APPENDIX A

SELECT AREA FISHERY EVALUATION PROJECT

ENVIRONMENTAL MONITORING REPORT

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INTRODUCTION

The SAFE Project Environmental Monitoring Program has two objectives. The first is to assess the environmental suitability of water bodies being considered for fish rearing and to monitor water quality parameters of these water bodies while fish are being reared to document their continuing suitability. Achieving this goal is part of a larger effort involving social and political considerations such as land ownership, access, and the popularity of the project with residents of the area.

The environmental considerations include hydrographic parameters such as depth and flow patterns and accessibility for fishing vessels. Biological considerations include the lack of native fish or other species listed under the Endangered Species Act (ESA) that might be harmed by the fish rearing or subsequent harvest of the returning net pen fish. Water quality parameters of concern are temperature, dissolved oxygen, pH, turbidity and conductivity. The benthic fauna of the water body is examined as a long-term indicator of environmental health.

The second objective of the SAFE Environmental Monitoring Program is to monitor the effects of the fish rearing activities on the environmental health of the water bodies where the net pen operations are located. This is done with input from the state regulatory bodies that have jurisdiction over environmental issues.

BACKGROUND

Net pens are located at eight sites. Three sites are in Washington; one in Steamboat Slough and two sites in Deep River at Robert Fauver’s property about a half mile downstream from the highway 4 bridge, and the other at Walter Kato’s property about a half mile upstream from the highway 4 bridge. Five sites are in Oregon; one at Tongue Point, one at the Marine and Environmental Research and Training Station (MERTS) facility near Tongue Point, one in Blind Slough, and two in Youngs Bay at Tide Point and the Yacht Club site.

The net pen facilities at Youngs Bay and Tongue Point have production levels that require National Pollutant Discharge Elimination System (NPDES) permits (40 CFR 122,24) issued by the Oregon Department of Environmental Quality (ODEQ). Under these permits the net pens at Youngs Bay and Tongue Point are allowed a 15-meter mixing zone extending in all directions from the net pen structure. No environmental impact is permitted outside of the mixing zone as compared with reference conditions, and no impact which adversely effects aquatic life or any beneficial use is permitted within the mixing zone. The purpose of the monitoring effort at these locations is to determine if these criteria are at risk of being violated so that corrective measures can be taken.

The production levels at Steamboat Slough, the two Deep River sites, Blind Slough, and the MERTS site are below the level that would require discharge permits. These five locations incur minimum impact, and the purpose of the monitoring effort at these sites is to document any environmental changes that may occur under the net pens as compared to a reference condition. The MERTS site is new and in the future it is anticipated that production here will increase. The Tongue Point facility is expected to be vacated and the equipment moved to the MERTS site.

Raising fish in net pens has been practiced in various parts of the world for decades. The following environmental issues have arisen in different places and situations where net pens have been employed for fish farming (Brooks, Kenneth M et al. 2002). Each issue is addressed as it pertains to the SAFE net pen operations.

- Introduction of non-native fish
  With the exception of the SAB fall chinook, only fish stocks native to the Columbia River basin are reared in the SAFE net-pen operations. These are coho salmon (*Oncorhynchus kisutch*) and chinook salmon (*Oncorhynchus tshawytscha*).

- Introduction of non-native disease from non-native fish
  The one-time transfer of non-native SAB fall chinook did not result in the introduction of non-indigenous disease, and all other stocks are native.

- Concentration of parasitic sea lice (*Lepeophtheirus salmonis*) around the net pens that can infect wild fish
  Since the SAFE net pens are all located in fresh water, sea lice are not a problem.

- Aesthetic impact on the surroundings
  Part of the site selection process for net pens is to meet with people in the area to make sure that the net pens will be welcome. There have been no complaints about the aesthetics of the net pens.

- Predator Control (birds, otters, seals, etc)
  With the exception of permitted trapping of otters at Oregon sites, only non-lethal forms of predator control are used in the SAFE net-pen operations. Nets are placed over the top of the net pens to limit predation by birds. Wires that deliver a mild electric shock are tacked around the net pens to reduce access to the pens by otters. Live traps are also used occasionally so the otters can be relocated. Seals and sea lions have not created problems.

- The quality of farmed fish for human consumption has been questioned as a result of the diet of the fish, which consists of manufactured fish food usually containing dye.
  Fish raised by the SAFE project are raised to smolt size in the net pens. During this time they are fed manufactured fish food pellets that do not contain dye. When they reach the smolt stage they are released to migrate out to the ocean where they spend their adult life feeding on natural food sources.

- Impact of therapeutic compounds (pharmaceutical and pesticides) on non-target species
  The principal use of therapeutic compounds at some net pen sites has been to control sea lice. Sea lice are not an issue for the SAFE project net pens being at fresh-water sites. Erythromycin and Oxytetracycline are the only therapeutic compounds used by the SAFE project on the fish when they are in the net pens. The fish are not released until at least three weeks after being treated with the compounds to avoid human consumption. No environmental impact is expected to occur as a result of the use of erythromycin by the SAFE project. However, the monitoring program is designed to detect such an impact should it occur.

- Sediment Chemistry (nitrogen, phosphorus, zinc, copper, ammonia, hydrogen sulfide, Eh)
  Since antifouling agents are not used on the net pen structures, and production during the course of a year is lighter than at commercial production facilities where sediment chemistry parameters have been adversely affected, it is not anticipated that these parameters would be affected enough to produce an unacceptable impact. However, the monitoring program is designed to detect impacts from changes in sediment chemistry.

- Sediment Total Organic Carbon (TOC) to Grain Size relationship
  This relationship may be affected by the generation of organic materials from the net pens. It is monitored by laboratory analysis and by visual observation.

- Accumulation of organic matter (fouling organisms, uneaten fish food, fish feces, fish carcasses)
  This is the principle environmental impact of concern for the SAFE project net pen operations. The input of organic matter creates a localized impact. This differs from a systemic impact in that it is confined to the areas under the net pens. It is unlikely to spread and produce systemic effects. The focus of the monitoring program is to determine that the impact is small in intensity and limited to the mixing zone under and around the net pens. When there is an input of organic matter to a particular location it settles to the bottom sediments where it produces a range of effects as the input is increased. At low levels the first effect is an increase in the population density of those species that can utilize the organic matter. As the input increases, the species that can utilize the organic matter are increasing in numbers at the expense of species that cannot utilize the organic input or are not tolerant of high levels of organic material. As the input increases further, other species disappear from the area leaving only one or two hardy species. Finally, as the input exceeds the ability of the environment to keep up with the rate of input of the organic material, it begins to decay bacterially and deplete the dissolved oxygen at the surface of the sediment creating an anoxic layer. This would be considered to be an unacceptable impact.

  There are four sources of organic matter from the net pen operations. The first results from the presence of the net pen structures. They provide surfaces in the water column for aquatic species to attach. When these structures are disturbed, such as when work is done on the nets or when the fish are released, the attached organisms and organic debris fall to the surface of the underlying sediment. The second source of impact is from uneaten fish food that passes through the bottom of the nets and can accumulate on the bottom beneath the net pens. The third source of impact is from the waste produced by the fish. Much of this waste is in the form of ammonia in solution and is quickly diluted and carried away by the current. It is not likely to have any measurable impact on the large water bodies where the net pens are located. However, the solid waste produced by the fish can also accumulate under the net pens, adding to the other sources of organic material. The fourth source of organic input results when fish die and are not removed from the net pens, but instead, sink to the bottom of the pens and decay.

The environmental impact of the type of net pen salmon rearing being conducted by the SAFE project tends to be small when compared with commercial net pen fish production. The fish are not grown to marketable size in the SAFE net pens, and the fish usually occupy the net pens for only a part of the year. This allows a period of recovery for the environment around the net pens.

Two additional considerations for the SAFE project that are not encountered by most commercial operations are a result of the fish being released to migrate to the ocean and then return to the location of the net pens.

- Impact of released smolts on threatened or endangered species
  Site selection by SAFE project includes a test fishery and stream surveys to determine the absence of species that are protected and could be adversely affected by the presence of smolts upon their release from the net pens.

- Impact of returning fish and fishing activity on threatened or endangered species
  The test fisheries and stream surveys indicate that the harvest of the net pen fish can be conducted without significant impact on other non-target species.

QUALITY ASSURANCE

All work is done following Good Laboratory Procedures and in accordance with the Quality Assurance Project Plan associated with this project (DEQ, Quality Assurance Project Plan) (EPA Guidance for Quality Assurance Project Plans) (Water Quality Monitoring Technical Guide Book July 1999) (PSEP, Collection of Environmental Data 1997).

METHODS AND MATERIALS

Water Chemistry

Physicochemical parameters are monitored at the proposed net pen site using one of two instrument clusters to record temperature, pH, dissolved oxygen, conductivity and turbidity (PSEP, Conventional Water Quality Variables and Metals in Fresh Water 1990) (PSEP, Measuring Conventional Marine Water-Column Variables 1991). These instruments are contained in both the HydrolabJ Surveyor 3 Datalogger with an H_2O Datasond and the HydrolabJ Surveyor 4A Datalogger with a Surveyor 4 Datasond. One of these instruments is deployed at each net pen location for one 24-hour period each month coinciding with the growing season. The instruments are calibrated with standards according to the manufacturer's instructions. The data is generated in electronic files that are downloaded directly into a personal computer.

Sediment Chemistry

Baseline sediment chemistry samples are collected for Total Organic Carbon (TOC) and Grain Size Distribution at both a prospective net pen site and a reference site (PSEP, Measuring Conventional Sediment Variables 1986). These samples are collected by using a core plunge sampler to collect 2-inch diameter cores. When the coring device is retrieved the top flap valve is opened. The core is extruded through the top of the sleeve and the top 5 cm section of a core is cut off into a jar. One sample for each TOC and grain size is collected from the proposed net pen site and from the reference site.

Monitoring Benthic Populations

Baseline samples are collected for benthic population structure at both a prospective net pen site and a reference site (R.W. Plotnikoff and J.S. White1996) (PSEP, Analyzing Subtidal

Benthic Macroinvertebrate Assemblages 1987). These benthic samples are collected using a core sampler to collect 3-inch diameter cores (nominal). When the coring device is retrieved, the core sleeve is separated from the device. The core is extruded through the top of the sleeve. The overlying water is allowed to run into a plastic tub to capture any epibenthic animals that may swim into the overlying water. The top 5 cm section of a core is cut off into the tub and then the water and sediment is transferred to a one-gallon plastic bucket with lid. Sediment samples are sieved through a 500-micron mesh sieve and the materials retained on the sieve are fixed using a 10 percent buffered formalin solution. After one to four days the samples are transferred to 70 percent ethanol. They are stained with rose bengal to aid in sorting. Each sample is sorted under a binocular dissecting microscope and all of the animals are removed and stored in ethanol. These animals are identified and enumerated. This is the source of the benthic population data provided for each net pen location in the Results and Discussion section.

ASSESSING SITE SUITABILITY FOR FISH REARING

The following steps are taken to identify a water body suitable for net pen operations:
- Identify water bodies with suitable depth and access to fishing vessels
- Measure physicochemical parameters
- Investigate the history of the site for the possible presence of toxic waste
- Sample sediment for benthic population structure and sediment chemistry
- Investigate ownership and resident’s interest
- Determine if natural fish runs exist, which would be in conflict with a net pen fisheries
- Conduct a test fishery to determine if a conflict with endangered species exists

Data Interpretation

Physicochemical data is displayed on a Figure to determine if any parameters are outside of the acceptable range for the culture of salmon. Sediment TOC and grain size distribution data is baseline data used for comparison with data collected during salmon rearing to assess any changes resulting from the net pen operation.

The benthic population structure is examined for the presence of pollution tolerant species, the absence of pollution sensitive species, and the absence of long lived species that are expected to be present in the lower Columbia River estuaries. These factors are used to assess the suitability of the site for salmon rearing. The benthic macro invertebrate data also provides baseline data used to detect any future changes.

MONITORING THE ENVIRONMENTAL IMPACT OF NET PEN OPERATIONS

The SAFE net pen facilities operate under the environmental regulations of the state in which they are located. Both Oregon and Washington conform with the National Clean Water Act (40 CFR 122,24). Under this act the net pens are considered to be concentrated aquatic animal feeding operations. As such, net pen operations that hold 20,000 pounds of fish or more, or feed 5,000 pounds of food or more during any calendar month are required to have a discharge permit. The facilities at Steamboat Slough in Washington, and Blind Slough in Oregon operate below this production limit. Monitoring at these sites is voluntary.

The facilities at Tongue Point, Youngs Bay (Tide Point), and Youngs Bay (Yacht Club) all produce more than this limit, therefore an NPDES Permit is required. Environmental monitoring is required by the conditions of the permit at these locations. At sites where discharge permits are required, the permit allows for a mixing zone that extends 15 meters from the net pen structure in all directions.

The production levels at the facilities in Deep River, Washington and the MERTS site in Oregon have been less than that which requires a discharge permit, and monitoring at these sites has been voluntary. However, both of these sites are expected to be expanded to a level requiring a permit in the future, and the monitoring is expected to become mandatory and expanded.

The ability of the monitoring effort to detect an environmental impact depends on the degree of resolution that the monitoring design provides (Ferraro et al. 1989, 1991, 1992). More resolution usually requires that more samples be collected and processed, and therefore it requires more effort and greater expense. Since the regulated party has an interest in minimizing expense, the design of the monitoring program at sites where a permit is required is developed with the consensus of the state agency that issues the discharge permit.

Monitoring Benthic Populations

There are three net pen sites operating under NPDES discharge permits. The perimeter of the mixing zone at these sites is sampled to insure there is no environmental impact outside of the mixing zone. Stations are selected at points along the perimeter of the mixing zone and replicate samples are collected for benthic population analysis at each station. In addition, samples are collected from a station under each set of net pens to monitor the impact of the fish rearing activities and determine whether an unacceptable condition is developing.

Three Reference stations are identified for each site operating under a permit. These Reference stations are representative of the biological and chemical conditions that are normal for that body of water. Core samples are collected for benthic population analysis at each reference site to compare with benthic population analysis of the samples collected at the perimeter of the mixing zone and also with the samples collected from under the net pens.

As described in the Background section, monitoring the net pen sites that do not require a discharge permit is done to detect any changes in the environment under the net pens that may be attributed to the fish rearing activities. At these sites samples are collected from one station under both the net pens and one Reference station.

Core samples are collected for benthic population structure analysis at each station. Samples are collected at the end of the growing season when the impact of the fish rearing should be at a maximum. Samples are collected again before the beginning of the next growing season from any station where an impact had been detected by the June monitoring and from one Reference station to measure the recovery of the net pen site.

Reference Site Selection

In order to determine if changes in the benthic population structures under the net pens are a result of the fish rearing activity or of some other change affecting the entire water body, the impact site must be compared to a reference site. The reference sites are located by hand held Global Positioning System receivers that are accurate to approximately 10 meters (PSEP, Station Positioning 1998). They should be close enough to the impact site as to experience the same influences as the impact site, but well outside of the influence of the fish rearing activities. The reference sites should be of approximately the same depth and have the same flow patterns, sediment chemistry, and benthic community structure as the impact site.

