988 in the Salmon River estuary are documented and published. A full scale research program to further investigate dike breaching success and restoration progress will occur in summer 1999; Oregon Department of Fish and Wildlife (ODFW) and University of Washington will jointly administer the program (Robert Frenkel, pers. comm., 14 Apr. 1999). Future projects involving dike breaching can be modeled after the Salmon River site in terms of restoration methods and monitoring strategies. The Salmon River project is a successful example of how a straightforward restoration action can return diked agricultural land to functioning tidal marsh.

Tillamook Bay has recently implemented its CCMP and will be monitoring several variables. Therefore, no considerations for the future can be discussed at present. However, the watershed framework is in place to monitor environmental variables throughout Tillamook Bay. Monitoring burden is shared by all entities involved in management of the estuary. This allows for more frequent sampling at various sites throughout the watershed. In other words, one agency's resources are not strained in monitoring activities. The TBNEP will be responsible for coordination of monitoring activities among these agencies.

Monitoring of mitigation projects in Coos Bay is less detailed than in the Salmon River estuary due to geographic size. Monitoring in Coos Bay is not as comprehensive as Tillamook Bay due to lack of a watershed management plan. Mitigation sites in Coos Bay have individual monitoring plans that are limited in scope. Successful restoration is dependent on an estuarine or landscape scale perspective to determine distribution and availability of habitat restoration sites (Simenstad and Thom 1992). A coordinated mitigation monitoring plan is necessary to be able to gauge restoration of Coos Bay as a whole. In addition, resources to carry out monitoring of mitigation sites are limited to local government agencies in Coos Bay, such as ODFW. South Slough staff would also be involved in monitoring Reserve projects throughout Coos Bay.

Implications for Restoration Project at South Slough NERR

Analysis of the three Oregon estuaries reveals positive and negative aspects of coastal wetland restoration. One concern is lack of monitoring to determine restoration progress. Biological, chemical and physical monitoring should follow all restoration projects. Otherwise, degree of success of the project will not be known.

A case study of tidal wetland restoration at South Slough National Estuarine Research Reserve (NERR) is presented in Chapter III. It focuses on fish monitoring to evaluate fish usage of the estuary and tidal marshes. Fish monitoring is central to determining success of the wetland restoration. The primary goal is to restore tidal wetlands that function to benefit anadromous salmonids, such as coho salmon (*Oncorhynchus kisutch*) and sea-run cutthroat trout (*Salmo clarkii clarkii*) (Cornu 1998). If fish monitoring can document usage of the estuary and wetlands by anadromous salmonids, then the primary management target will be met. Furthermore, funding to continue monitoring and restoration activities would likely be extended.

The fish monitoring project in South Slough exemplifies of the type of activity that should follow estuarine restoration. Monitoring data from the South Slough restoration site needs to be incorporated into a watershed scale analysis of natural resources in Coos Bay. Results from individual projects should be linked to determine health of the entire Coos Bay watershed. This reiterates the need for a watershed based approach to ecosystem restoration and monitoring embodied in the Oregon Plan.

CHAPTER III

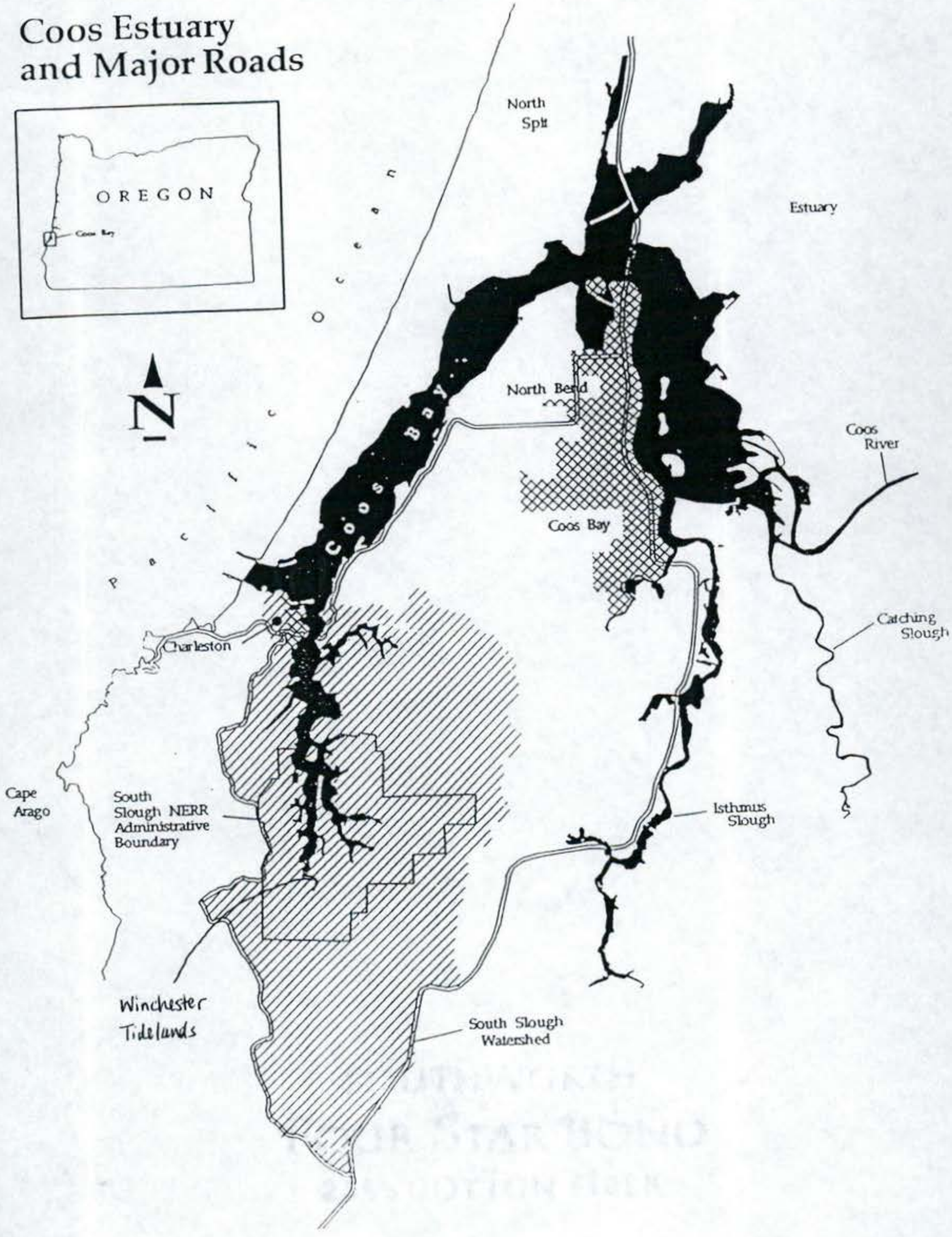
CASE STUDY ON FISH MONITORING: WINCHESTER TIDELANDS RESTORATION PROJECT, SOUTH SLOUGH NATIONAL ESTUARINE RESEARCH RESERVE

Introduction

Dike breaching has become a popular method of restoring former agricultural lands to functioning marshes along the Oregon coast. Around the turn of the century, many wetlands were diked to eliminate tidal inundation and drained for agricultural purposes. Tidal channels were either eliminated or fitted with tidegates to promote freshwater runoff while preventing saltwater from moving upstream into the marsh. Practices such as these were common on the Oregon coast as tidal marshes were considered to be the foremost crop and pasture land. These tidal channels were once utilized by anadromous fish as refuge and by fish prey species as habitat (Cornu 1998a). Dike breaching is a way of reintroducing tidal circulation into former salt marshes.

South of Coos Bay and the town of Charleston lies the 5,000 acre South Slough National Estuarine Research Reserve (NERR) (see Figure 4). South Slough NERR is one of 22 similar sites located along U.S. shorelines. The Reserve was established in 1974 to "enhance informed management and scientific understanding of the Nation's estuarine

FIGURE 4. South Slough National Estuarine Research Reserve and its environs (Cornu 1998)



and coastal habitats" (NOAA 1996). By the late 1960's, most diked agricultural lands in South Slough had become fallow due to lack of human use. Limited tidal functioning began to reoccur in these wetlands as tidegates and drainage culverts deteriorated from neglect. Restricted circulation in these marshes allowed for limited tidal inundation and a mixture of native and exotic salt marsh vegetation. The partially functioning wetlands supported a limited number of estuarine-dependent plant and animal species including emergent salt marsh vegetation, seagrasses, algae and phytoplankton (Cornu 1998).

Study Area

The Winchester Tidelands are a 50 acre component of the South Slough NERR, located near the southern administrative boundary. Similar to other tidal marshes in South Slough, the Winchester Tidelands were diked and drained for agricultural purposes. In 1992, the staff of South Slough NERR established the Winchester Tidelands Restoration Project (WTRP). The objective of the WTRP was consistent with the goal of the NERR:

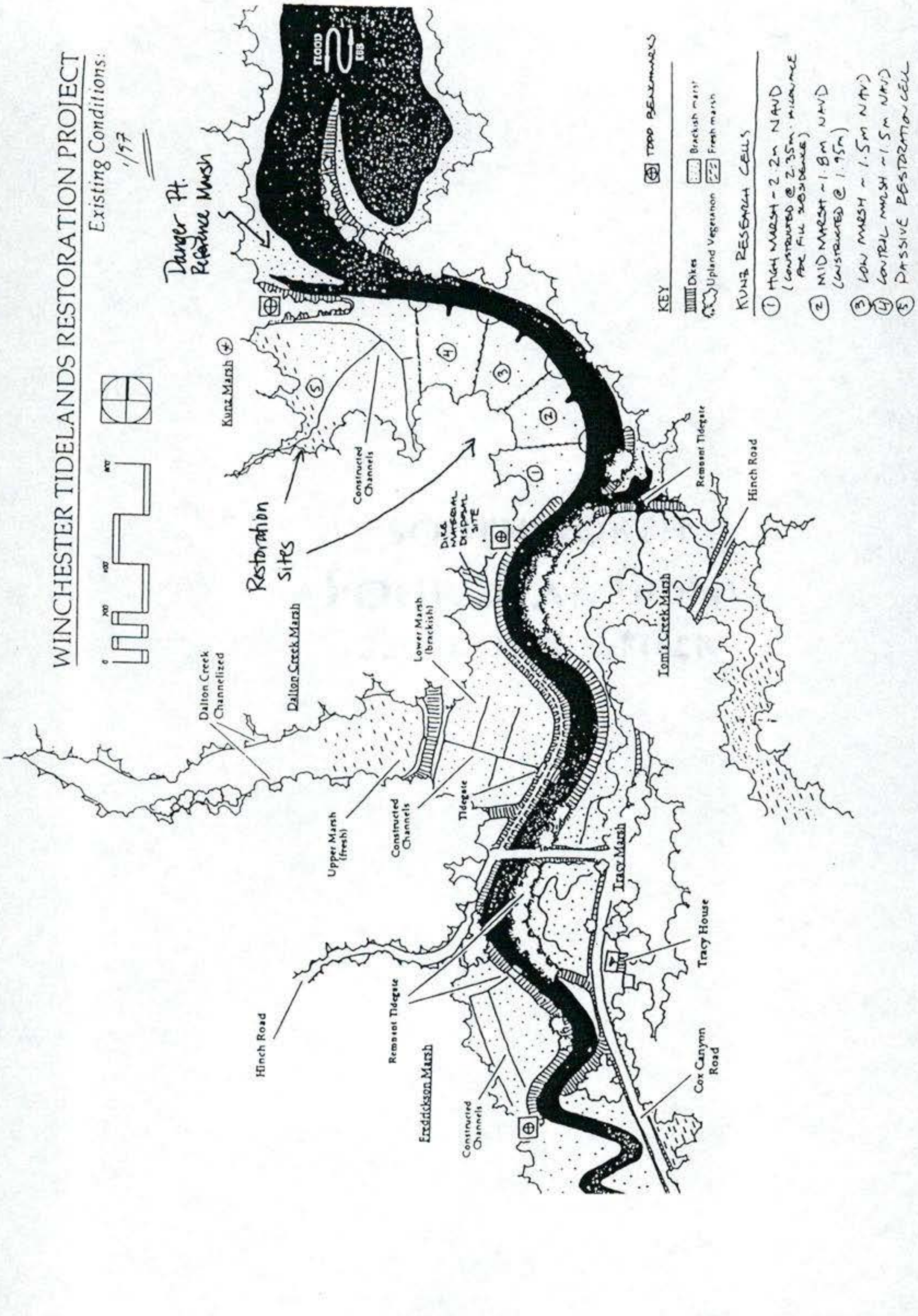
> To emulate the structure, functional diversity and dynamics of native biotic communities in lands currently managed by South Slough NERR, eliminating to the extent practicable evidence of changes in natural biological and hydrological systems stemming from human activity after 1850 (Cornu 1998).

Recovery of anadromous fish species, including the endangered coho salmon (*Oncorhynchus kisutch*) and sea-run cutthroat trout (*Salmo clarkii clarkii*), was the core goal of the WTRP. This was to be accomplished by restoration of tidal channels for off-channel refuge and feeding habitat and development of emergent salt marsh vegetation communities for primary production and food web support (Cornu 1998).

The first phase of the WTRP involved the Kunz Marsh Restoration Project. The 12 acre Kunz Marsh is located in the northernmost portion of the Winchester Tidelands (see Figure 5) and was selected for dike breaching and tidal reintroduction. A series of four restoration "cells" (including a control) were created to replicate South Slough natural marsh surface elevations: control marsh Cell 4, +1.4 m NAVD (North American Vertical Datum); low marsh Cell 3, +1.4 m NAVD; mid marsh Cell 2, +1.8 m NAVD; and high marsh Cell 1, +2.2 m NAVD (Rumrill and Cornu 1995). The control marsh Cell 4 was left ungraded at the former diked pasture level and served as a replicate of Cell 3. A fifth cell passive restoration Cell 5, is located adjacent to the control cell and was left unaltered to restore itself following dike breaching. Prior to dike removal, Cell 5 was primarily a freshwater cattail (*Typha latifolia*) marsh. Pre-breaching activities included establishing permanent topographic benchmarks for elevation, inventorying salt marsh vegetation species, and installing equipment to track sediment accretion and erosion.

In summer 1996, the Kunz Marsh dike was fully removed from five locations, and full tidal circulation was restored. Several dike islands were left as anchor points for walls to separate the cells. In Cells 1 to 3, marsh topsoil was graded and redistributed over the restored surfaces to facilitate vegetation community development (Cornu 1998). Qualitative observations of vegetation succession were made after dike breaching; quantitative monitoring of changes is scheduled to begin summer 1999. Following the

FIGURE 5. Winchester Tidelands Restoration Project, Kunz Marsh (Cornu 1998)



breaching, salt intolerant vegetation such as cattails quickly died. Succession of salt marsh species followed in predicted fashion with rapid colonizers flourishing, such as brass buttons (*Cotula coronopifolia*). A winter freeze in January 1999 eliminated most of the brass buttons and aided the colonization of Lyngbye's sedge (*Carex lyngbei*) in the marsh by reducing competition. The elimination of the brass buttons and replacement by Lyngbye's sedge occurred much faster due to the January freeze (Steve Sadro, pers. comm. 11 Apr. 1999).

Vegetation data is typically collected first in post-restoration monitoring activities. Other biota needs to be monitored in addition to vegetation to determine how restoration has affected the project ecosystem. Fish monitoring of the Kunz Marsh cells and adjacent estuary is critical to determining usage of restored habitat by key species. In addition to gauging wetland utilization by anadromous fish, monitoring will also examine resident populations of fish in the restored wetlands and estuary.

Materials and Methods

Seine net efficiency and deployment techniques were field tested in October 1998 prior to data collection. Sampling commenced in November 1998 on a monthly basis. Fish sampling occurred approximately 7 to 10 days per month and centered around the daily tidal schedule. On the Oregon coast, the tidal cycle experiences two low tides and two high tides; one high tide is higher than the other. From October 1998 to March 1999, the higher mean high tide peaked during daylight hours, and sampling was productive.

Unfortunately, beginning April 1999 the higher mean tidal height occurred during the middle of the night and made sampling unfeasible. The sampling schedule was altered to revolve around the lower mean high tide and affected sampling comparability in the cells.

Steve Sadro, Habitat Restoration Monitoring Coordinator at South Slough National Estuarine Research Reserve, designed and field tested the sampling methods used in this project. Sampling was divided into two tasks involving different materials and techniques. Fish sampling in the cells was passive netting and was meant to catch species that migrate into the marsh. Seine nets, measuring 25 m x 1.8 m with 3/16" mesh, 9" leads, and 3" floats, were used as "wings". Depending on the width of the cell opening, multiple lengths of net were lashed together and stretched across the cell to span the entire opening. The trapping system consisted of a short central bag section and large wings on each side. The bag was intended to trap fish; the wings were intended to direct fish into the bag. If more than one tidal channel existed in the cell, multiple bags were used. Stakes were used to keep critical points on the float line above the water, as well as to keep the lead line embedded in the marsh.

Fish migrated into the cell during tidal flood, and the nets were deployed at high tide. As the tide ebbed, fish were swept out of the cell. The majority of fish were collected in the bag since cell dewatering occurred most rapidly through the tidal creeks. However, some fish were caught in the wing sections of net and not in the bag. In other words, the fish did not migrate out of the cell via the tidal creeks and were trapped by the wing sections instead of in the bag. When the tide ebbed to a point where water was no longer escaping from the cell, collection of the samples commenced. Fish were collected along the length of the net (if present) and from the bag section and kept in a bucket of water. Species were identified and fork length (length from end of snout to center of fork of tail) was measured in millimeters. Fork length is a standard method of measuring fish size, and the age of the fish can be approximately estimated from fork length. Samples were returned to the water after measurement, and sample mortality varied depending on the species handled. For example, topsmelt (*Atherinops affinis*) were extremely fragile and the mortality rate was nearly 100 percent, but staghorn sculpin (*Leptocottus armatus*) withstood handling and had better survivorship.

The other method of sampling was active seining in the channel, which was meant to catch species resident in the estuary at low tide. Active sampling occurred once a month and was centered around the daily tidal schedule, regardless of overall tidal height. The estuary adjacent to the Kunz Marsh cells is divided into lower, middle, and upper reaches, numbered reach 1, 2, and 3 respectively. Each reach has a characteristic habitat, and seining occurred at several locations along each reach as replicate samples. One section of the passive seine net was dragged across the estuary and onto the opposite bank. Samples were collected as the net was pulled out of the water, and they were stored in a bucket of water. After all fish were removed from the seine net, samples were identified by species and measured for fork length as with passive sampling. Samples were released after measurement as with sampling in the cells. It may be that active seining in the estuary was less complete than passive sampling in the marsh cells. However, replicate samples for each reach of the estuary were taken as opposed to one sample for each marsh cell; this compensated for the lower sampling efficiency in the estuary.

Water chemistry measurements were taken for each sampling day. Measurements were taken from the middle of the channel. Water temperature was measured in degrees Celsius using a thermometer. Salinity was measured in parts per thousand using a salinometer.

Analysis

Seining data from November 1998 to April 1999 were analyzed, and cell data from November 1998 to March 1999 were analyzed. Six analyses of the data were conducted to gauge fish use of the restored wetland sites and are summarized in Table 6. Statistical analysis was not conducted due to the small data set. Since only 5 to 6 months of data were collected at the time of this thesis, graphical analysis was used to explain trends instead of statistical analysis.

TABLE 6. Analysis of monitoring data by cell and/or estuary reach.