Sediment Chemistry

TOC and grain size distribution are monitored by collecting core samples as previously described. One sample is collected for TOC analysis and one for grain size analysis from each station where samples are collected for benthic macro invertebrate. These samples are collected near the end of the growing season.

Sedimentation

The accumulation of organic mater from uneaten fish food or other net pen wastes is inferred from the measurements of TOC and grain size distribution of the samples collected from beneath the net pens. In addition, sediment samples are taken from beneath each net pen for visual inspection of the surface layer for the development of an anoxic condition. A log is kept of observations from each sample such as the presence of any anoxic condition as evidenced by the depth of the surface redox layer, the smell of hydrogen sulfide, the blackening of the surface, the presence of live sediment dwelling animals, and any other pertinent observations.

Data Interpretation

Analysis of benthic invertebrate samples produces a list of species present and the numbers of each species for each station sampled. With this information various characteristics of the invertebrate population of the impact sites and the perimeter sites can be compared to those of the reference sites.

The parameters of taxa richness (number of species present), abundance (the total number of animals present), and dominance (percent of population composed of the dominant species) at the Reference stations are compared to these parameters measured at the stations on the perimeter of the mixing zone and at the Impact stations under the net pens. In addition, significant differences in each species between stations is also analyzed. This allows for the assessment of the differences in species that may be sensitive to, or tolerant of, this type of impact. These population parameters are compared to those from Reference stations using the Wilcoxon Rank Sum Analysis (Lyman, O 1984). This statistical analysis allows 90% confidence when analyzing three samples from each population. When comparing an Impact station or a Perimeter station to three Reference stations, 95% confidence is attained. In the line Figures that follow, red dots on the data points indicate a statistically significant difference between the Reference station and the Impact station.

RESULTS AND DISCUSSION

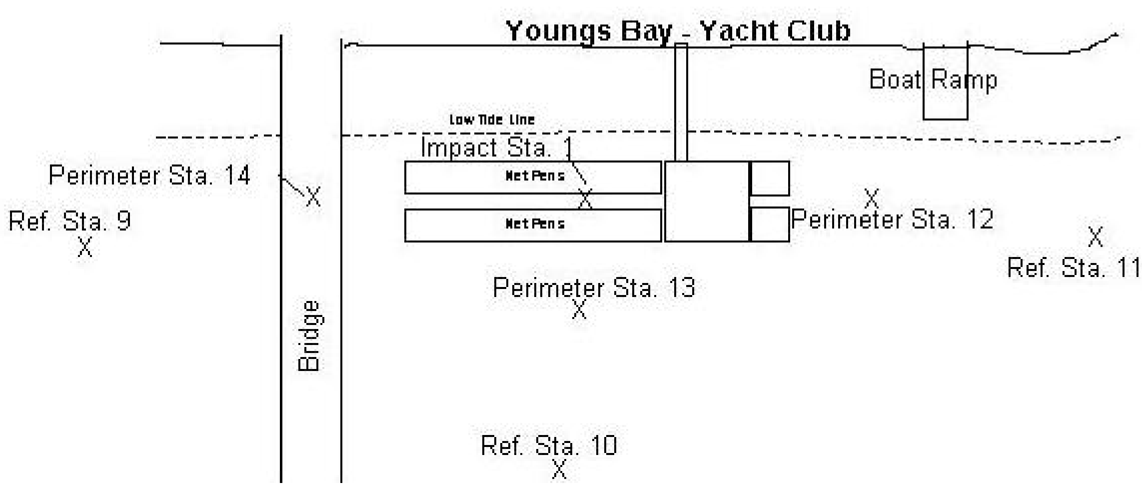
Youngs Bay, Yacht Club

This facility in Youngs Bay is located just upstream of the Warrenton/Astoria Highway bridge over Youngs Bay. Youngs Bay is located close to the mouth of the Columbia River and is subject to salt-water influence, especially during the summer months when rainfall is low as indicated by the specific conductivity readings. There is a fresh water influence from the Lewis and Clark, Youngs, and Klaskanine rivers. Fish rearing began here through the 1996 – 1997 season. The first samples were collected during the preceding summer of 1996.

This site is subject to several sources of impact besides the net pen fish rearing activities. Most notably, the net pen pier is also used by a number of commercial fishing boats. At the peak of the fishing season there may be as many as 50 fishing boats tied up. Other influences are a bridge about fifty feet to the west, a public boat ramp just to the east, an abandoned cannery just east of the ramp, and the use of the net pen pier by the public for recreational fishing and other activities. The impact on the environment in this area must be taken in the context of all of the activities that occur at this site.

This facility has a production level that requires an NPDES discharge permit issued by ODEQ. A mixing zone has been defined by ODEQ as extending 15 meters out from the edge of the net pen facilities in all directions. The permit specifies that no environmental impact is to occur outside of the mixing zone. The location of sampling stations is illustrated in the drawing below. Three samples are collected from each station for benthic macro invertebrate analysis, one is collected for TOC, and one is collected for grain size Analysis. Sampling stations are located on three sides of the mixing zone. The fourth side of the mixing zone is too close to shore to monitor.

The permit also specifies that there shall be no sedimentation within the mixing zone that adversely affects aquatic life or any beneficial use. This could occur if organic matter accumulates faster than the environment can absorb it. A sampling station is located under the net pens.



In addition to the station where samples are collected for macro invertebrate analysis and sediment chemistry, a core sample is collected from under each net pen. Each of these cores is visually inspected to insure that the organic material is not accumulating faster than the environment can absorb it. If this were to occur, patches of an anaerobic surface “mat” would be expected to appear. This may be accompanied by the odor of hydrogen sulfide. The light brown oxidized surface layer would disappear and live animals would be absent. A log is kept with the observations from each core. There are three Reference stations associated with this net pen facility site to provide a more accurate assessment of the normal benthic invertebrate populations and sediment chemistry of the area.

The plan for monitoring the environmental impact at this facility was written and approved by ODEQ prior to the end of the fish rearing season in June 2002. Prior to this, only benthic macro invertebrate samples were collected, and they were only collected from the Impact station under the net pens and from one Reference station. Therefore, historical comparisons can only be made between these two stations.

The sediment at this facility is not as organically rich as the Blind Slough or Deep River sites. They are similar in TOC to sediments at Tongue Point and the Tide Point/Bornstein facility. They are organically richer than those at Steamboat Slough where the sediments are coarser and more sandy as a result of the strong currents. The TOC at each sampling station is provided in Table 1. for the two years that TOC samples were collected.

Table 1. Total Organic Carbon of the Sediments of the Youngs Bay, Yacht Club Stations

Station	June 2002	June 2003
Impact station 1	2.68	0.94
Reference station 9	1.58	1.05
Reference station 10	0.89	2.15
Reference station 11	1.42	1.54
Perimeter station 12	1.78	1.49
Perimeter station 13	1.34	2.00
Perimeter station 14	2.33	1.53

Figure 1. shows the population density at this facility. The first summer samples were collected before fish rearing began in the summer of 1996, and sampling continued through the summer of 2003. Fall sampling began in 1996, just before fish were added, and continued through the fall of 2002; the last samples that have been analyzed at the time that this report was written.

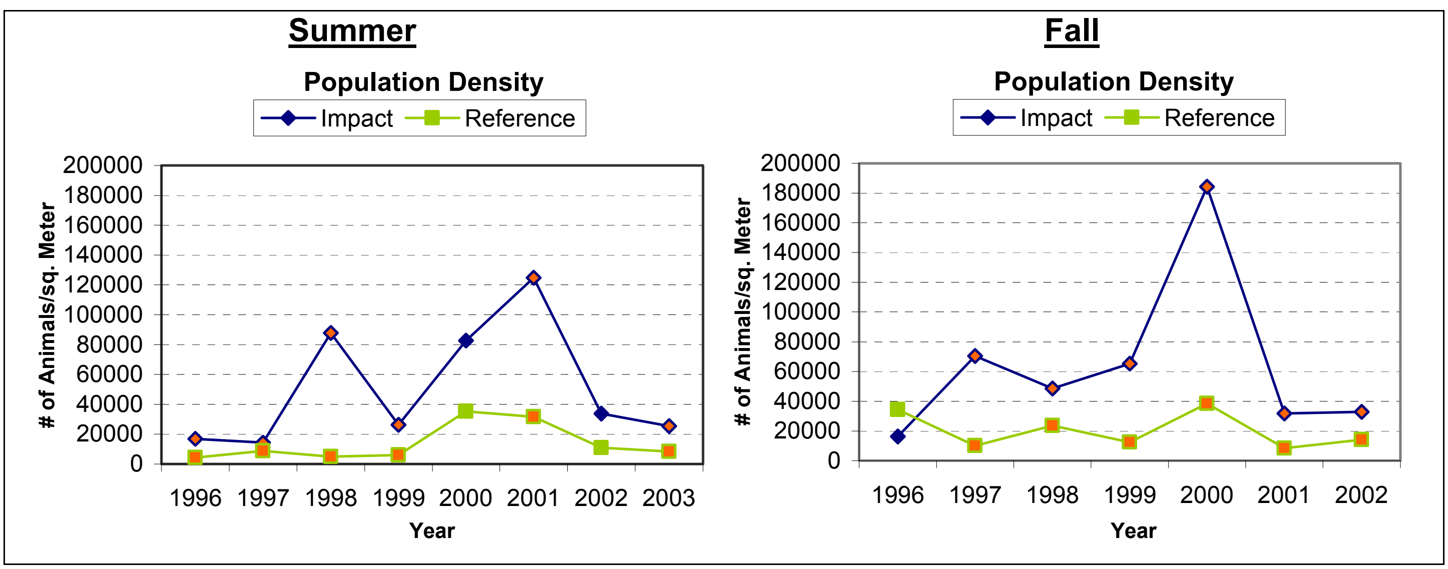


Figure 1. Summer and fall macro invertebrate population density, Youngs Bay Yacht Club facility (YB,YC), 1996-2003.

The population at the Impact station is consistently more dense than the population at the Reference station in the summer, even before fish rearing began, when the difference was small but statistically significant. The initial difference is probably due to the other influences on this station that were described earlier in this section. By the end of the second year of fish rearing activity the difference has increased, and in some years the difference in population density between the two stations is very large. Spikes in the population density occur in the summers of 1998, 2000 and 2001. The spikes that occurred in the summers of 2000 and 2001 occurred at the Reference station, as well as at the Impact station, so this was due to system-wide environmental conditions. However, the increase in density was much larger at the Impact station than at the Reference station.

The fall samples of 1996 show that the population density at the Reference station is slightly higher than at the Impact station. After the start of fish rearing at this site the population is consistently and significantly more dense than the population at the Reference station. This indicates that the organic material that is added to the environment at the Impact station is not depleted. Some fish are held in the net pens at this facility through the summer and early fall in some years. This may contribute to the lack of recovery.

The structure of the benthic macro invertebrate population in Youngs Bay is more complex than at the other net pen sites. At other sites the benthic macro invertebrate population is dominated by *Oligochaeta*. Youngs Bay has been invaded by the non-indigenous New Zealand mud snail, *Potamopyrgus antipodarum*, a very hearty and prolific species. This species has come to dominate the benthic macro invertebrate population in most years but other species are also present in high population densities. The *amphipod Americorophium* spp. sometimes outnumber the mud snail. Figure 2. shows the relationship between the density of the population of these species and that of the whole population during the summer. While the *Oligochaeta* are always present, they do not dominate the population as they do in other locations. At the Impact station of this facility it is the mud snail that is best able to utilize the organic material that results from the fish rearing activities.

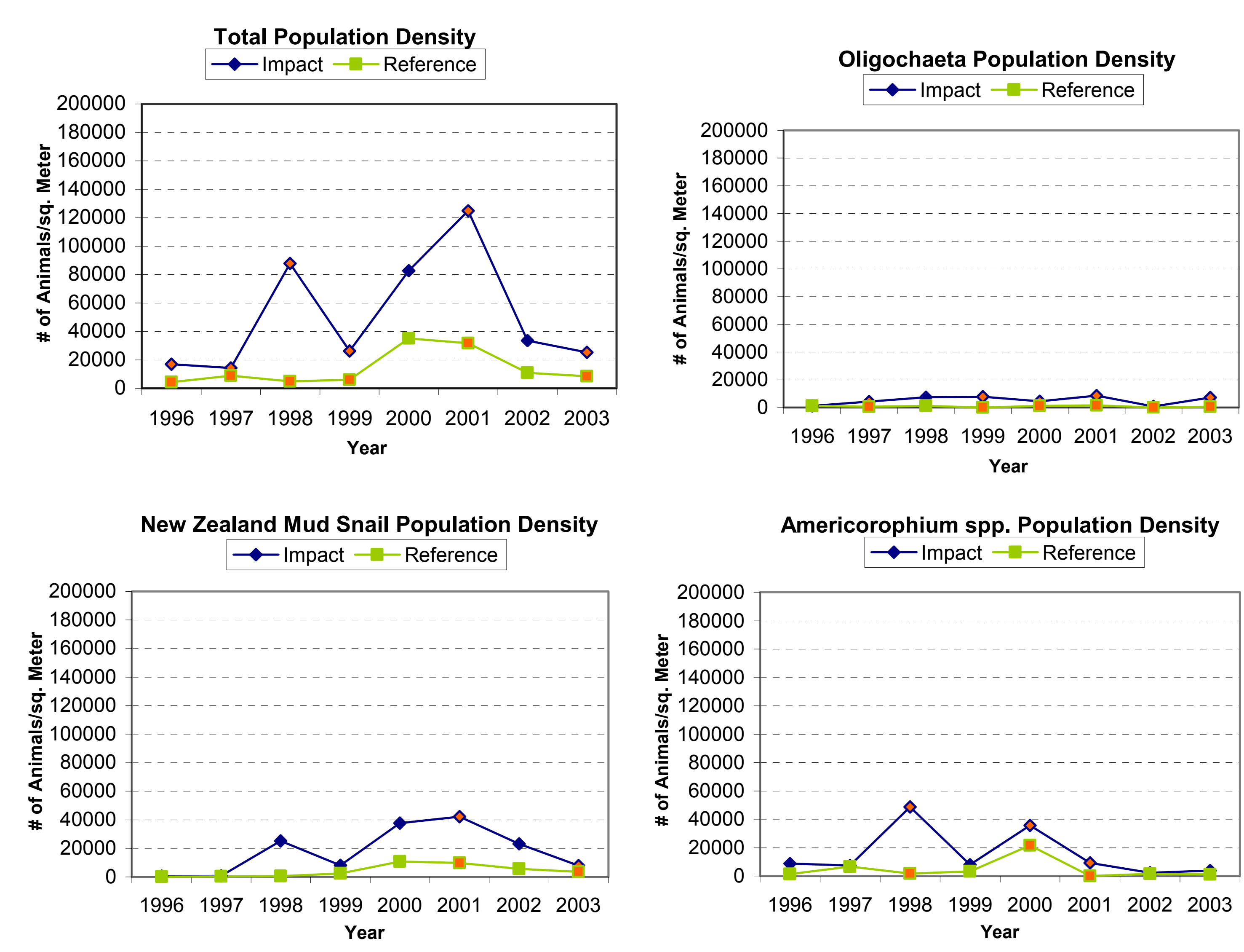


Figure 2. Population density of dominant species compared to total population at Youngs Bay Yacht Club facility, 1996-2003.