Analysis	Purpose	Cell or estuary
1. Number of individuals over time by species	Increase in usage of restoration area	Both
2. Number of individuals over time by species	Usage of cells by preferred tidal height	Cell
3. Number of individuals over time by species	Usage of estuary reaches by preferred habitat type	Estuary
4. Number of species over time	Diversity of cells vs. estuary using species richness	Both
5. Number of species over time	Diversity of cell vs. cell using species richness	Cell
6. Mean fork length over time by resident species	Determination of residence in restoration area	Both

The hypothesis for Analysis 1 is that the number of individuals per species will increase over time. The restoration area will provide beneficial habitat for fish, and the population will increase due to more usage. Analysis 2 will provide guidance as to what the preferred tidal marsh height should be to benefit fish in restoration projects. Analysis 3 will also indicate what estuarine habitat type is preferred by various species although the WTRP is not directly involved in estuarine restoration. It is expected that the cells will provide more habitat diversity for a greater number of species than the estuary in Analysis 4. The hypothesis for Analysis 5 mirrors that of Analysis 2: preferred tidal height will benefit a greater number of individuals, and those preferred cells will support a higher diversity of species due to more complex habitat. Analysis 6 will indicate growth of the population of resident fish in both the cells and the estuary.

Results

Results of short-term monitoring were favorable in terms of fish usage of the restoration site. Analysis 1 was conducted to determine whether an increase in fish usage of the Kunz Marsh restoration area had occurred over 5 to 6 months. Figure 6 illustrates trends in number of individuals found in all restoration cells combined. The figure depicts increasing trends in number of individuals for both staghorn sculpin (*L. armatus*) and topsmelt (*Atherinops affinis*). Only *L. armatus* and *A. affinis* populations were analyzed as samples of other species were too scarce to detect noticeable trends. Figure 7 illustrates trends in number of individuals found in all reaches of the adjacent estuary. The graph shows an approximately 30 percent decrease in *L. armatus* individuals

FIGURE 6. Number of individuals found in all marsh cells over time.

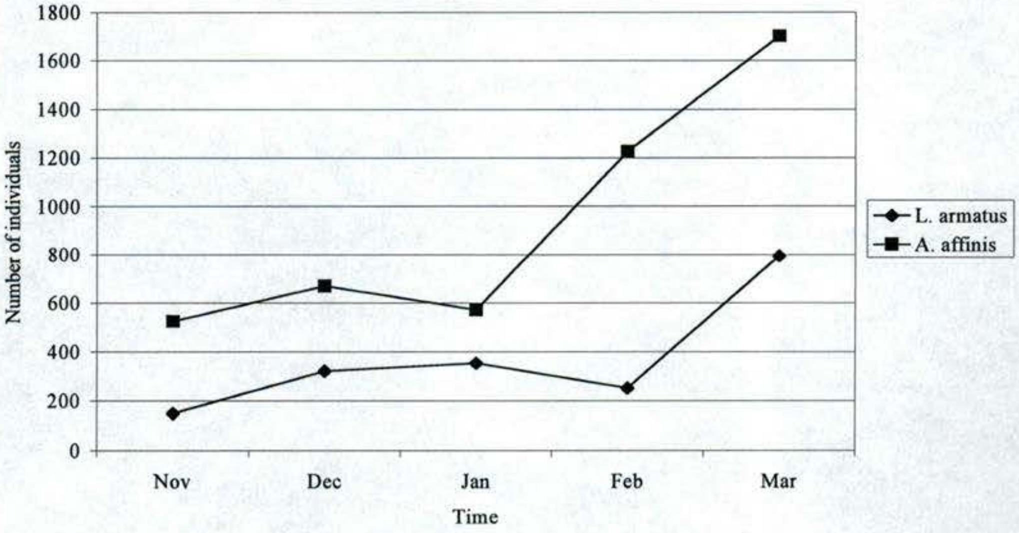
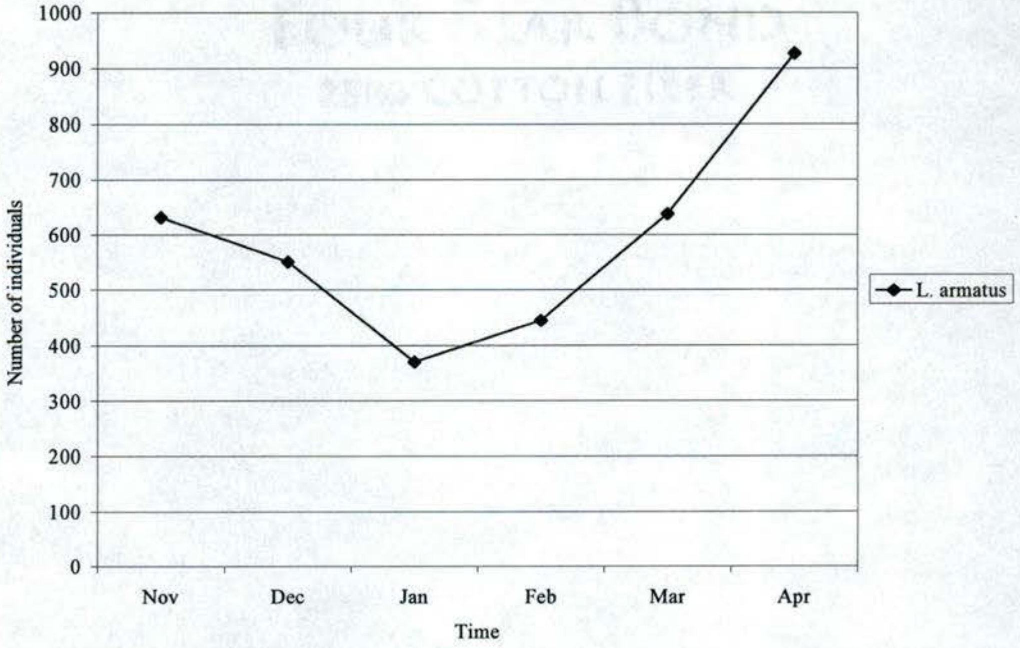


FIGURE 7. Number of individuals found in all estuary reaches over time.



between November and January, but the number of individuals increases from January to April. Only *L. armatus* was investigated in the estuary since it is a resident species and remains in the channel during low tide. Some fish species are unable to maintain their position in the estuary and are subjected to the ebb and flow of the tide.

Analysis 2 was conducted to investigate fish usage of restoration cells by preferred tidal height. Figure 8 indicates that by the end of the 5 months sampled, *L. armatus* has a preference for Cell 4 and Cell 2, with Cell 1 being at the highest tidal height. Although Cell 5 is at the lowest height and is regularly flooded, *L. armatus* shows a preference against it. Figure 9 shows that *A. affinis* has a distinct preference for Cell 4 and Cell 5. Tidal height alone cannot explain differences in species' cell preference, and a wide spectrum of channels and habitats are found across the cells. This will be discussed in the next section.

Analysis 3 was analogous to Analysis 2 in that it sought to explain fish usage by preferred tidal height, but in the estuarine channel rather than the cells. Tidal height is a major factor in determining how far up the estuary fish can migrate. Each reach in the estuary has its own distinct habitat type. Figure 10 shows major variation in *L. armatus* caught in Reaches 1 and 3 with strong positive trends from basically February to April. Reach 2 maintained average numbers of *L. armatus* during the 6 month sampling period. One other species, threespine stickleback (*Gasterosteus aculeatus*) was found in relative abundance in the channel. Figure 11 illustrates a sharp drop off in *G. aculeatus* individuals from November to December and extremely low numbers from December to April. Long-term monitoring over several years will reveal whether this is merely a

FIGURE 8. *L. armatus* individuals found in each marsh cell over time.

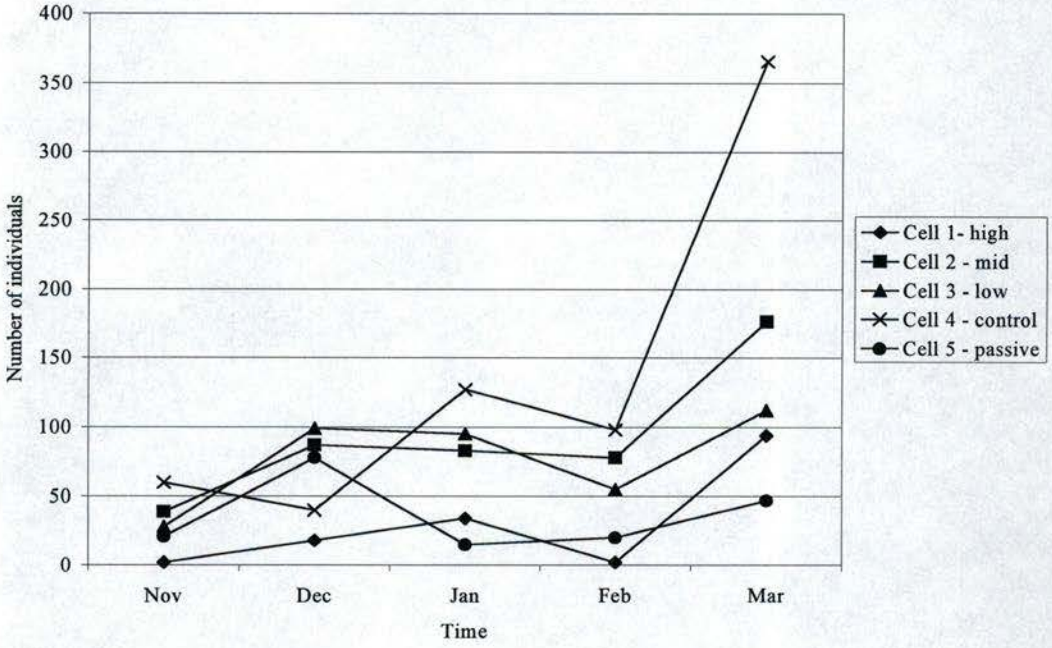


FIGURE 9. *A. affinis* individuals found in each marsh cell over time.

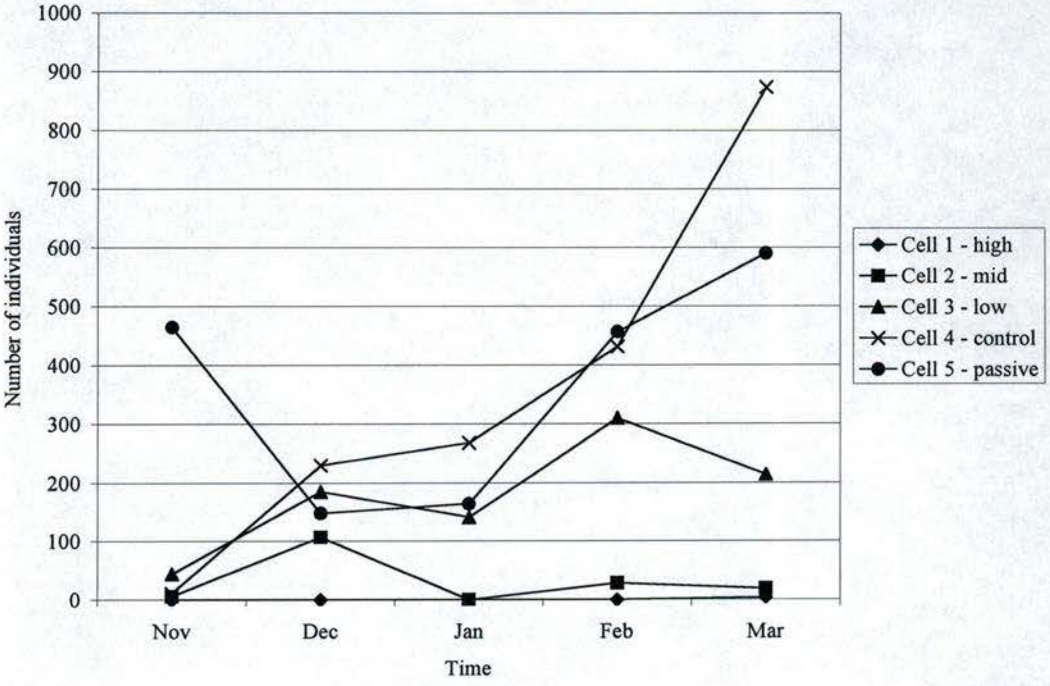


FIGURE 10. *L. armatus* individuals found in each estuary reach over time.

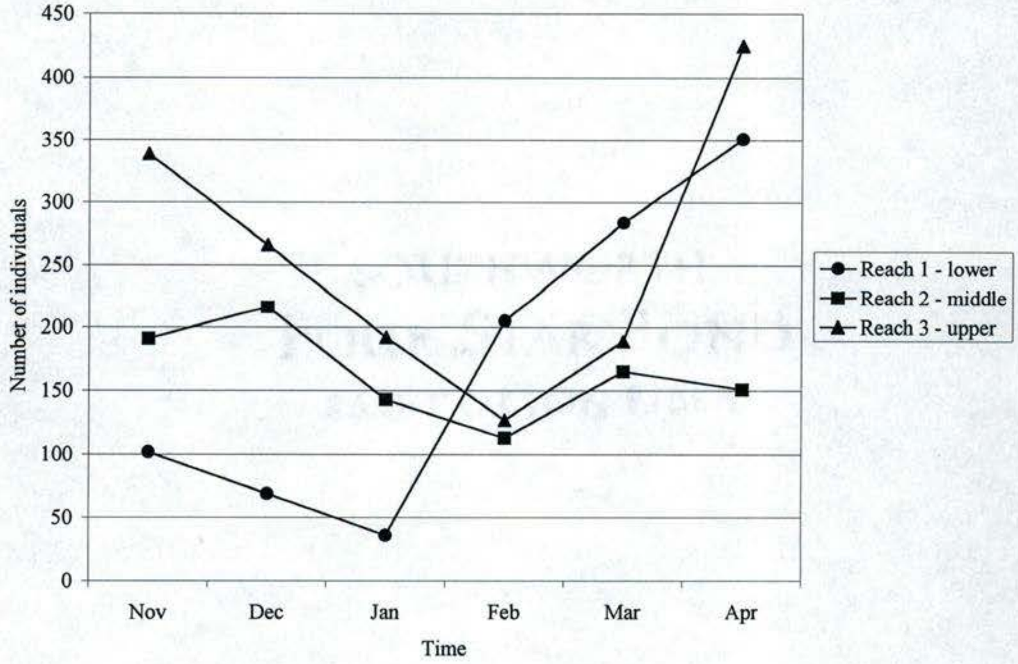
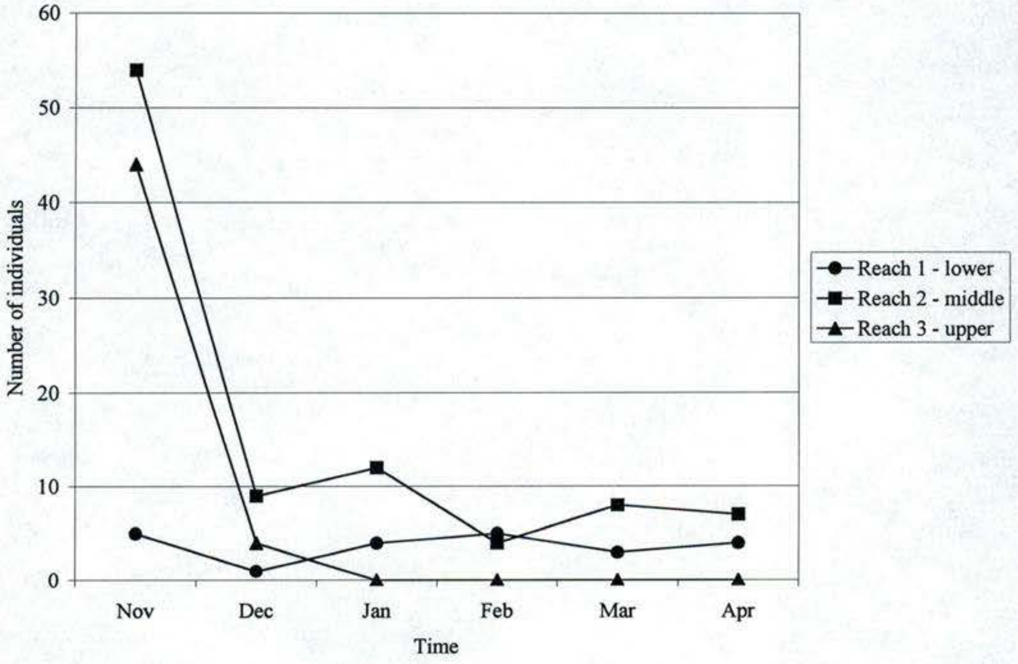


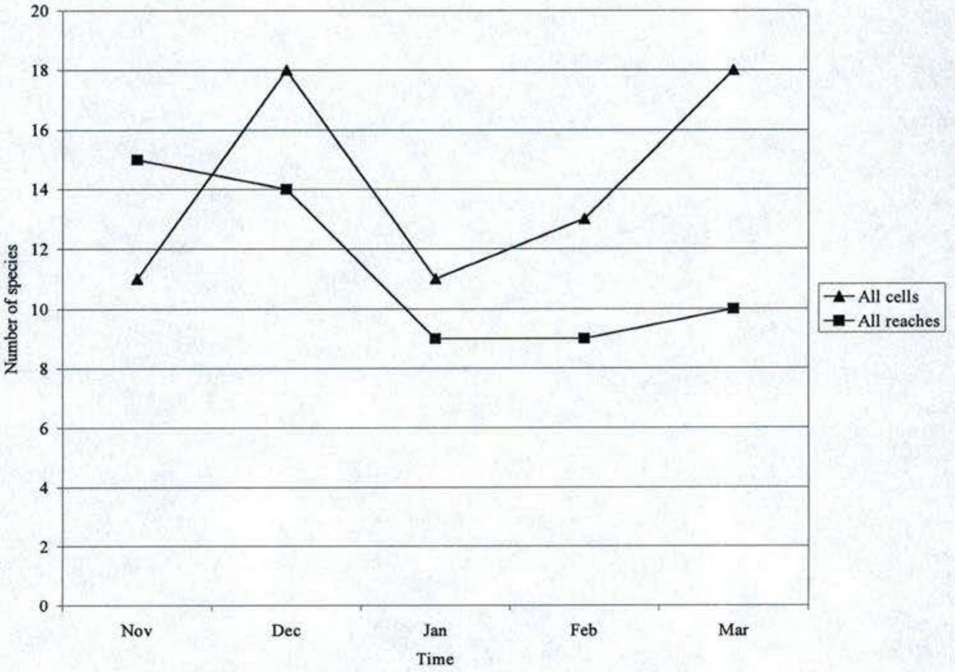
FIGURE 11. *G. aculeatus* individuals found in each estuary reach over time.



natural seasonal variation or caused by marsh restoration progress. The seasonality of estuarine fish populations depends on their responses to several factors, such as temperature, salinity, oxygen levels, and marsh vegetation (Moyle and Cech 1996). Due to their lack of commercial value, little is known about the life histories of *L. armatus* and *G. aculeatus* (Steve Sadro, pers. comm. 31 May 1999).