Figure 3. shows the effect of the organic enrichment on the number of species present at the impact and Reference stations in the summer and fall of each year that samples were taken.

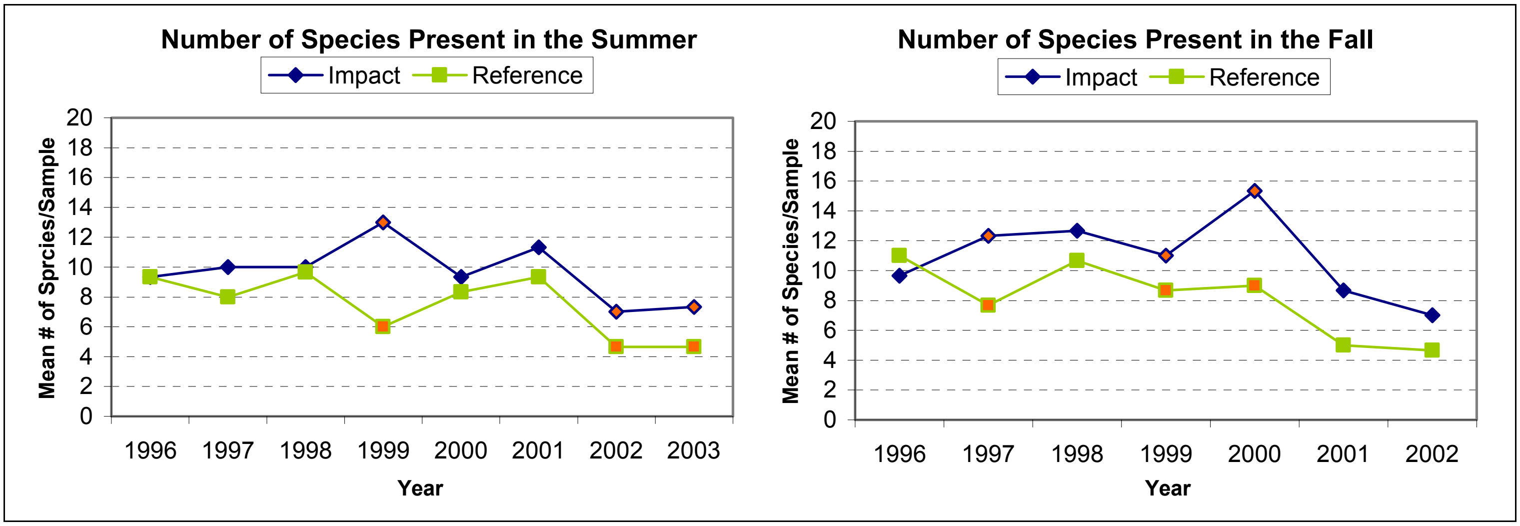


Figure 3. Mean number of species present in Youngs Bay Yacht Club facility samples, spring versus fall, 1996-2003.

Just as the population density is higher at the Impact station in both the summer and the fall, the number of species is also usually greater at the Impact station. In this complex environment there are more species able to take advantage of the infusion of organic material.

The long-term data shows a measurable response in the basic population parameters to the organic enrichment associated with net pen fish rearing. This response persists through the summer and fall months when fish rearing activities are at a minimum. However, there is no indication at this time that the environment under the net pens is unable to absorb the organic materials generated at this facility. The number of species that utilize the material actually increases and there has been no indication of the development of an anoxic condition beneath the net pens.

Beginning in the summer of 2002 the monitoring plan was implemented that was developed to meet the permit conditions. As described previously, this plan requires that samples be collected from stations on the perimeter of the mixing from three Reference stations instead of just one. Having three Reference stations allows for statistical confidence of 95 percent and better represents the variability of the environment.

Two years of data does not permit a long-term analysis of the data or the detection of trends. Therefore, the data does not allow an historical view of the Perimeter stations or of the two additional Reference stations.

Figure 4. shows the benthic macro invertebrate data collected from all of the stations at this site where samples were collected under the current work plan in the summer of 2002.

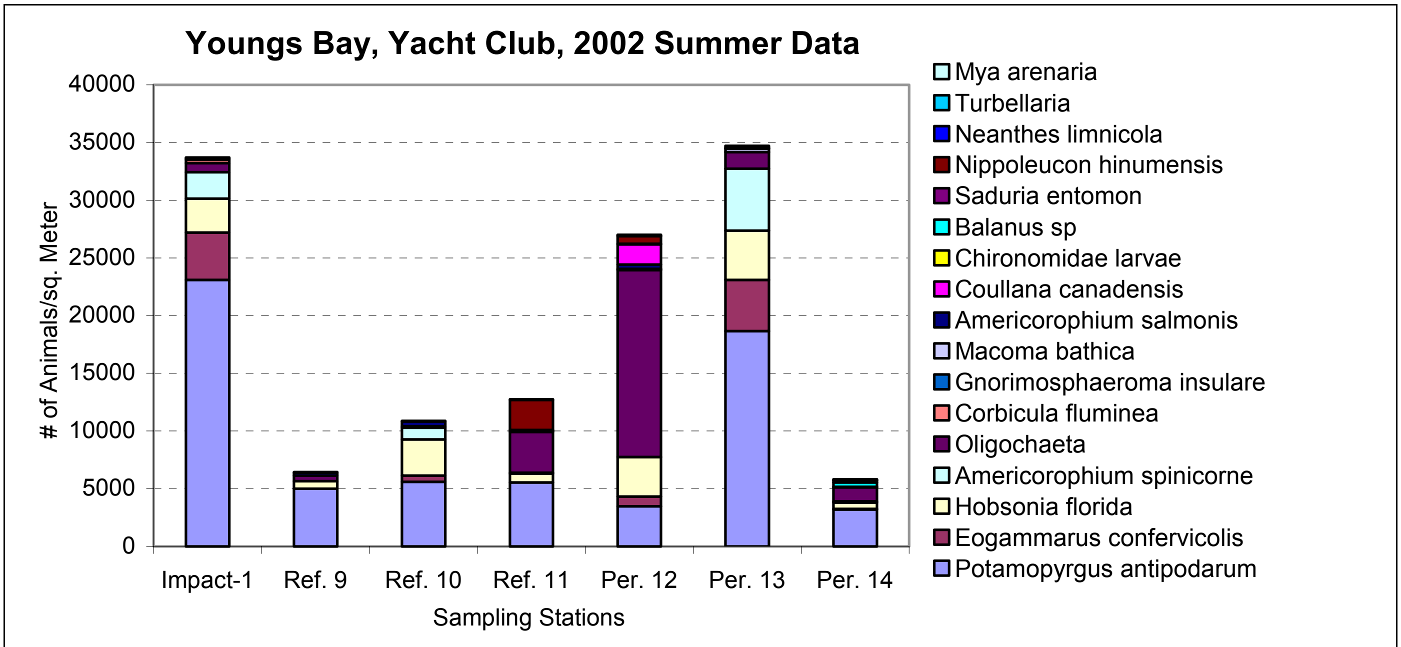


Figure 4. Macro invertebrate data, population size and composition at Youngs Bay Yacht Club facility, summer of 2002.

The Impact station shows a disproportionately dense population of the mud snail in the samples. However, due to variability between the samples, neither the population density of the mud snail or the overall population density is significantly different from the reference condition. The population density of three species was consistent enough to detect a statistically significant difference. This difference is seen in *Eogammarus confervicolus*, *Americorophium spinicorne* and *Corbicula fluminicola*, all of which were more dense at the Impact station than at the Reference station.

Perimeter station 12 differs from the reference condition in that it has a greater population density, a greater number of species, and more dense populations of *Oligochaeta* and *Coullana canadensis*. These parameters are consistent with a response to organic enrichment. There should be no detectable environmental impact at this station. If this condition persists, it may be necessary to take steps to reduce the amount of organic matter reaching this side of the mixing zone.

While the Figure shows a large difference in several population parameters at Perimeter stations 13 and 14, overall population density, the density of the mud snail population and to a lesser extent the population density of *Hobsonia florida* and *Americorophium spinicorne*, the samples are too variable to detect any statistically significant difference. There is no detectable impact at Perimeter stations 13 and 14.

Figure 5. shows the benthic macro invertebrate data collected from all of the stations at this facility in the summer of 2003. The most notable feature of this Figure is at Perimeter station 14. This station is located under the Warrenton/Astoria Highway bridge. The type of sediment under this bridge and the debris from bridge work and other activities associated with the bridge create an environment unique from Reference stations and all of the other stations. This environment, at the time of this sample collection was very hospitable to the amphipod, *Americorophium salmonis*. It is this species that accounts for the huge population increase at Perimeter station 14. While this species benefits from organic enrichment that accompanies net

pen fish rearing activities, it is the physical characteristics of the habitat that contribute to the dense population of the amphipod.

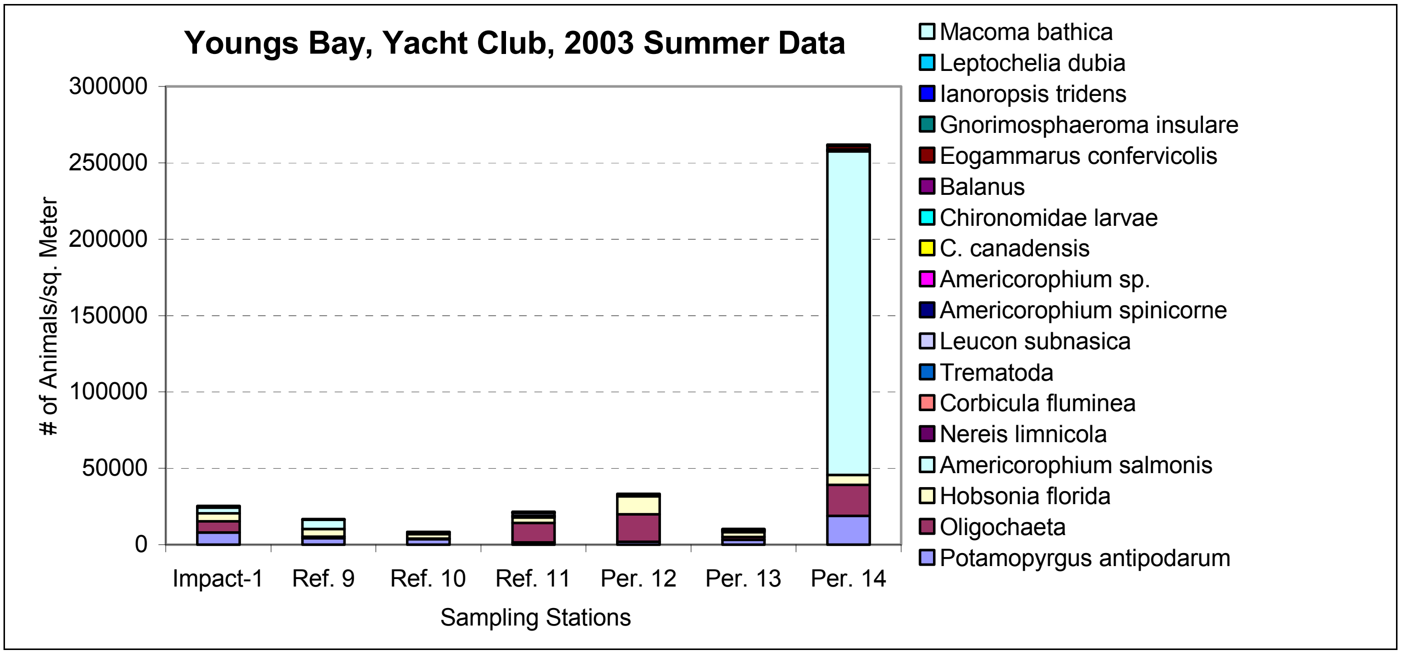


Figure 5. Macro invertebrate data, population size and composition at Youngs Bay Yacht Club, summer of 2003.

By eliminating this species from the Figure, the Figure better illustrates the relationship between the populations at the various stations. Figure 6. illustrates the benthic macro invertebrate population structure at this facility in the summer of 2003 with the *A. salmonis* data eliminated from Perimeter station 14.

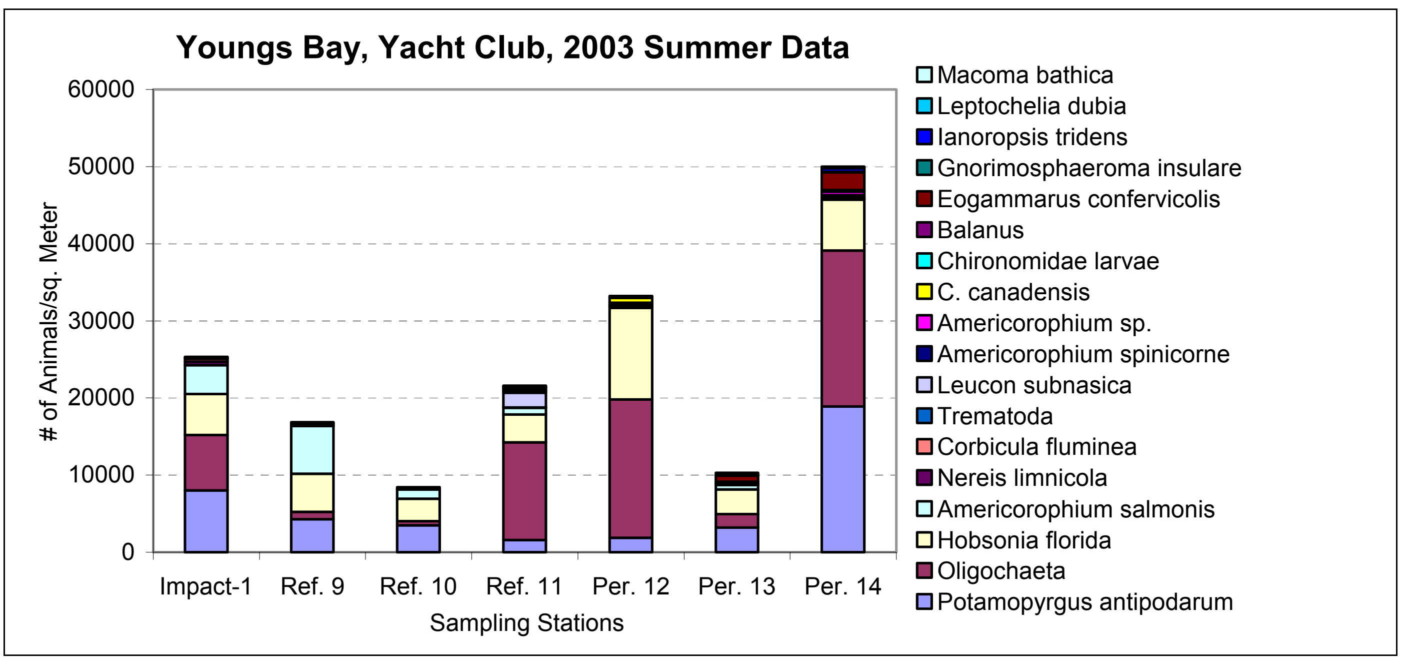


Figure 6. Macro invertebrate data, population size and composition at Youngs Bay Yacht Club site, summer of 2003, with *A. salmonis* eliminated from perimeter Station 14.