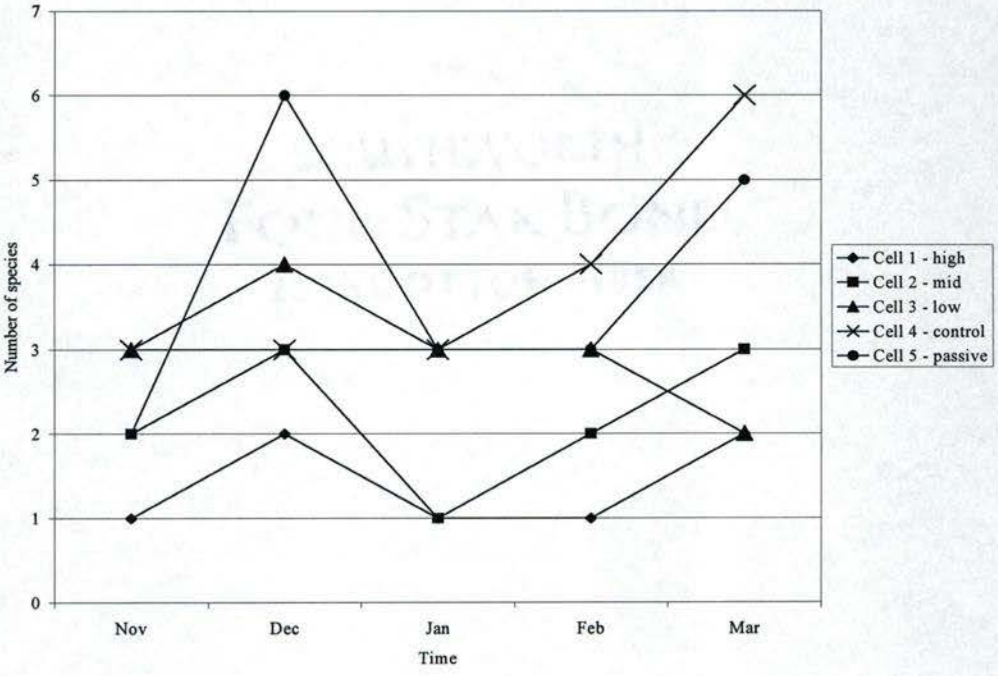
The purpose of Analysis 4 was to determine whether the restoration cells or estuarine channel had better habitat diversity. This was gauged by measuring species richness. Figure 12 shows that all marsh cells as an entity have a higher species richness than the channel. Furthermore, the period from January to March shows an increasing trend for the cells.

FIGURE 12. Species richness of all marsh cells vs. all estuary reaches over time.



Analysis 5 was conducted to investigate differences in habitat type for each cell using species richness. Species richness for each cell was analyzed over time, and Cell 4 and Cell 5 supported the highest number of species as illustrated in Figure 13. Analysis 5 is related to Analysis 2 which sought to determine fish preference for tidal height.

FIGURE 13. Species richness by marsh cell over time.



Analysis 6 was performed for an estimate of residence time in the restoration area. The analysis was divided according to sampling regime: all cells and all reaches. Fork length was measured over time, and a mean fork length for all individuals was acquired by species. Only the resident *L. armatus* was analyzed due to the large number of samples. If the fish population is growing in size in the restoration area, then there should be an increase in mean fork length over time. Figure 14 shows an initial decline in the mean fork length of *L. armatus* in the cells from November to December. However, the period from December to March shows a steady increase in *L. armatus* mean fork length thus indicating growth of the resident population.

FIGURE 14. Mean fork length of *L. armatus* for all marsh cells over time.

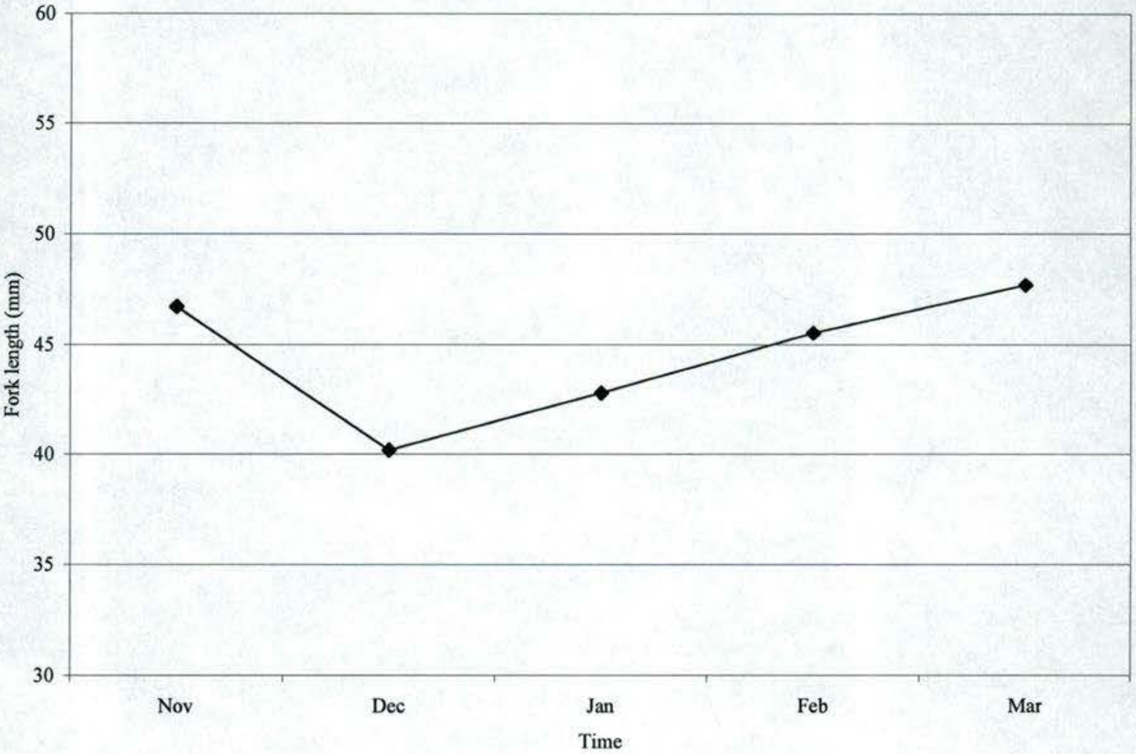
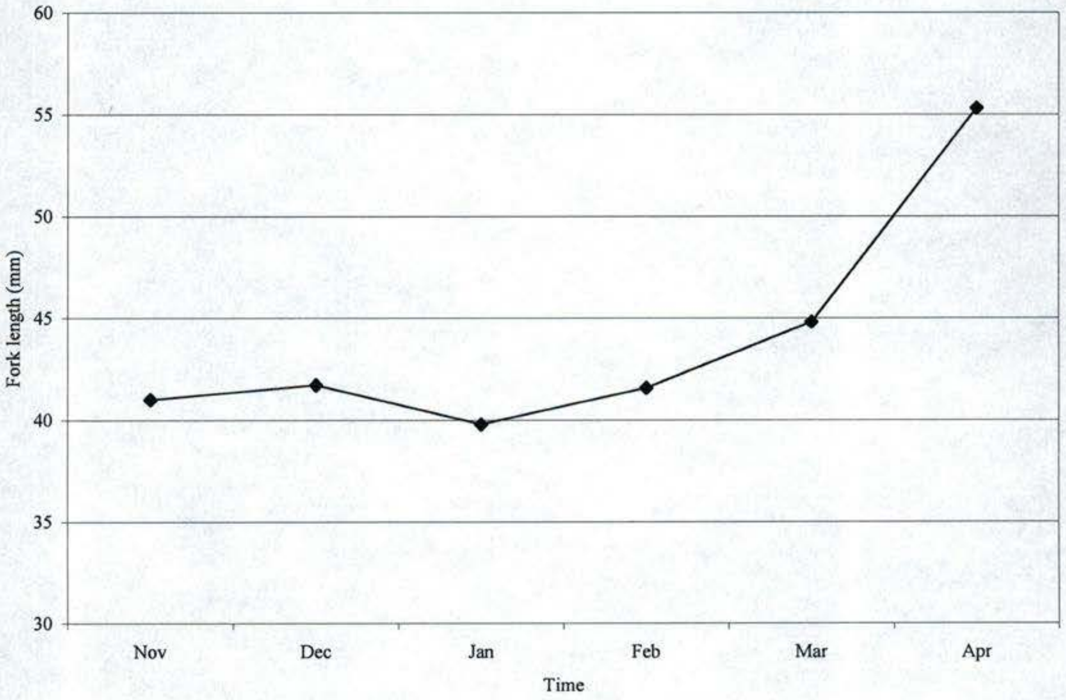


Figure 15 indicates steady growth of the *L. armatus* population in the estuary from January to April with initial fluctuations from November to January. Length-frequency distribution per month also illustrates a shift in mean fork length for all cells and for all reaches.

FIGURE 15. Mean fork length of *L. armatus* for all estuary reaches over time.



Discussion

Results from the six fish monitoring analyses should not be interpreted as conclusive. On the contrary, the results should be used as indicators of trends in fish communities found in the WTRP. Several confounding factors outside the scope of this case study have impacts on habitat and fish. Therefore, one must be cautious about making conclusions or passing final judgement on the restoration project, either positive or negative. Long-term monitoring over the course of several years will yield more conclusive results about the progress of the WTRP and benefits for fish.

One common aspect among all six analyses was the influence of precipitation during the months of January and February. Heavy snow and rainfall during the winter months increased freshwater influx in the Coos Bay watershed. Salinity measurements decreased from the normal range of approximately 15 ppt to approximately 2 ppt. Fish population numbers increased during these months, as did the number of species inhabiting the restoration area. The increase in freshwater in the estuary lowered the "salt wedge" in the system, allowing more freshwater organisms to move further down the estuary. Conversely, marine organisms such as striped bass (*Morone saxatilis*) were limited to regions of saline water and did not enter the restoration area.