The Impact station does not differ significantly from the reference condition in any of the general population parameters. It is not more dense, the number of species does not differ, and there is no significant difference in the percent of the population comprised of the dominant species. However, the population of *Potamopyrgus antipodarum*, the mud snail, is more dense at the Impact station, as is the populations of the *Polychaeta* worm *Nereis Limnicola* and the bivalve, *Corbicula fluminea*. This indicates organic enrichment.

Perimeter station 12 shows indications of organic enrichment again this year. Although there are no significant differences in the general population parameters, the population of both the *Oligochaeta* and the *Polychaeta* worm, *Hobsonia florida* are more dense than the reference condition. The amphipod, *A. salmonis* is absent from this station.

Perimeter station 13 does not differ significantly from the reference condition again this year.

The population measurements of *A. salmonis* at Perimeter station 14 contains a statistical oddity. Two of the samples contained large numbers of the amphipod, and the third had none. Therefore, despite the large number of this species at Perimeter station 14, the statistical analytical method used to assess differences, the Wilcoxon Rank sum analysis, does not detect a difference in the population density of this species between this station and the Reference stations. With or without this species, Perimeter station 14 differs from the reference condition in that it has a more dense total population and a more dense population of the mud snail and of *Hobsonia florida*. This station is also showing indications of organic enrichment.

Sediment core samples were taken from under each net pen in the summers of 2002 and 2003. In both years and from under each net pen every sediment core had a measurable oxidized surface layer, the presence of live animals, and no signs of a surface mat of decaying organic material. There is no indication that an anoxic condition is developing under the net pens.

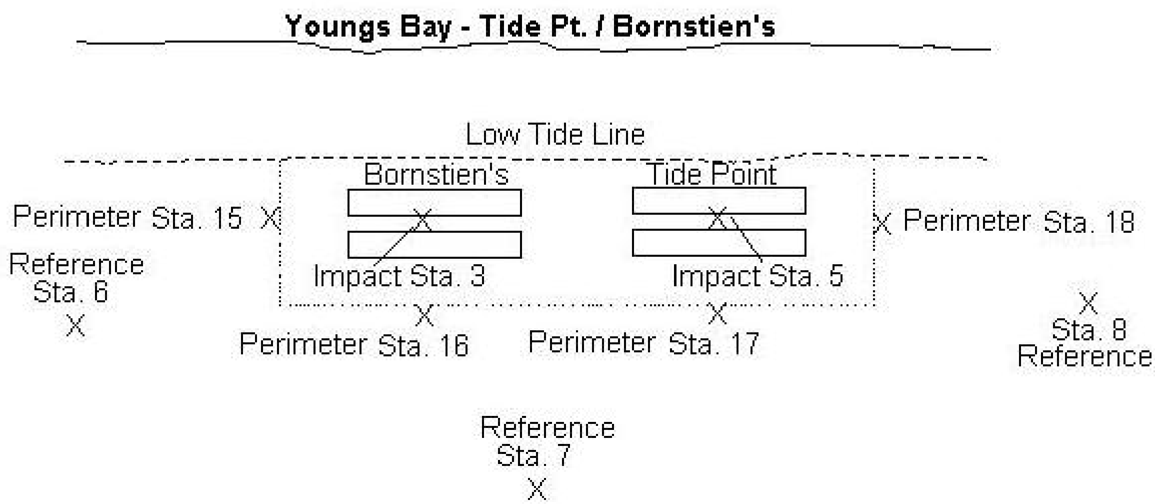
Perimeter stations 12 and 14 lie downstream of the net pens during the incoming tidal currents and the outgoing tidal currents respectively. Perimeter station 13 does not lie downstream of the net pens so the currents do not carry wastes from the net pens to this Perimeter station. The two stations that lie in the paths of currents show indications of organic enrichment. This is not allowed by the discharge permit. These stations must be closely monitored in the future, and if this condition persists, then changes may be necessary in the management practices at this facility.

Youngs Bay, Tide Point/Bornstein

The Tide Point and Bornstein facilities in Youngs Bay are located about 0.5 miles upstream from the Warrenton/Astoria Highway bridge near the north shore of Youngs Bay. There is a salt-water influence especially in the summer months when the rainfall is low. Freshwater influence comes from the Lewis and Clark, Youngs and Klaskanine Rivers. This location experiences strong tidal currents and is well flushed.

These facilities consist of two sets of net pens that are close together. They operate under the Youngs Bay NPDES discharge permit issued by ODEQ. For the purpose of environmental monitoring they are treated as having a common mixing zone. The permit specifies that no environmental impact is to occur outside of the mixing zone. Sampling stations are specified, and at each station three samples are collected for benthic macro invertebrate analysis; one for TOC and one for grain size analysis. Sampling stations are located on three sides of the facility on the edge of the mixing zone. There are four Perimeter stations associated with this net pen facility site. The forth side of the mixing zone is too close to shore to monitor.

There are three Reference stations associated with this net pen facility to provide a more accurate assessment of the normal benthic macro invertebrate populations and sediment chemistry of the area. The location of the sampling stations relative to the net pens is illustrated in the Figure below. The scale is not intended to be accurate.



The permit also specifies that there shall be no sedimentation within the mixing zone that adversely affects aquatic life or any beneficial use. This could occur if organic matter accumulates faster than the environment can absorb it. A sampling station is located under each set of net pens.

In addition to the station where samples are collected for macro invertebrate analysis and sediment chemistry, a core sample is collected from under each net pen. Each of these cores is visually inspected to insure that the organic material is not accumulating faster than the environment can absorb it. If this were to occur, patches of an anaerobic surface “mat” would be expected to appear. This may be accompanied by the odor of hydrogen sulfide. The light brown oxidized surface layer would disappear and live animals would be absent. A log is kept with the observations from each core.

The sediment at this facility is not as organically rich as sites such as Blind Slough or Deep River. The substrate contains much woody debris and mudstone making it very difficult to sample. The sediments are similar in TOC to sediments at Tongue Point and the Youngs Bay, Yacht Club facility. They are organically richer than those at Steamboat Slough where the sediments are coarser and more sandy as a result of the strong currents. The TOC at each sampling station is provided in Table 2. below for the two years that TOC samples were collected.

Table 2. Total organic carbon of the sediments of the Tide Point Bornstein's stations, 2002-2003.

Station	June 2002	June 2003
Impact Sta. 3	2.28	1.66
Impact Sta. 5	3.8	2.90
Ref. Sta. 6	2.53	1.40
Ref. Sta. 7	2.1	0.89
Ref. Sta. 8	1.81	1.69
Perimeter Sta. 15	2.1	1.94
Perimeter Sta. 16	1.34	1.46
Perimeter Sta. 17	1.01	1.25
Perimeter Sta. 18	1.25	0.71

The Bornstein net pens have only been in operation since the fall of 2002. It has not been active long enough to detect any long-term trends. The following long-term trends pertain only to the Tide Point net pens. Figure 7. compares the Impact station and Reference station population density history in the summer just after the fish rearing season and in the fall, after several months of inactivity prior to the next season.

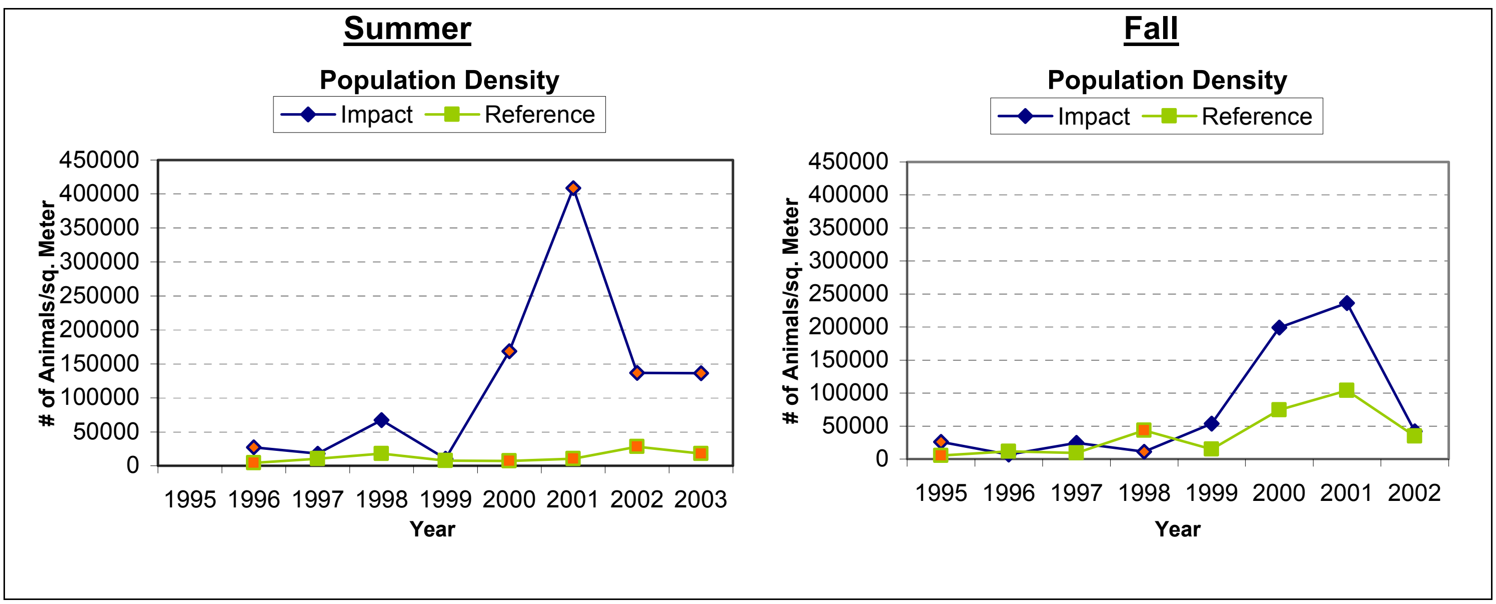


Figure 7. Macro invertebrate population density at Youngs Bay Tide Point facility, summer versus fall, 1995-2003.

The populations started out being slightly but significantly more dense at the Impact stations in both the fall of 1995 and the following summer of 1996. After this there is no difference in population densities between the Impact station and the Reference station in the summer until 2000. After the summer of 2000 the population density at the Impact station increases over that of the Reference station significantly and by a wide margin. This situation persists through the summer of 2003. During the fall months there is seldom any significant difference in population density, and the Reference station is sometimes more densely populated than the Impact station. This indicates that the organic enrichment that occurs at the Impact station does not persist through the months of inactivity.

The benthic macro invertebrate population structure at this facility is dominated by the mud snail, *Potamopyrgus antipodarum*, most years. Amphipods of the genus *Americorophium* frequently constitute a large percent of the population, especially at the Impact station. The *Oligochaeta* do not dominate the populations at this facility as they do at facilities further up the Columbia River.

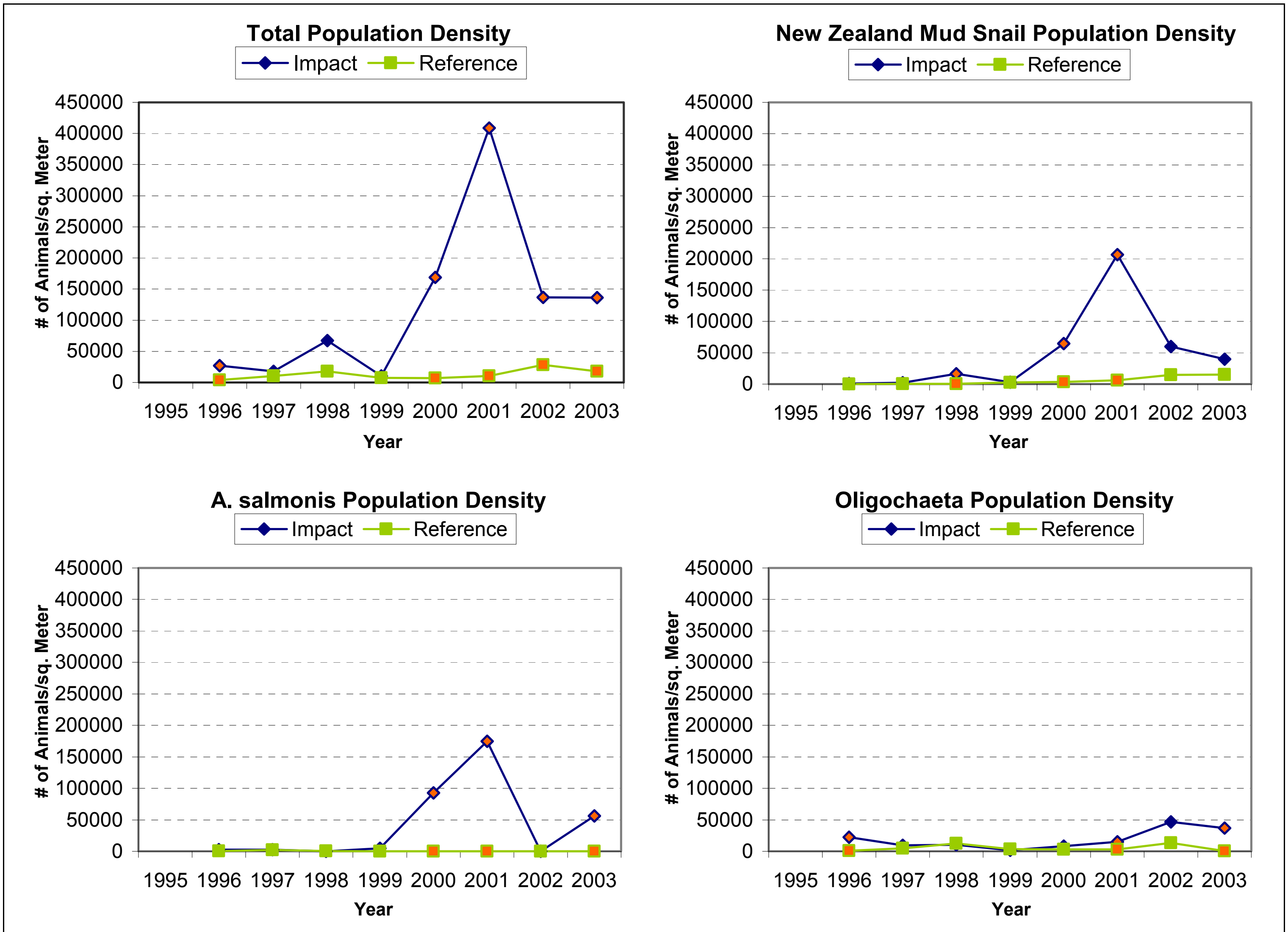


Figure 8. Population density of dominant species compared to total population at Youngs Bay Tide Point facility, 1995-2003.