Tidal fluctuations also have a major impact on fish communities inhabiting the area. The high marsh Cell 1 is rarely flooded by tidal waters. The tidal maximum must be very high for tidal waters to enter the cell. Therefore, fish species such as *A. affinis* that migrate into cells to feed rarely enter the high marsh. On the other end of the spectrum, Cell 4 and Cell 5 undergo tidal flooding every day. Migratory species enter the cells with the tide and retreat as the tide ebbs. Smolts of species such as *O. kisutch* spend the majority of their time in the estuary (McMahon and Holtby 1992). However, these fish may migrate into the wetland areas in search of food as the tide floods. Sampling has revealed that a few *O. kisutch* and *S. clarkii clarkii* adults and juveniles have migrated into the cells during the high tide. Although prey organisms are present in the marsh, it is unclear whether the fish's primary incentive is food since no gut content analyses were performed.

The short-term results of Analysis 1 are favorable. A positive trend in the number of individuals found in both cells and reaches indicates that more fish are utilizing the restoration site. Long-term monitoring of this trend will indicate whether more fish are moving into the WTRP because of restoration progress. The positive trend may be part of a population cycle in which numbers of fish are higher during the spring and summer months than the fall and winter.

Analysis 2 indicates that *L. armatus* has a preference for Cell 4 and secondarily for Cell 2. Cell 4 is the control marsh and is adjacent to the passive restoration Cell 5. Since Cell 4 is at the lowest tidal height, it is flooded with every tide cycle. However, this does not explain why *L. armatus* is found in greatest abundance in Cell 4. *L. armatus* is a resident species and does not migrate with tidal ebbing and flooding, as does *A. affinis*. *L. armatus* may move into the restoration cells for better feeding opportunities as other organisms are swept into the nutrient-rich marsh. Cell 4 has two well-developed tidal channels that allow organisms to swim into the marsh, and Cell 2 has one main tidal channel. *Carex* communities are abundant and offer cover and a source of food for fish. *L. armatus* may prefer these cells because of the cover provided by the deeper tidal channels. Other cells do not have distinctly formed tidal channels and have a flat topography that would expose fish to predators, except for Cell 5 which has a deeply incised channel. The tidal channels provide fish with better cover and do not leave them exposed in shallow water when the cells are flooded. The restoration cells are still evolving in terms of vegetation and hydrologic structure, and long-term monitoring will determine how fish habitat is affected by these changes in the future.

A. affinis shows a preference for Cell 4 and Cell 5. There is a preference against Cell 1 and 2. This dualism in tidal preference can be tied into tidal flooding as Cells 4 and 5 flood during every tidal cycle, whereas Cells 1 and 2 flood only during high tidal maxima. *A. affinis* is not found in Cells 1 and 2 often because the marsh rarely floods, and the fish depend on the tide to move into the marsh. Cells 4 and 5 also offer complex tidal channel structure as opposed to shallow water above the marsh where fish are likely to feel exposed.

The estuary is divided into 3 reaches, each with fairly distinct habitat characteristics. Reach 1 is the lowest in the estuary and is wide, flat bottomed and fairly shallow. The reach is basically straight with no sinuosity. Habitat is limited to *Carex* salt marsh and mudflats that are exposed at low tide. Eelgrass (*Zostera marina*) is also dominant in the channel itself. Reach 2 is narrower with a deeper channel than Reach 1, and there are a few bends in the channel. Vegetation is a mixture of *Carex* salt marshes and riparian hardwood forest. Reach 3 is the narrowest with a deeply incised channel, and the channel is most sinuous. The habitat is dominated by riparian forest with a few downed snags and some woody debris in the channel.

Analysis 3 was conducted to determine whether fish species exhibited a preference for a particular estuarine reach or habitat. *L. armatus* indicated preferences for the lower (1) and upper (3) reaches as opposed to the middle (2) reach. Fewer individuals were found in the middle reach, which is adjacent to the wetland restoration cells. The period of agricultural diking and draining disrupted tidal inundation and nutrient cycling for several decades. Since fish monitoring is occurring within a short time period following dike breaching, the ecosystem has only partially recovered from the effects of farming the drained marshes. *L. armatus* communities migrated away from the nutrient deficient agricultural lands and into other parts of the estuary. The diked pasturelands also provided no habitat for fish, and farming removed nutrients that would have been recirculated into the estuary by tidal flux. Thus, *L. armatus* numbers are higher for the lower and upper reaches of the estuary in comparison to the middle reach. A long-term assessment of population trends for the estuary will reveal whether the restoration is progressing successfully. If the tidal marshes return to a functioning state, nutrients will be cycled between the marsh and estuary in a fashion similar to pre-diking conditions. Fish usage of the middle reach should increase as restoration progresses.

The *G. aculeatus* population drastically decreased during the month of December. One hypothesis is that *G. aculeatus* is a seasonal visitor and prefers salt marshes to spawn during the spring (Moyle and Cech 1996). Although their salinity tolerance is high, *G. aculeatus* prefers brackish to saline water. Precipitation during the winter months increased, and the estuary became less saline as freshwater influx increased. *G. aculeatus* migrated further down the estuary where more saline water could be found.

Both *O. kisutch* and *S. clarkii clarkii* have been increasing in numbers in the estuary. In April, 5 *O. kisutch* and 13 *S. clarkii clarkii* were caught in the estuary. At this early stage of monitoring, it is important to at least have “presence” data that documents use of the estuary by anadromous fish. Individuals of both species have also been sampled in the cells, but numbers have not been high enough to detect trends. It is still important to note the presence of these salmonids inhabiting the restoration cells. *O. kisutch* smolts have been found in the middle and upper reaches of the estuary. *S. clarkii clarkii* have been caught in increasing numbers in the middle and especially upper reach. The salmonid species exhibit a preference toward the upper reach which is a narrower channel with riparian hardwoods. These trees provide shade and cover for the fish, as well as input of terrestrial prey organisms. Initial data trends indicate that both salmonid species prefer the more complex habitat found in the upper reach of the estuary.

ODFW installed a screw trap sampling device in Winchester Creek upstream of the Kunz Marsh cells during the month of February. Salmonids migrating downstream into the estuary are temporarily caught and deposited into a holding pen. ODFW staff are marking salmonids caught in the trap with various pigments. Each colored pigment represents a week of a certain month. When fish are sampled downstream during the Kunz Marsh fish monitoring, the South Slough staff can identify when the fish was marked and released. This provides a rough estimate of how long the fish has been resident in the estuary. The information gathered from the mark and recapture procedure will be helpful in understanding *O. kisutch* and *S. clarkii clarkii* life histories in the South Slough ecosystem.

Analysis 6 indicated that a *L. armatus* community is resident in the Kunz Marsh cells and adjacent estuary. The increase in mean fork length over time suggests growth in size of the same community of individuals. Monitoring of this trend over the long term will be useful in determining whether the community is a permanent resident or seasonal visitor. If the community is permanent, the mean fork length of *L. armatus* individuals should hypothetically continue to increase. Since large quantities of *L. armatus* are sampled, this type of analysis is feasible. Unfortunately, other species are not found in quantities large enough to perform length-frequency distributions.

Conclusion

The purpose of ecological restoration in the Winchester Tidelands is to improve habitat and ecosystem functioning. One of the cornerstones of any restoration project should be a monitoring scheme. Fish monitoring in the WTRP is performed to measure restoration progress. Without long-term monitoring, the success of a project cannot be determined. Frenkel and Morlan (1991) suggest monitoring for at least ten years. Such extensive monitoring is usually beyond the economic and personnel scope of most projects. On the other hand, consistent monitoring provides proof of successful restoration and reason to hopefully fund another restoration project.

Dike breaching is a relatively simple and straightforward method of restoration. Reconnecting diked agricultural lands to tidal circulation initially appears to be effective in regaining functioning tidal marsh. Therefore, breaching can be a useful restoration tool in a watershed with diked marshes. Early evidence indicates that the WTRP is beneficial for anadromous and resident fish. It has been consistently stated that the results of this fish monitoring analysis should not be taken as conclusive evidence. The results are an initial investigation into the structure of fish communities inhabiting the

Kunz Marsh area. The graphical data presented here should serve as guidance for long-term monitoring and statistical analysis. Watershed management that is performed under the Oregon Plan should incorporate this type of fish monitoring in any coastal wetland restoration project.

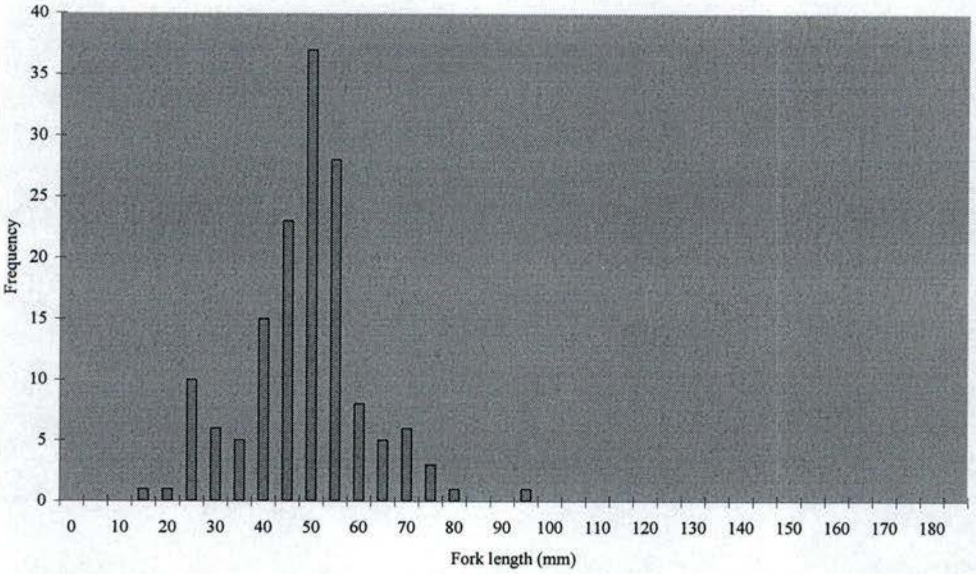
Vegetation and fish monitoring methods are relatively simple and cost effective in terms of equipment. However, several personnel are required to perform extensive biological monitoring on a large scale, and the cost of labor is usually high. It is important to have voluntary citizen involvement in monitoring efforts. Citizen volunteers provide cost-free monitoring assistance for the agency performing restoration. In return, the public receives hands-on education about watershed restoration.

Fish monitoring in the WTRP has not yielded comprehensive results for the tidal marsh restoration. There are several other biological, chemical, and physical factors that may affect fish populations in tidal marshes. Fish monitoring methods need to be refined over time so that future monitoring efforts can provide a clearer picture of how restoration has progressed.

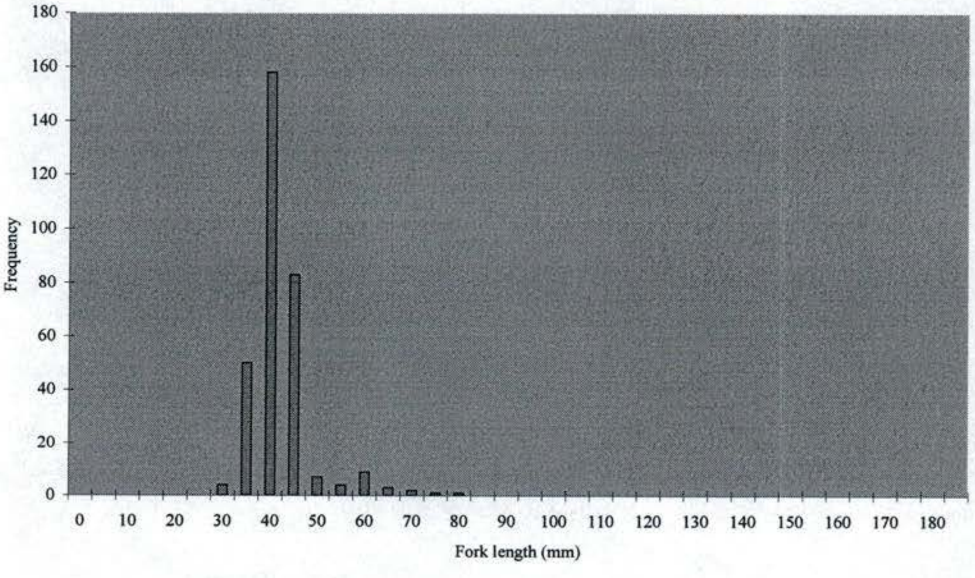
APPENDIX A

LENGTH-FREQUENCY DISTRIBUTIONS OF L. ARMATUS OVER ALL CELLS

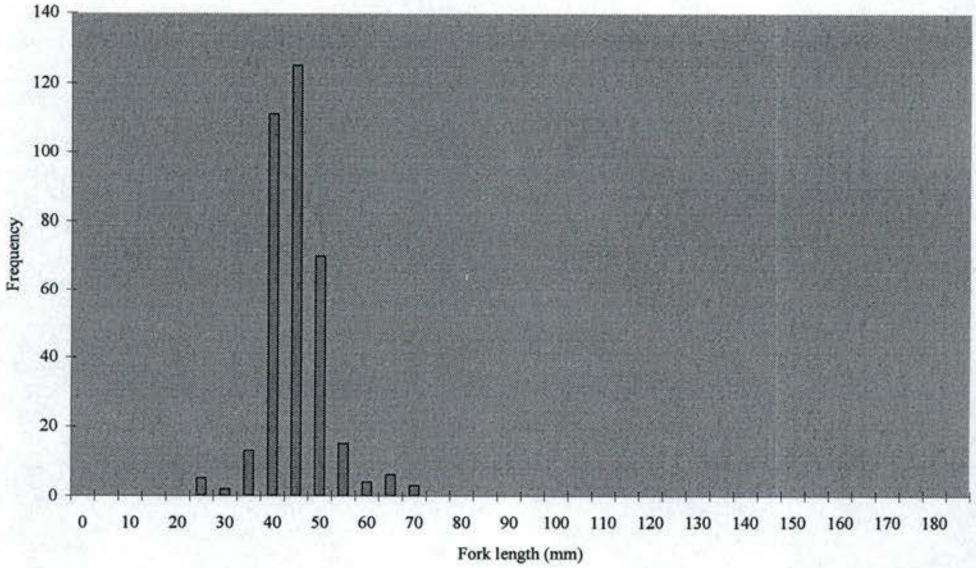
Length-frequency distribution of *L. armatus*
over all cells during November 1998



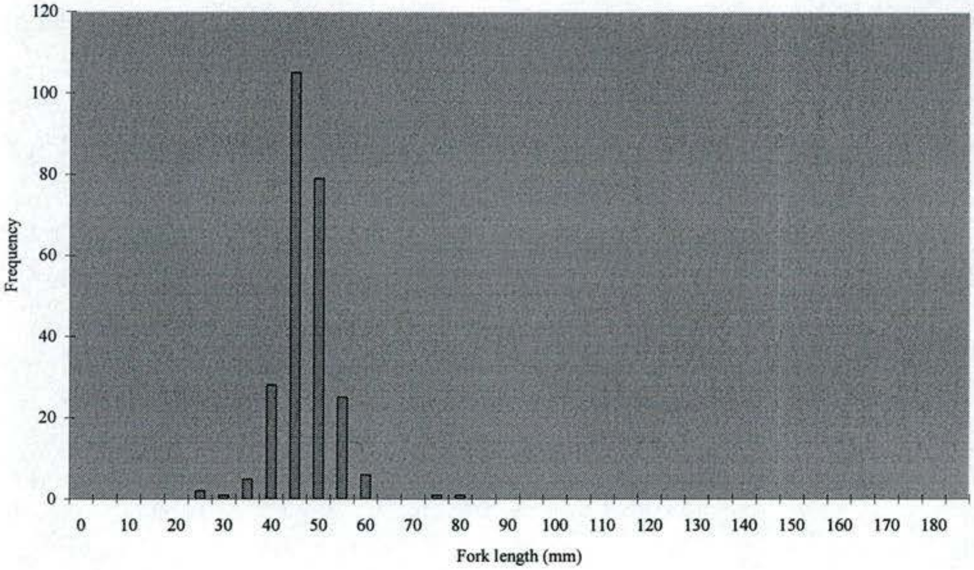
Length-frequency distribution of L. armatus
over all cells during December 1998