The large population density increases in the summers of 2000 and 2001 are driven primarily by the mud snail and *Americorophium salmonis*, but other species that increased in density were amphipod *Eogammarus confervicolus* and the *Polychaeta* worm *Hobsonia florida*. Increases of this nature were seen at other facilities and, to some extent, at the Reference stations, as well as the Impact stations. However, at this facility the increase in population density was seen almost entirely at the Impact station and among taxa that are able to utilize the organic material produced by the fish rearing activities.

The trend of increasing benthic macro invertebrate population density at the Impact station in recent summers is reason to be concerned about the impact of organic enrichment of the environment at this facility. However, since the situation does not appear to persist over the months of inactivity it is not of as much consequence as it would be if it persisted. Other population parameters do not show a detectable trend of response to the organic enrichment. Future monitoring will detect any increased response to the fish rearing activities.

The current work plan specifies that the edge of the mixing zone will be sampled to insure that any environmental impact that occurs will be confined to the mixing zone. This plan was adopted just before the summer of 2002 samples were collected. This has only provided two years of samples for the Perimeter stations. Two years of data do not permit a long-term analysis of the data or the detection of trends. However, the data for those two years provides a snap shot to determine if the facility is in compliance with the rule that there will be no impact beyond the mixing zone.

The Figure 9. shows a large increase in population density at both of the Impact stations as compared to the Reference stations. This density increase is statistically significant at both stations. At Impact station 3 the increase is due to the significant increases in the *Oligochaeta*, the amphipods, *Americorophium spinicorne* and *Eogammarus confervicolus*, *Corbicula fluminea* as well as and *Hydroida* colonies. At Impact station 5 the increase is due to the mud snail, *Potamopyrgus antipodarum, Americorophium spinicorne* and *Eogammarus confervicolus*, *Polychaeta* worm, *Hobsonia florida, Turbellaria* and *Hydroida* colonies. Both stations also have a greater number of species. Increases in these taxonomic groups indicates population increases due to organic enrichment.

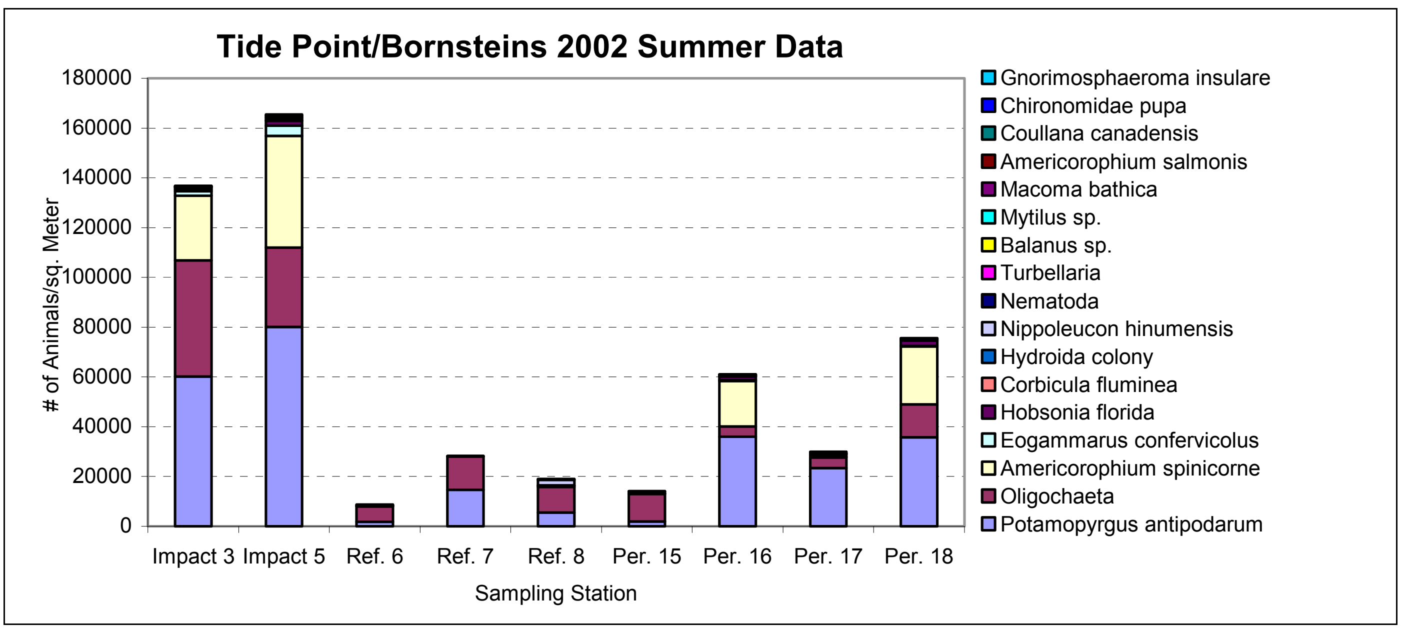


Figure 9. Macro invertebrate data, population size and composition at Youngs Bay Tide Point facility, summer of 2002.

Perimeter station 15 has no statistical differences from the Reference condition.

Perimeter station 16 differs from the Reference condition in having a more dense overall benthic macro invertebrate population due to more dense populations of the mud snail, *Americorophium spinicorne* and *Hydroida* colonies. It also has more species.

Perimeter station 17 differs from the Reference condition in having more dense populations of the mud snail and *Americorophium salmonis* but not a more dense overall population.

Perimeter stations 16 and 17 have a different benthic substrate than the Reference stations. They have a great deal of large woody debris. This bottom structure also offers many crevices and sheltered spots that provide more protected habitat than the muddy bottom of other stations. The direction of current does not carry organic materials from the net pens in the direction of these stations. Therefore, it is unlikely that the increase in population at these stations is a result of the fish rearing activities. The differences in population are likely a result of the bottom structure at these stations.

Perimeter station 18 has no statistical differences from the Reference condition due to variability between the samples. However, there were a much larger number of animals in two of the samples. Since incoming tidal currents could carry materials to this station, and since the two species that were more numerous in two of the samples from this station than at the Reference stations benefit from organic enrichment, this station may be experiencing an impact from the fish rearing activities.

Figure 10. shows the benthic macro invertebrate data collected from all of the stations at this site in the summer of 2003. The most notable aspect of this Figure is the large population density at Perimeter station 16. This is a significant difference in overall population density from the Reference condition. This overall population density is due to a significantly more dense population of *Americorophium salmonis* and of the mud snail, *Potamopyrgus antipodarum*. Since the currents do not run in the direction that would carry organic material to this station, and since other Perimeter stations do not show any impact, it is unlikely that the differences between this station and the Reference condition in the benthic macro invertebrate population is a result of the fish rearing activity.

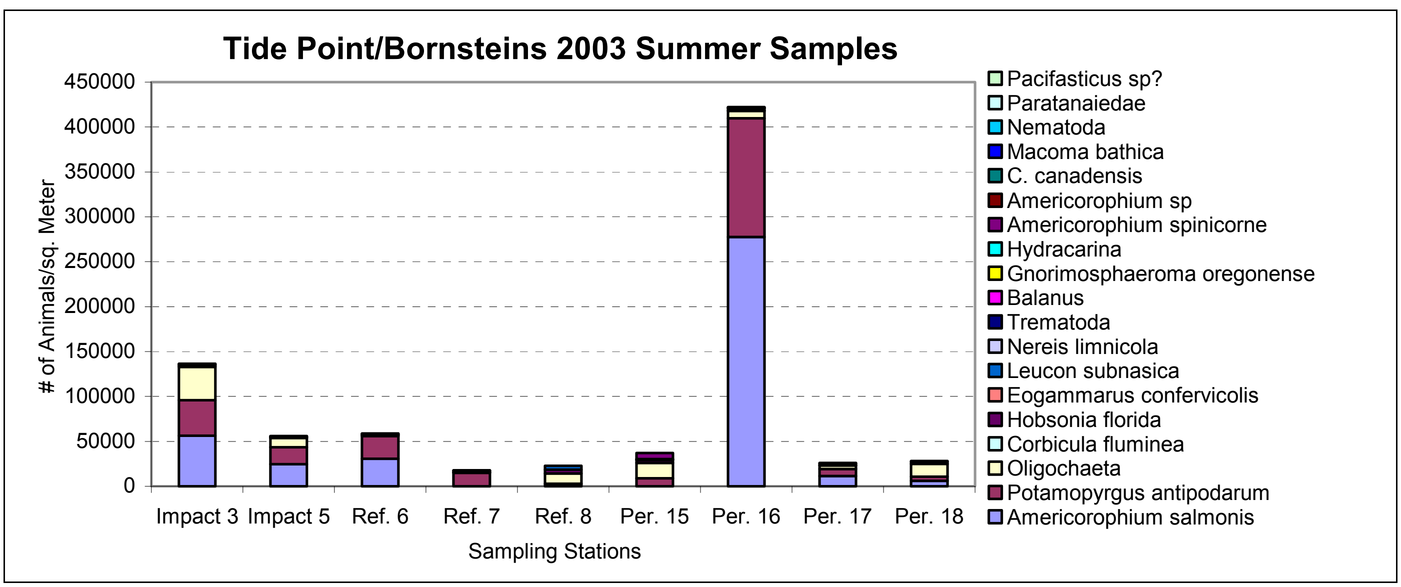


Figure 10. Macro invertebrate data, population size and composition at Youngs Bay Tide Point facility, summer of 2003.

Impact station 3 differs significantly from the Reference condition only in the population density of *Oligochaeta*. Samples also contained larger numbers of *Americorophium salmonis* and of the mud snail, *Potamopyrgus antipodarum* than the samples from the Reference stations, but there was too much variability in these numbers to detect a statistical difference.

Impact station 5 has no statistical differences from the Reference condition.

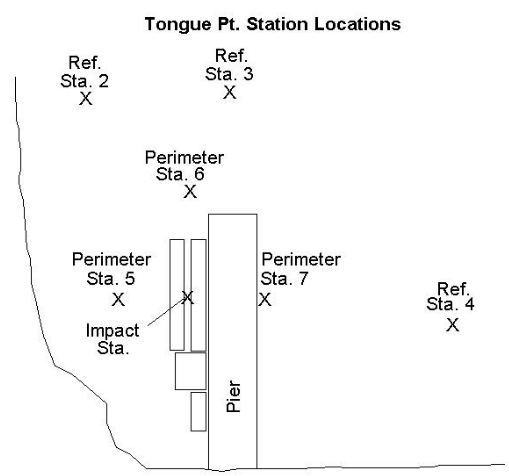
Perimeter stations 15,17 and 18 have no statistical differences from the Reference condition.

The Tide Point/Bornstein facilities produce organic enrichment that creates a small but measurable impact at Impact station 3 under the net pens. The net pens at Impact station 5 have only been in operation for two years as of the time of the last sampling. The effect here is not yet pronounced enough to be reliably detectable at the resolution that the monitoring plan provides. In the future it is expected that the impact at this station will become more pronounced. The impact does not appear to persist through the months of inactivity and it is not expected to reach an unacceptable level.

The Perimeter stations that are in the direction of tidal currents do not show any Impact. The differences from the Reference condition that appear at Perimeter station 16, and to a lesser degree at Perimeter station 17, are believed to be due to the physical structure of the benthic substrate. The differences are not due to organic enrichment from the fish rearing activities because currents do not flow in the direction that would carry organic materials from the net pens to these stations.

Tongue Point and MERTS Facilities

The Tongue Point facility is located at the federal government's Job Corp pier, which is the second pier to the north from the boat ramp. This site was used by the U.S. Navy during World War II. It is inside of the channel formed by Tongue Point and Mott Island. There is a slight salt-water influence here, primarily during the months of low rainfall, but the predominant influence is from the main stem of the Columbia River and from the John Day River.



This facility has a production level that requires a NPDES discharge permit issued by the ODEQ. A mixing zone has been established and is defined by ODEQ as extending 15 meters out from the edge of the net pen facilities in all directions. The permit specifies that no environmental impact is to occur outside of the mixing zone. The location of sampling stations are specified, and at each station three samples are collected for benthic macro invertebrate analysis, one for TOC, and one for Grain Size Analysis. Sampling stations are located on three sides of the facility on the edge of the mixing zone. The forth side of the mixing zone is too close to shore to monitor.

The permit also specifies that there shall be no sedimentation within the mixing zone that adversely affects aquatic life or any beneficial use. This could occur if organic matter accumulates faster than the environment can absorb it. A sampling station is located under the net pens.

In addition to the station where samples are collected for macro invertebrate analysis and sediment chemistry, a core sample is collected from under each net pen. Each of these cores is visually inspected to insure that the organic material is not accumulating faster than the environment can absorb it. If this were to occur, patches of an anaerobic surface “mat” would be expected to appear. This may be accompanied by the odor of hydrogen sulfide. The light brown oxidized surface layer would disappear and live animals would be absent. A log is kept with the observations from each core.

There are three Reference stations associated with this net pen facility site to provide a more accurate assessment of the normal benthic invertebrate populations and sediment chemistry of the area. The location of the sampling stations relative to the net pens is illustrated in the Figure on the right.

The plan for monitoring the environmental impact at this facility was written and approved by ODEQ before to the end of the fish rearing season in June 2002. Prior to this, only benthic macro invertebrate samples were collected and they were only collected from the Impact station under the net pens and from one Reference station (Ref. Sta. 2). Therefore, historical comparisons can only be made between these two stations.

The sediment at this facility is not as organically rich as sites such as Blind Slough or Deep River, but the area is somewhat depositional in nature so the sediments are organically richer than those at Steamboat Slough where the sediments are coarser and more sandy as a result of the strong currents. The TOC at each sampling station is provided in Table 3. at the right for the two years that TOC samples were collected. The TOC increases slightly at the stations that are located further to the south.

Table 3. Total organic carbon of the sediments of the Tongue Point stations, 2002-2003.

Station	June 2002	June 2003
Impact station 1	1.32	1.45
Reference station 2	1.25	1.30
Reference station 3	1.28	1.39
Reference station 4	1.73	1.68
Perimeter station 5	0.85	1.43
Perimeter station 6	1.21	1.45
Perimeter station 7	1.65	1.52

Figure 11 indicates the population comparison between these two stations in the summer, just after the fish rearing season and in the fall prior to the start of the next season.