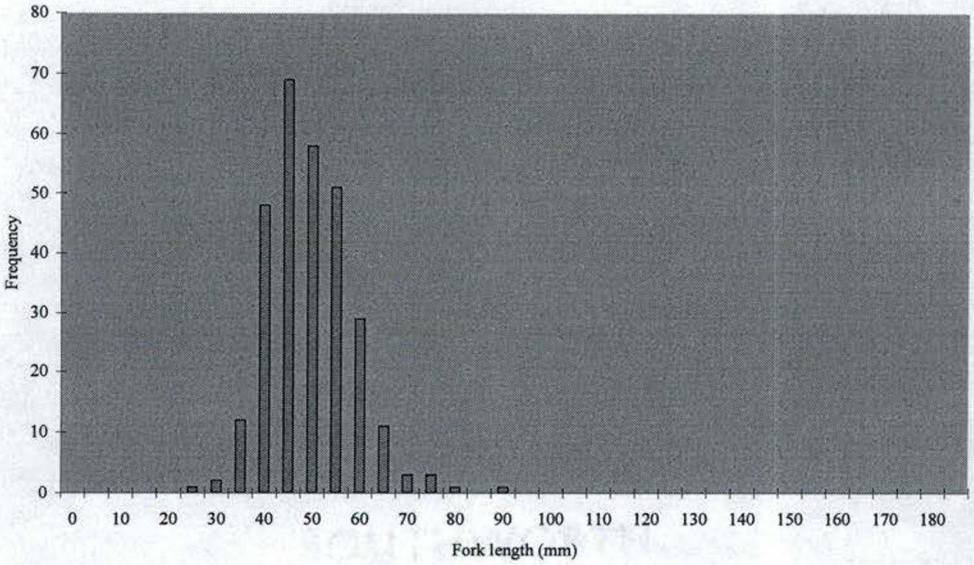


Length-frequency distribution of L. armatus
over all cells during January 1999



Length-frequency distribution of L. armatus
over all cells during February 1999



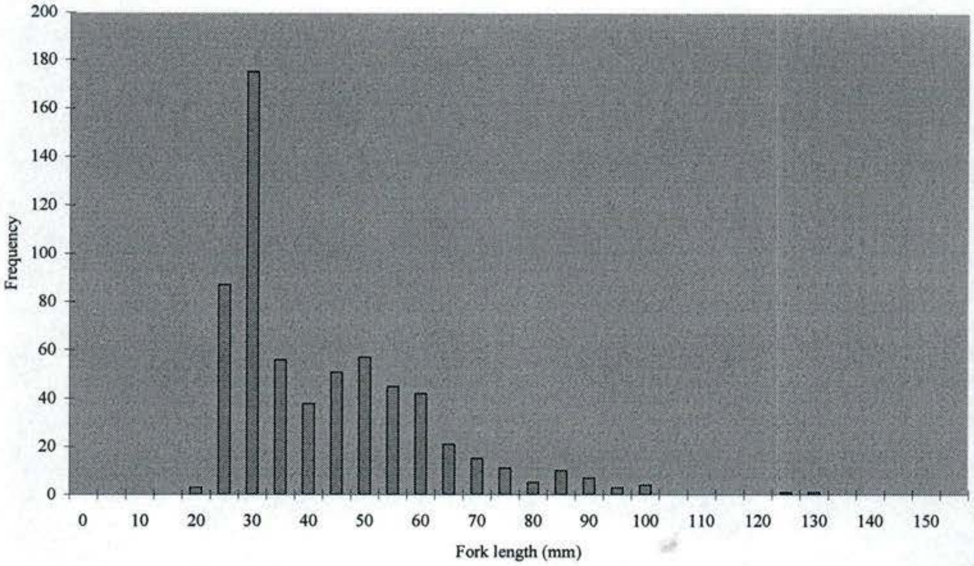


Length-frequency distribution of L. armatus
over all cells during March 1999

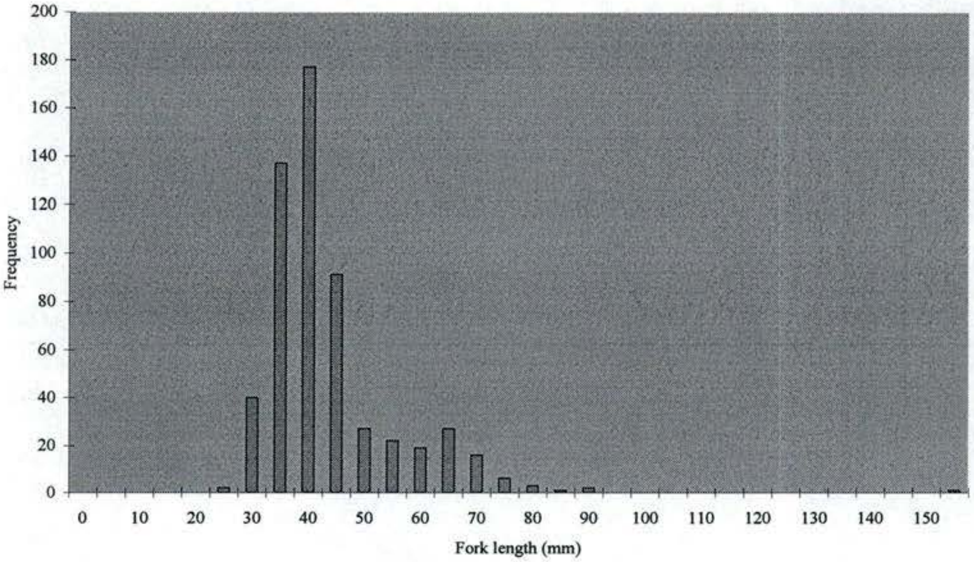
APPENDIX B

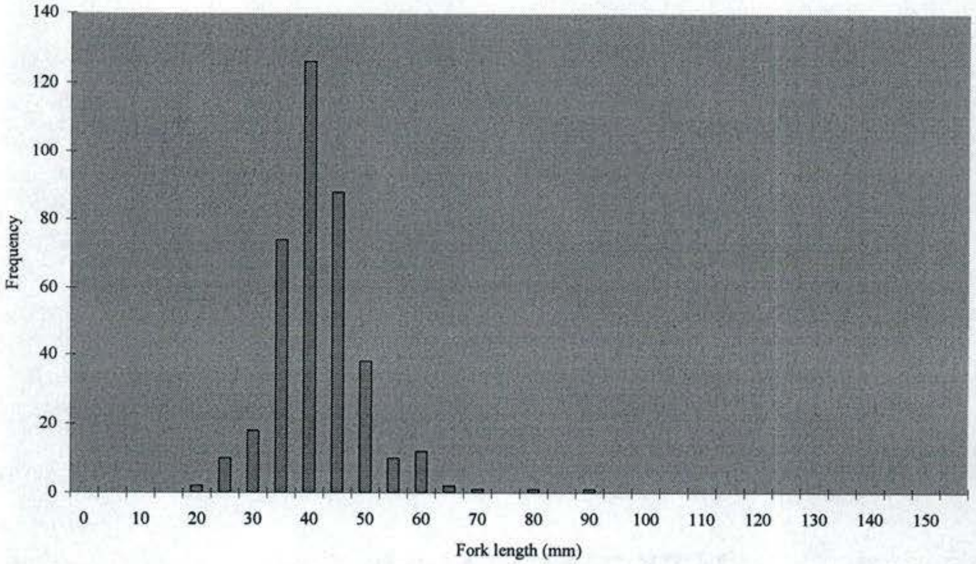
LENGTH-FREQUENCY DISTRIBUTIONS OF L. ARMATUS OVER ALL REACHES

Length-frequency distribution of L. armatus
over all reaches during November 1998

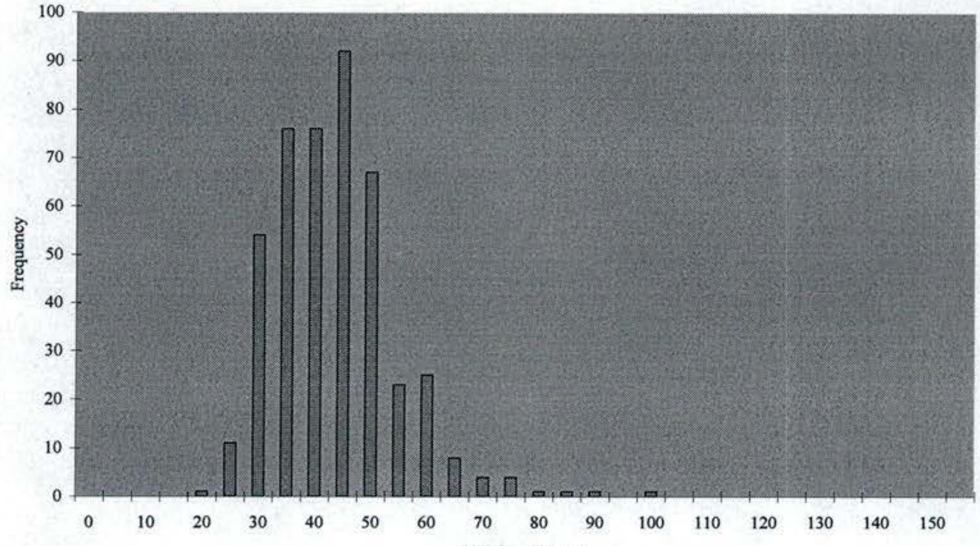


Length-frequency distribution of L. armatus
over all reaches during December 1998



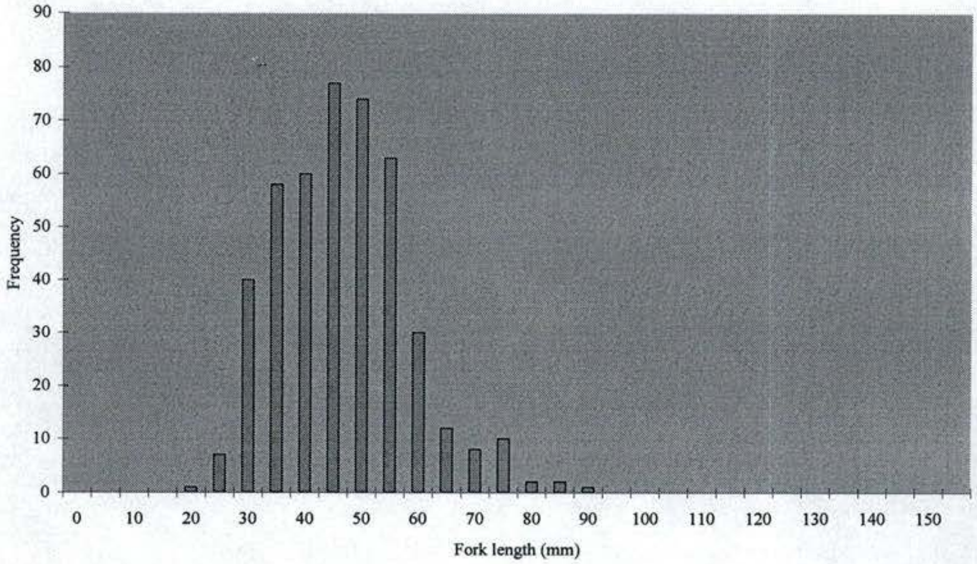


Length-frequency distribution of L. armatus
over all reaches during January 1999

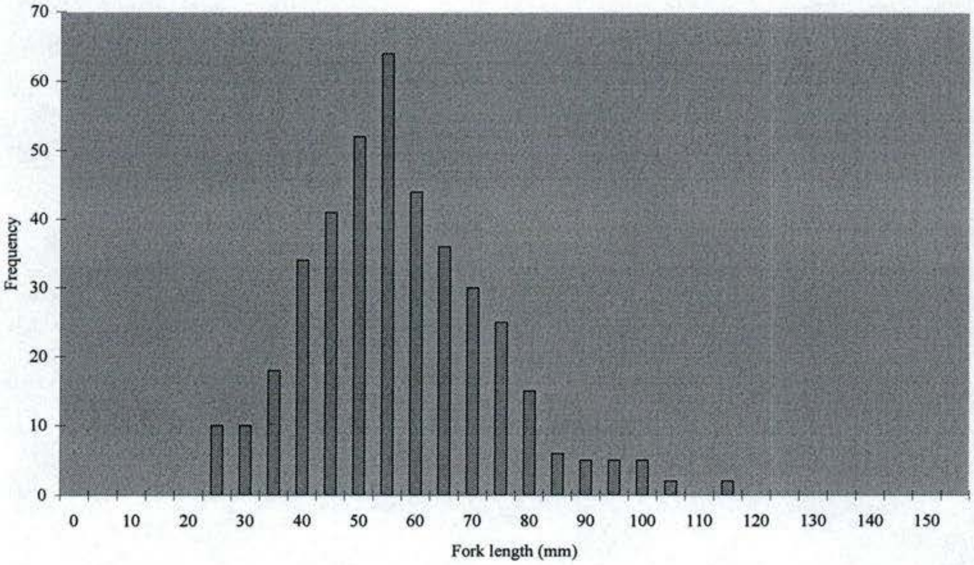


Length-frequency distribution of L. armatus
over all reaches during February 1999

Length-frequency distribution of L. armatus
over all reaches during March 1999



Length-frequency distribution of L. armatus
over all reaches during April 1999



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