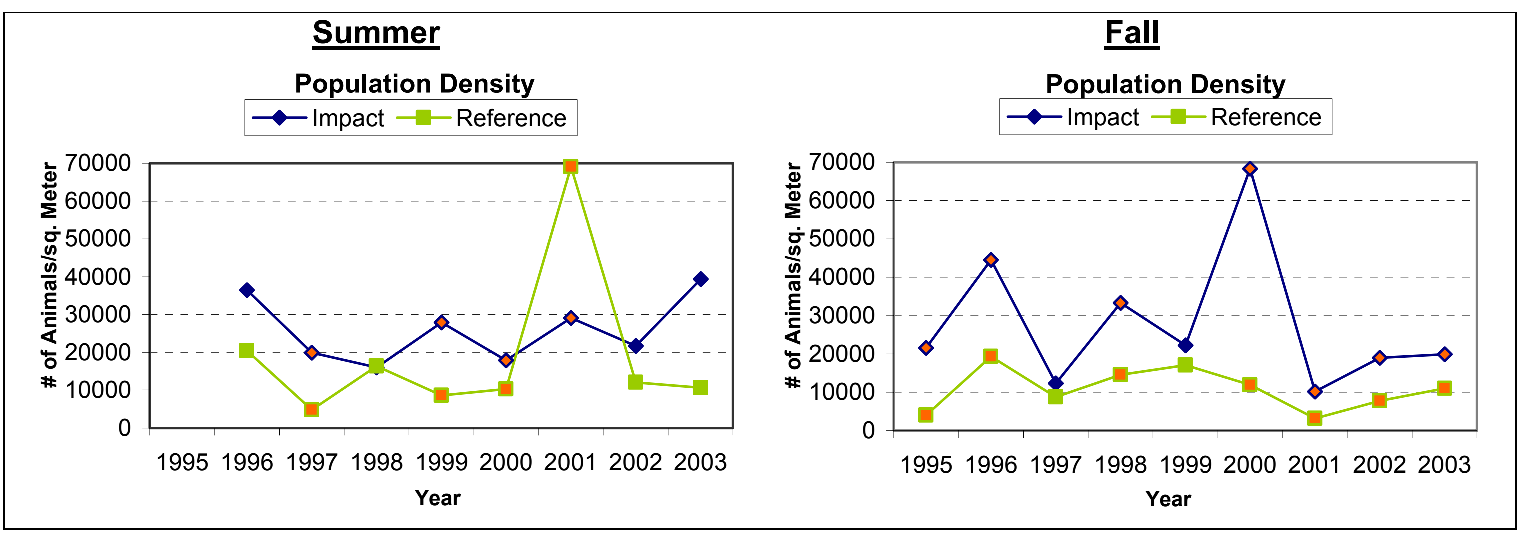


Figure 11. Macro invertebrate population density at Tongue Point facility, 1995-2003.

The population at the Impact station is usually more dense than at the Reference station. An exception to this occurs in June 1998 when the population density is about the same and in June 2001 when the population at the Reference station greatly exceeds that at the Impact station. This latter population increase resulted from an increase in a number of species. At the Impact station the *Oligochaeta* population density increased more than it did at the Reference station. However, the other species that increased dramatically at the Reference station did not increase at the Impact station, These species were *Coullana canadensis, Americorophium salmonis, Hobsonia florida* and *Potamopyrgus antipodarum. Oligochaeta* are not very sensitive to toxicants in the environment while most of these other species are. There may be some low level of toxic material present in the sediments around the pier that stifles the populations of more sensitive species.

It is notable that the population density at the Impact station is consistently greater in the fall, prior to the next growing season and after the site has been inactive for several months. This indicates that the Impact station is a richer habitat for macro invertebrates even well after the input of organic material has ceased. This could occur because the organic material is not depleted over the months after the cessation of fish rearing activity. This may not mean that the organic material is constantly increasing, but it may indicate that biological activity is occurring at a more intense or dynamic level.

The dominant taxonomic group, the *Oligochaeta*, is a more sensitive indicator of the long-term organic enrichment as shown in Figure 12 below. This Figure shows data that reinforces the probability that the Impact station is consistently more organically rich than the Reference station, even in the fall.

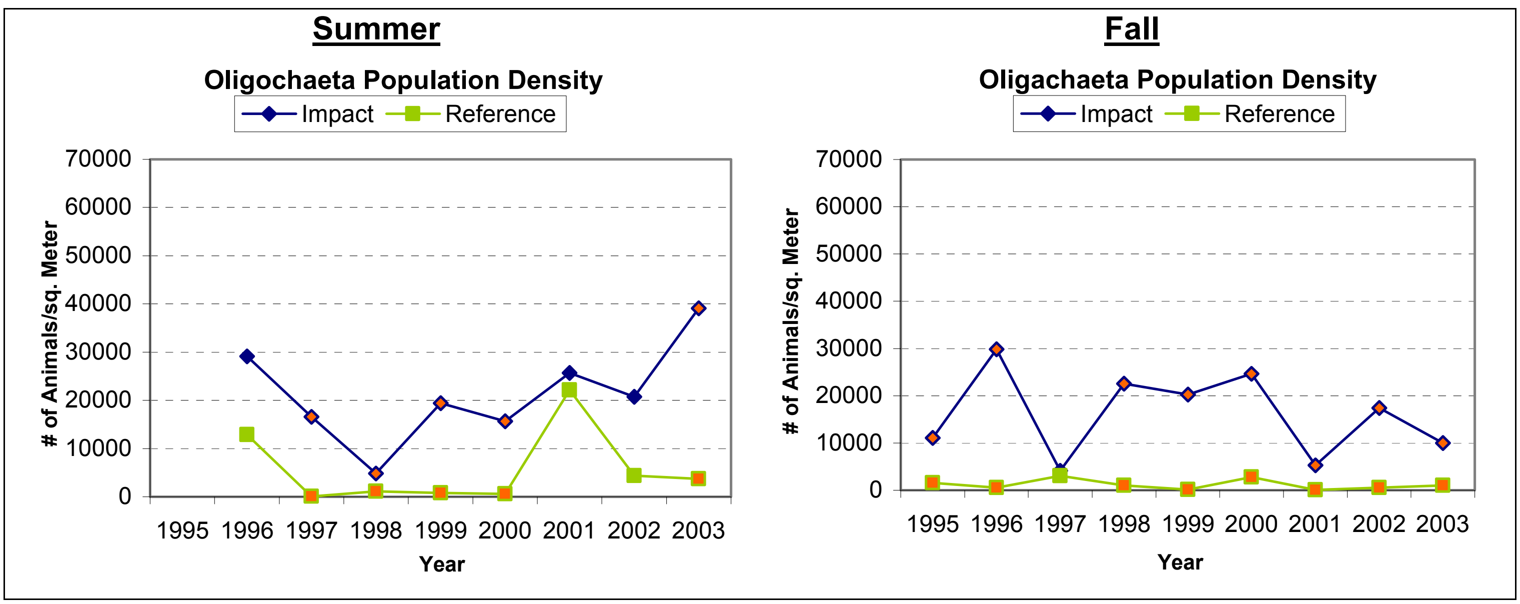


Figure 12. *Oligochaeta* population density at Tongue Point facility, summer versus fall, 1995-2003.

The benthic macro invertebrate population in the sediments at this facility are dominated by *Oligochaeta* at the Impact station, but at the Reference station the amphipod *Americorophium salmonis* is the dominant taxon in most years. This situation occurs both in the summer and the fall.

Figure 13. displays the percent of the population that is composed of the dominant species. *Oligochaeta* dominate at the Impact station, and the percent by which they are dominant over other taxonomic groups is increasing during the summer. As the input of organic material

increases, the taxonomic group that is best able to utilize this material is expected to increase its dominance of the population, eventually to the exclusion of other taxonomic groups. This appears to be occurring in the summer, when the impact of the fish rearing activities are the greatest. By the fall of each year this situation has changed. The degree by which the *Oligochaeta* dominate at the Impact station is little different from the degree by which the *A. salmonis* dominate at the Reference station and sometimes the *A*. salmonis are more dominant at the Reference station than are the *Oligochaeta* at the Impact station.

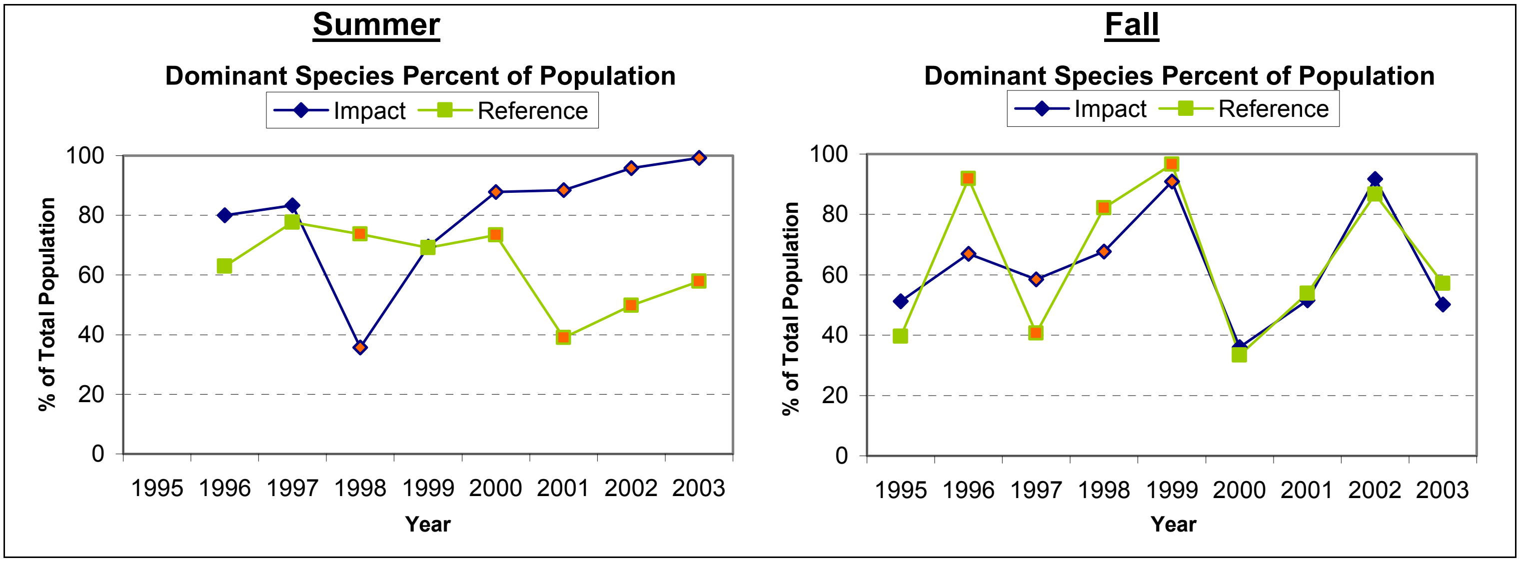


Figure 13. Percent of total population that is composed of the dominant species, summer versus fall, 1995-2003.

While the Impact station is heavily dominated by *Oligochaeta* in the summer, other species are reduced in numbers but have not been eliminated. As Figure 14. indicates, the number of species does not differ significantly between the Impact station and the Reference station in either the summer or fall samples except on two occasions, summer of 2002 and fall of 1999. This indicates that while the organic enrichment persists through the months of inactivity and has caused the *Oligochaeta* to be exceptionally dominant during the summer, the level of environmental impact has not reached the level where the Impact station is populated by just one species, and there has been no indication of the development of an anoxic condition beneath the net pens.

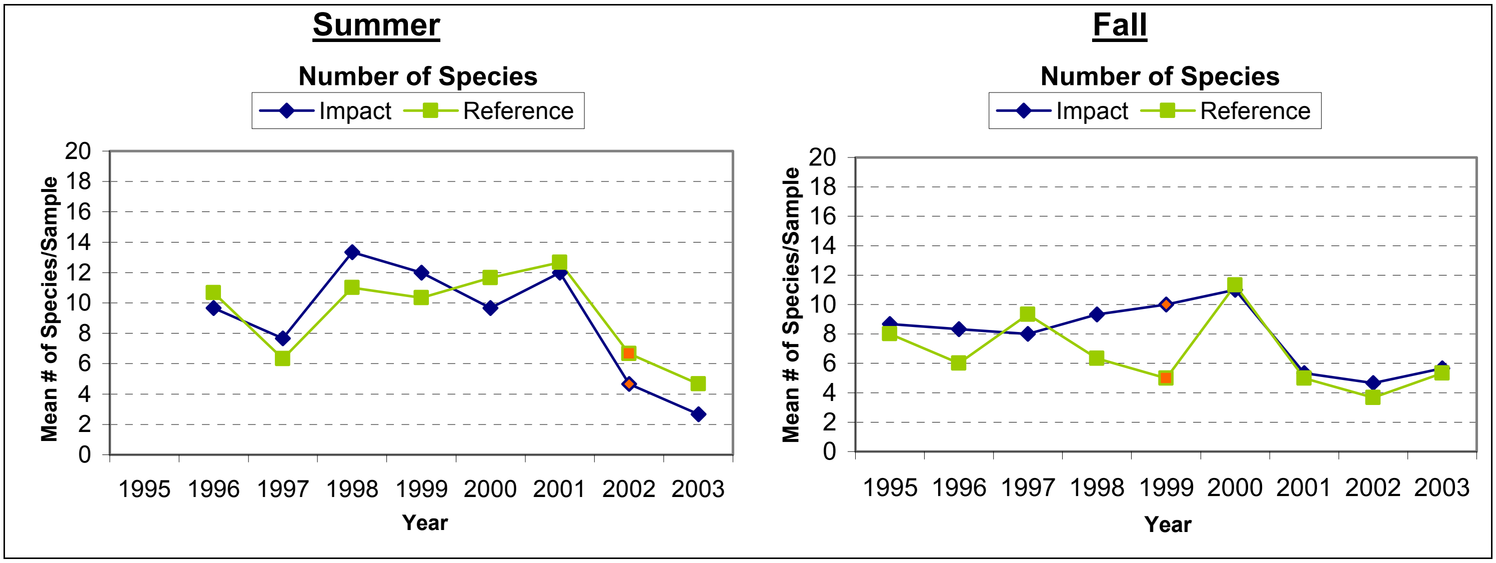


Figure 14. Mean number of species present in the Tongue Point samples, summer versus fall, 1995-2003.

Beginning in the summer of 2002 the monitoring plan was implemented that was developed to meet the permit conditions. As described previously, this plan requires that samples be collected from stations on the perimeter of the mixing zone as well as from the Impact station under the net pens. In addition samples are collected from three Reference stations instead of just one. Having three Reference stations allows for statistical confidence of 95 percent and better represents the variability of the environment.

Two years of data do not permit a long-term analysis of the data or the detection of trends. Therefore, the data does not allow an historical view of the Perimeter stations or of the two additional Reference stations.

Figure 15. shows the dominance of the *Oligochaeta* at the Impact station in the summer of 2002. Two other stations, Reference station 4 and Perimeter station 7, are dominated by *Oligochaeta* as well, but other taxa are better represented at these stations than at the Impact station. These stations are both located to the south of the Impact station and they are in the direction of higher sediment TOC. The high TOC
may contribute to this situation. Dominance is shared by *Americorophium salmonis* at the other stations.

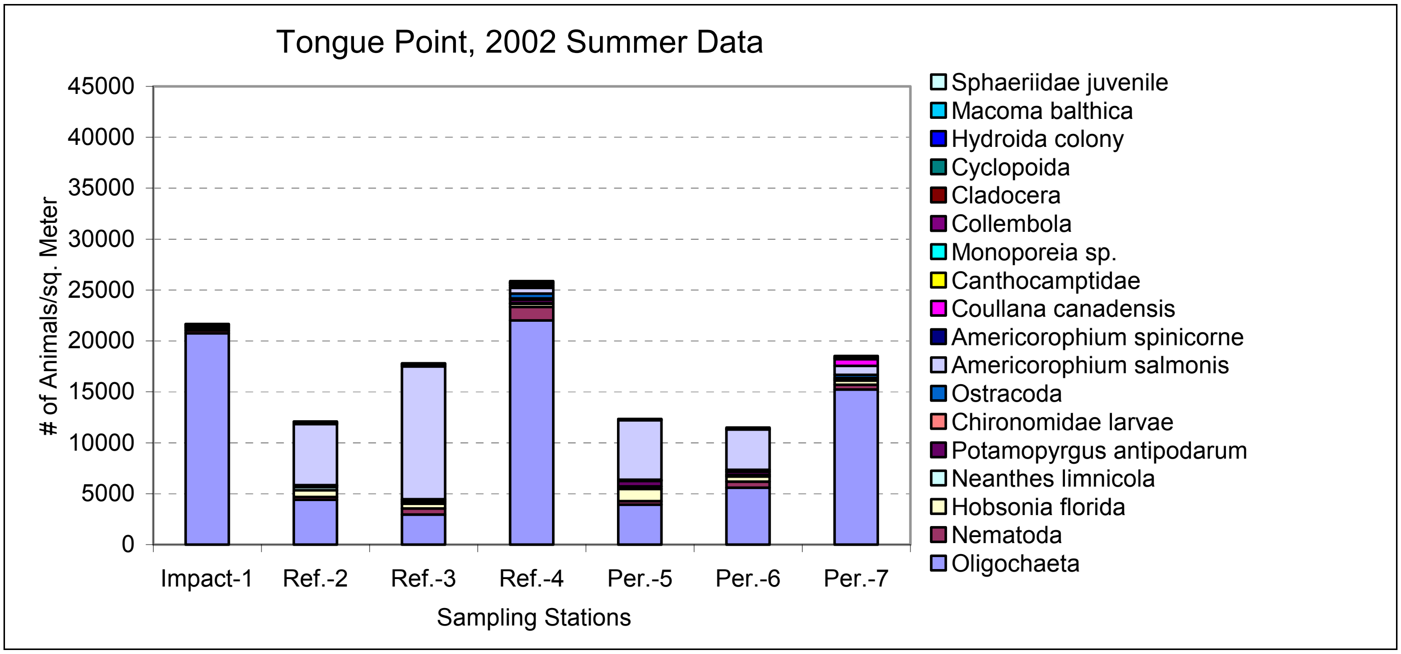


Figure 15. Macro invertebrate data, population size and composition at Tongue Point, summer of 2002.

In the summer of 2002 the Impact station differs significantly from the Reference stations in that it has fewer species, the dominant species comprises a larger percent of the population, and there is an absence of *A. salmonis*.

Perimeter station 7 differs only in having a greater number of the copepod, *Coullana canadensis*. This is not indicative of organic enrichment.

Figure 16. shows that the population density and dominance of *Oligochaeta* have increased at the Impact station, probably in response to the organic enrichment. The only significant differences are with the Impact station where the dominant species comprises a larger percent of the population, the *Oligochaeta* population is more dense at the Impact station than at the Reference stations, and *A. salmonis* is absent from the Impact station.

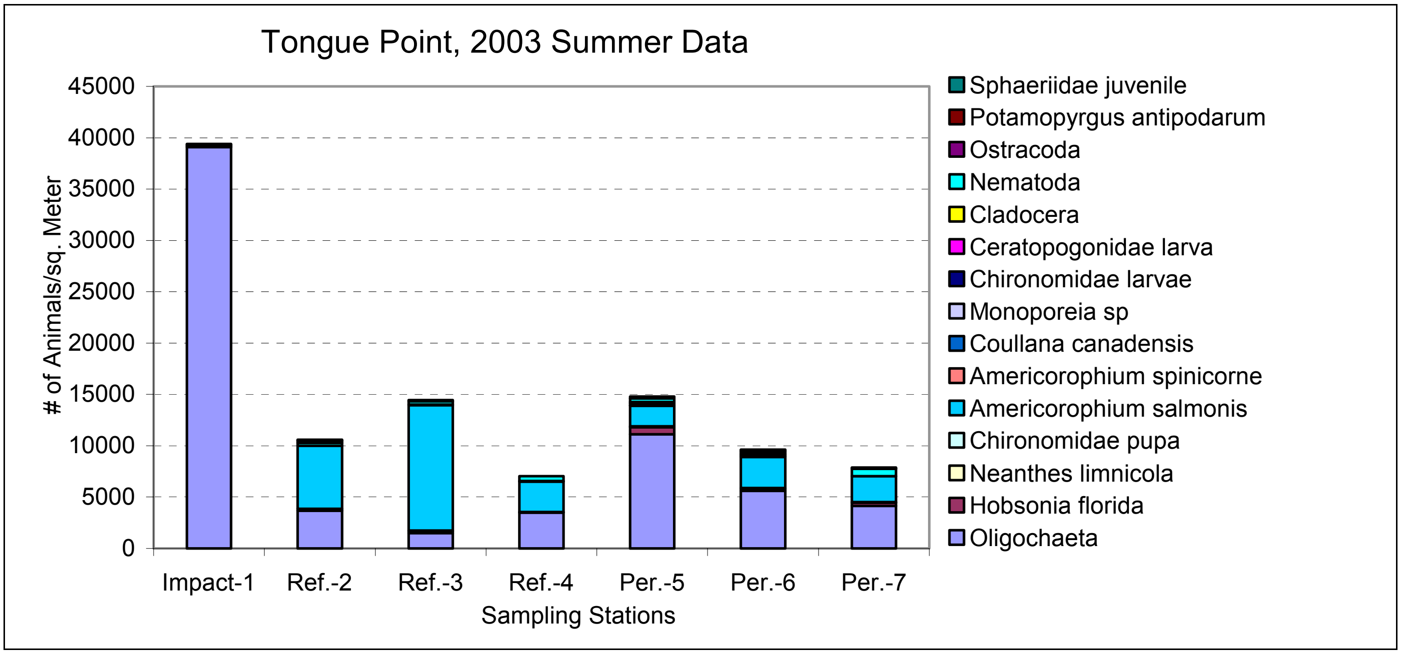


Figure 16. Macro invertebrate data, population size and composition at Tongue Point facility, summer of 2003.

Perimeter station 5 differs from the Reference stations in that it has fewer species, the population of *Oligochaeta* is more dense, the population of *Hobsonia florida* is more dense, and the population of *A. salmonis* is less dense. The increase in *Oligochaeta* is reason to be concerned about the possibility that this station may be impacted by the fish rearing activities. However, this situation did not exist in the summer of 2002 and the fish rearing has been in progress for several years, so this is probably not a trend.

Perimeter station 6 differs from the Reference stations only in that the population of *Oligochaeta* is more dense. As with Perimeter station 6 this is reason to be concerned about the possibility that this station may be impacted by the fish rearing activities. However, this situation did not exist in the summer of 2002 and the fish rearing has been in progress for several years, so this is probably not a trend.

As stated earlier, there is not enough data to determine whether any trends exist at any stations except the Impact station where the evidence clearly indicates organic enrichment.

Since it is currently planned to abandon this site and move the facility to the pier at the MERTS site owned by Clatsop Community College (CCC), there will not be time to determine if any trends exist with the Perimeter stations. Monitoring at the Impact station should continue through at least the summer 2005 to document the recovery of the Impact station. The MERTS dock is located about a mile southeast of the current Tongue Point facility. It is reached taking Liberty Lane from U.S. Highway 30.

MERTS

Baseline samples were first collected in the summer of 2002. They were collected from three Reference stations and the Impact station. Since the mixing zone is defined as extending 15 meters from the edge of the net pen facilities in all directions, and there were no net pens in place at the time, it was not possible to determine where the perimeter of the mixing zone will be.

Figure 17. represents baseline data from the samples collected in the summer of 2002. The populations at these stations are not very different from those at the Reference stations at the Tongue Point facility. *Oligochaeta* and the amphipod *A. salmonis* are present at all of the stations. However, *Oligochaeta* dominates the populations at the Impact site and at Reference station 2. The amphipod dominates the populations at Reference stations 3 and 4. The only significant difference between the Impact station and the Reference stations is a more dense population of the marine *Polychaeta* worm, and *Hobsonia florida* at the Impact station.

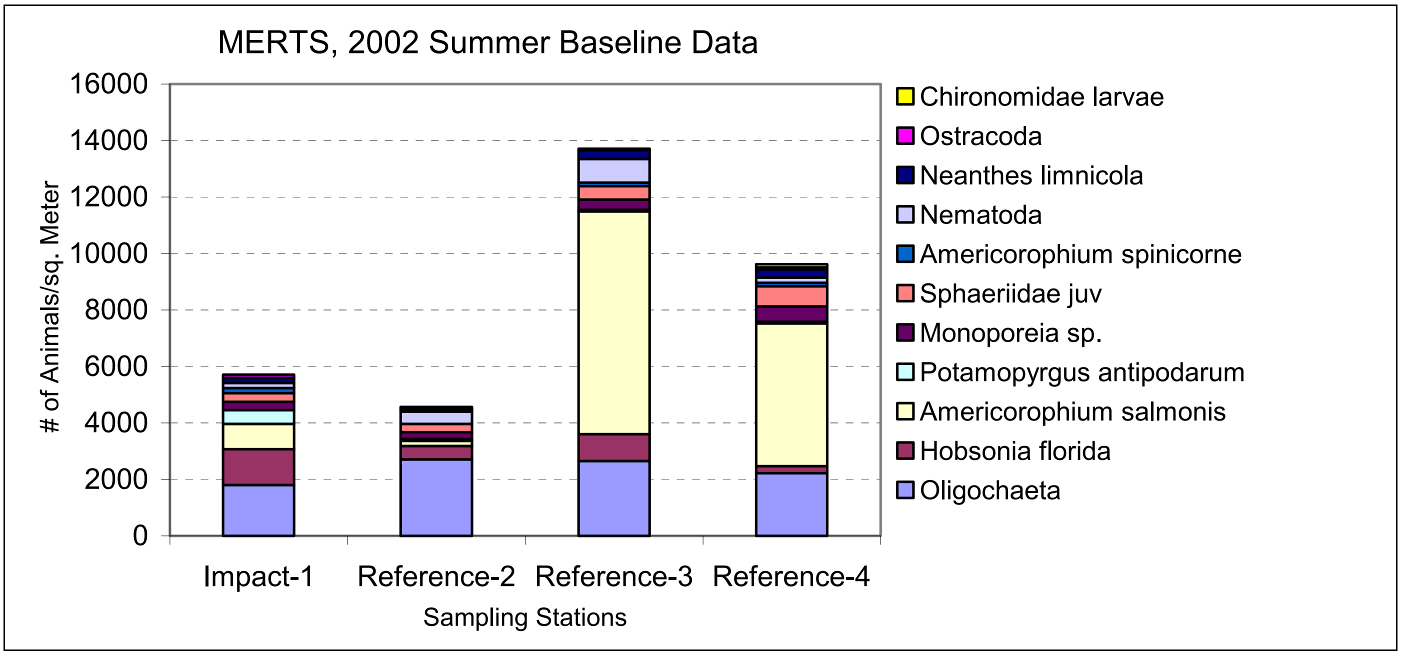


Figure 17. Macro invertebrate data, population size and composition at MERTS facility, summer of 2002.

Samples were also collected in the fall of 2002 after a small number of fish had been held in net pens at this facility. Figure 18. below shows that populations at both stations have decreased, probably due to seasonal changes, but the population at the Impact station is statistically different in four ways. It is significantly more dense, there are more species present, the population of *Oligochaeta* is more dense, as is the population of *Hobsonia florida*. This indicates some organic enrichment.

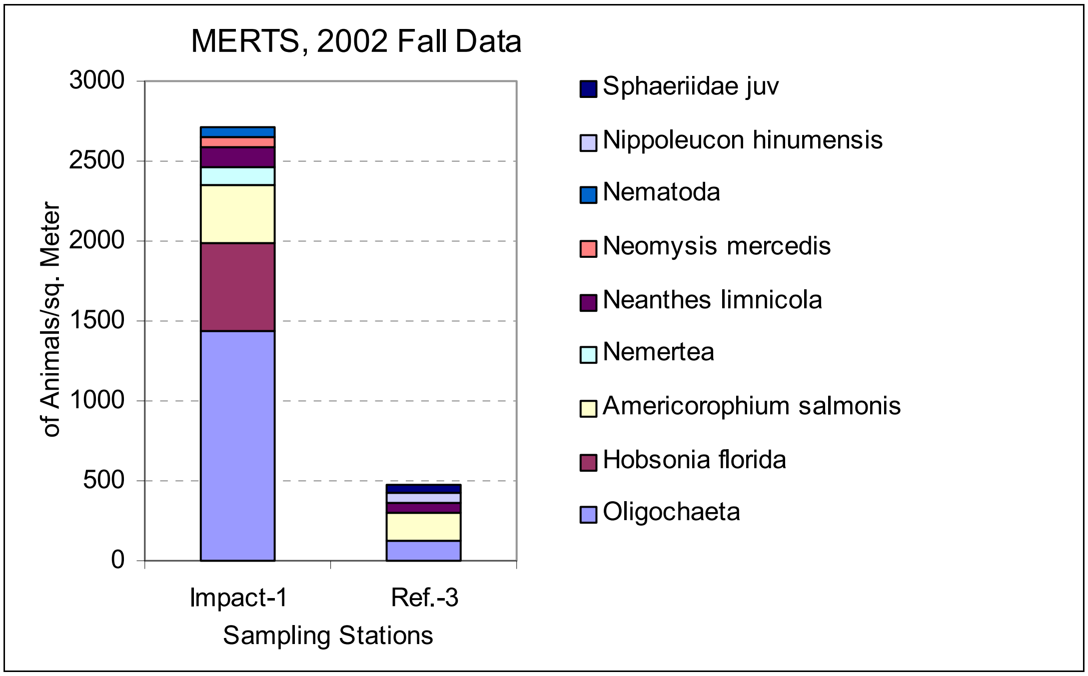


Figure 18. Macro invertebrate data, population size and composition at MERTS facility, fall of 2002.

Samples were collected again in the summer of 2003. Figure 19 shows the normal variability among the Reference stations with *A. salmonis* dominating the populations at two of the Reference stations and *Oligochaeta* dominating Reference station 2. *Oligochaeta* also dominates the Impact station. Since only a low level of fish rearing activity has been taking place at this facility this may be indicative of some organic enrichment. However, the only statistically significant difference between the Impact station and the Reference stations is that the Impact station has a more dense population of *Hobsonia florida*.

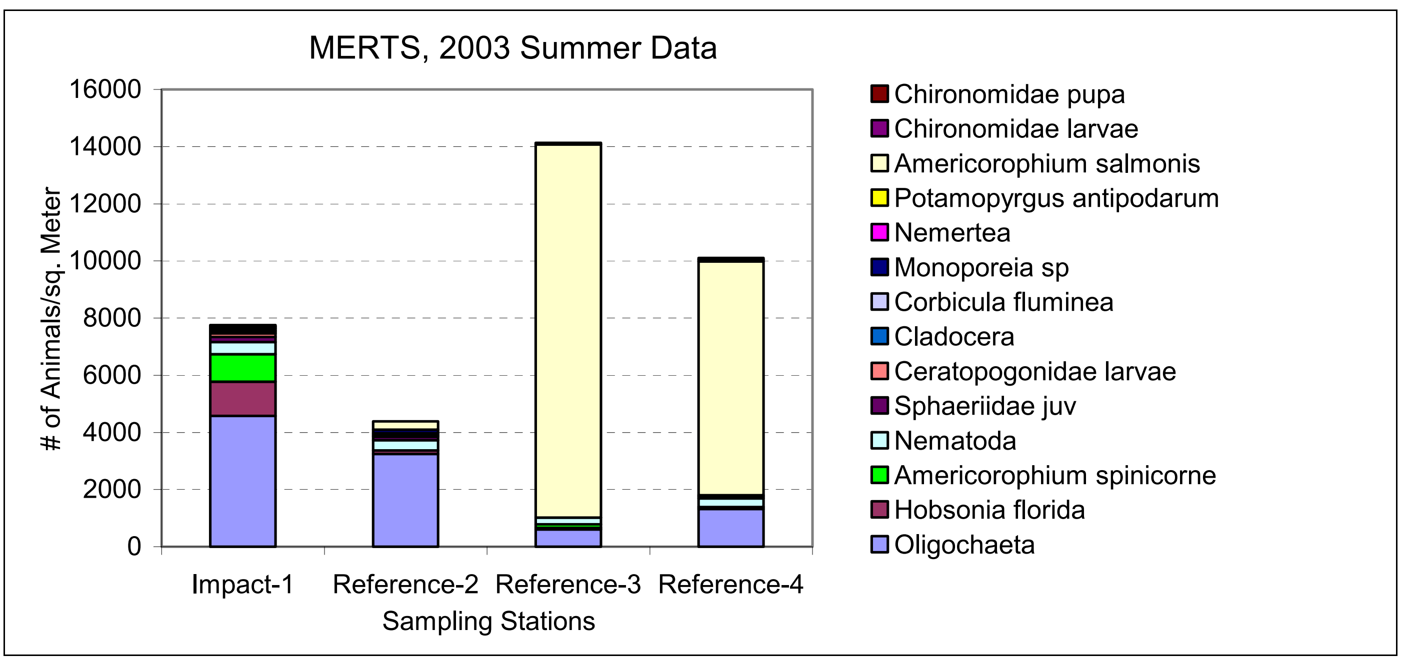


Figure 19. Macro invertebrate data, population size and composition at MERTS facility, summer of 2003.

This summer Perimeter stations will be established at the MERTS facility. As of the writing of this report, this site has had only a low level of fish rearing. As the facilities are moved from Tongue Point to this site the production level is expected to increase and the environmental monitoring effort will increase to meet the requirement of the discharge permit.

Blind Slough

The Blind Slough facility is located about 1.25 miles upstream from the confluence of Blind Slough and Knappa Slough, about 100 meters downstream from the Barendse Road bridge. Gnat Creek flows into Blind Slough. Production at this facility is below the level that would require a discharge permit. At this production level there is no mixing zone specified and the overall environmental impact is assumed to be low. Samples at this facility are collected from one station beneath the net pens and one Reference station.

This site is downstream from a former log dump and the sediments contain a lot of woody debris. The sediments at this site are very organically rich. TOC measured at the Reference station in the years 2002 and 2003 was 5.02 percent and 3.25 percent respectively. The TOC was 9.84 percent and 7.58 percent at the Impact station beneath the net pens in 2002 and 2003 respectively. This indicates an increase in organic richness of the sediments below the net pens due to the fish rearing activities. Since TOC samples have only begun to be collected recently it is too soon to detect any trends in TOC from direct measurements. However, benthic macro invertebrate samples have been collected since 1995, and trends in populations resulting from the input of organic material can be demonstrated. Figure 20. displays the overall density of the macro invertebrate population.

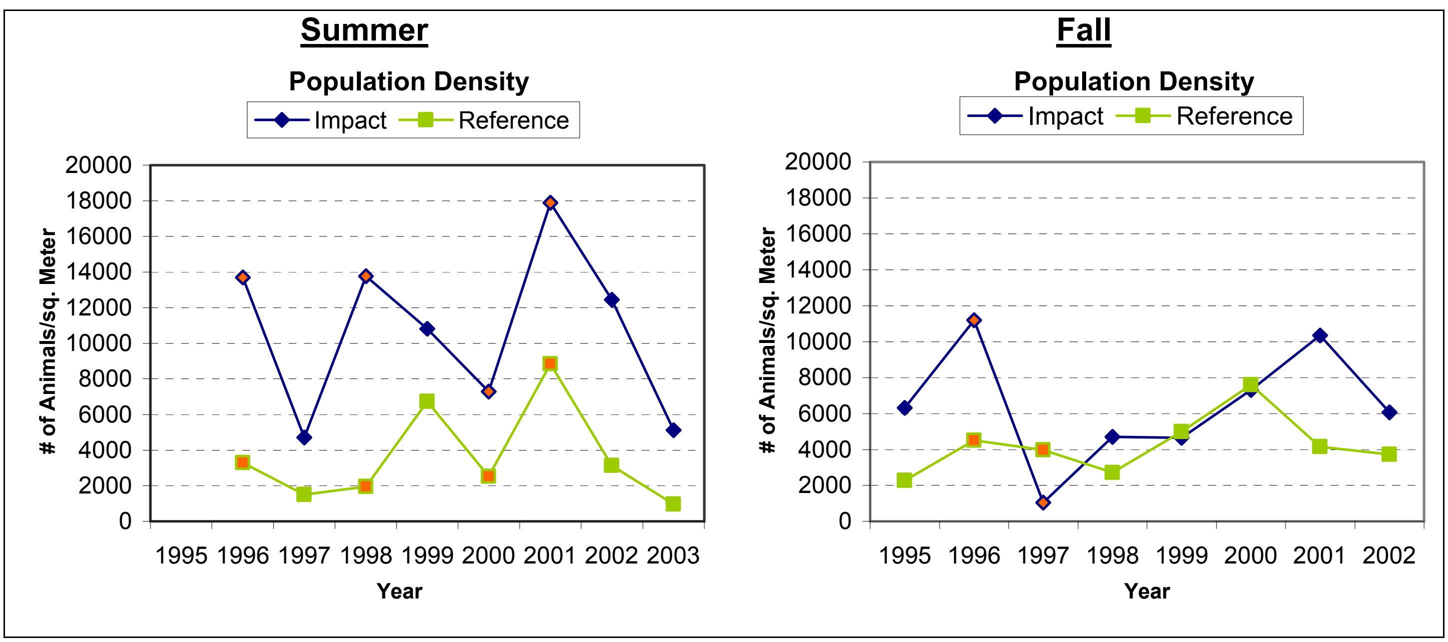


Figure 20. Macro invertebrate population density at Blind Slough facility, summer versus fall, 1995-2003.

Analysis of benthic macro invertebrate samples collected at the end of the growing seasons (summer) indicate that the size of the population under the net pens is consistently larger than the size of the population at the reference site. Analysis of the benthic samples collected in the fall, just before the start of the growing season, indicates that this situation ceases to exist after several months of inactivity between the end of the previous growing season and the start of the next growing season. The data does not indicate a trend towards an increasing population size at the Impact station. The controlling influence of the *Oligochaeta* on the overall population size is displayed by Figure 21

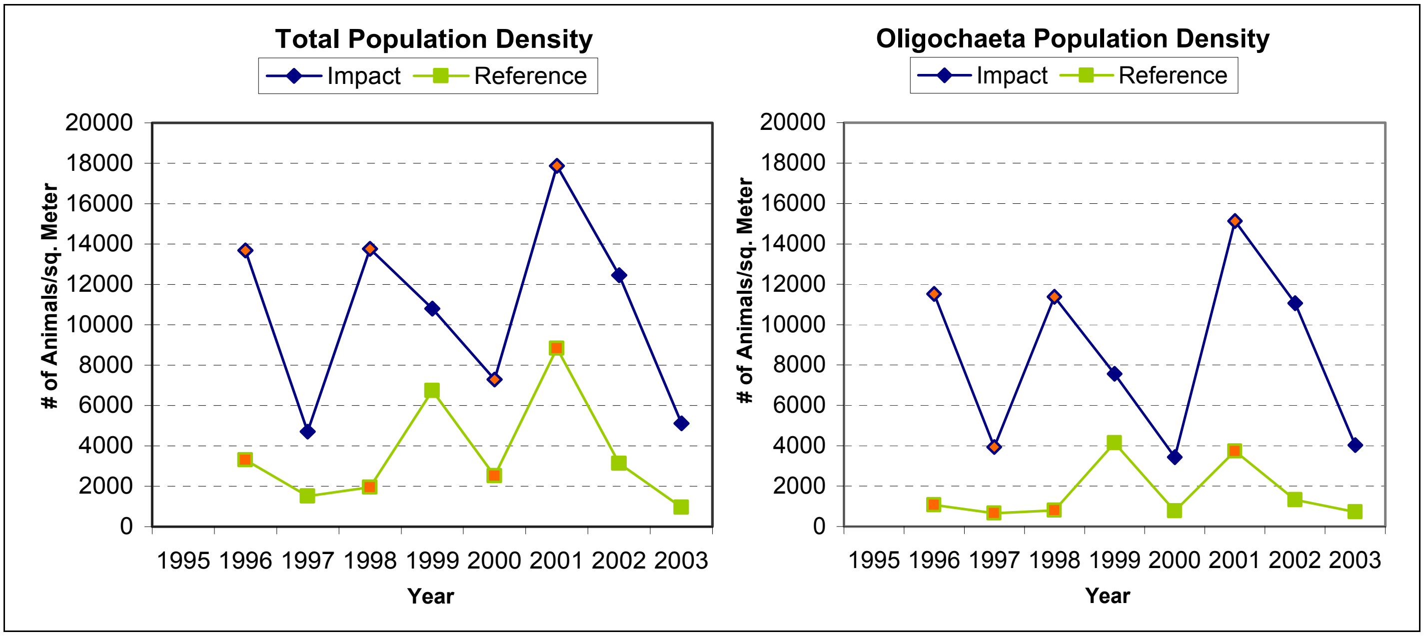


Figure 21. Summer population density of *Oligochaeta* compared to total population at Blind Slough facility, 1995-2003.

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Since *Oligochaeta* worms feed by processing sediment and utilizing the organic material in the sediment for food, this taxonomic group benefits from the organic input from the fish rearing activities. The population of *Oligochaeta* increases at the Impact station in response to the input of organic material. This causes the *Oligochaeta* to make up an even larger percentage of the overall population at this station than at the Reference station. Figure 22 below shows the increase in dominance of the most numerous species. Another taxonomic group that is usually present in large numbers is the *Chironomidae* (midge larvae). However, the *Oligochaeta* are by far the more dominant.

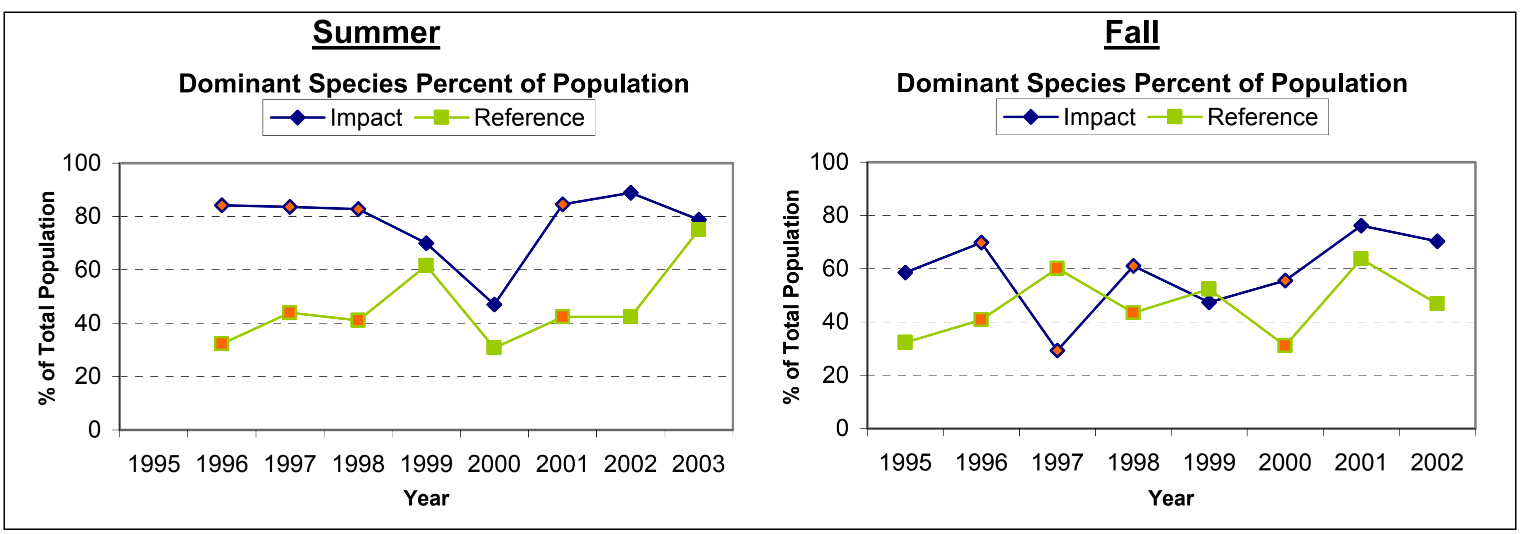


Figure 22. Percent of the total population that is composed of the dominant species at the Blind Slough facility, summer versus fall, 1995-2003.

Analysis of the fall samples indicates that this situation does not persist. In the fall the most dominant species is not consistently more dominant at the Impact site than at the Reference site.

Species richness can decrease with the input of organic material. As one or more species increases in number by utilizing the organic material, other species may disappear due to the increased competition. Figure 23 is produced from the benthic sample analysis and it shows that there are not consistently more species at the Reference site than at the Impact site. There are significantly more species at the Reference site in only one year, June 2001, and at other times there are more species present at the Impact site. Analysis of samples taken in the fall show that the number of species at the Impact site follows the number at the Reference site quite closely. There are no significant differences.

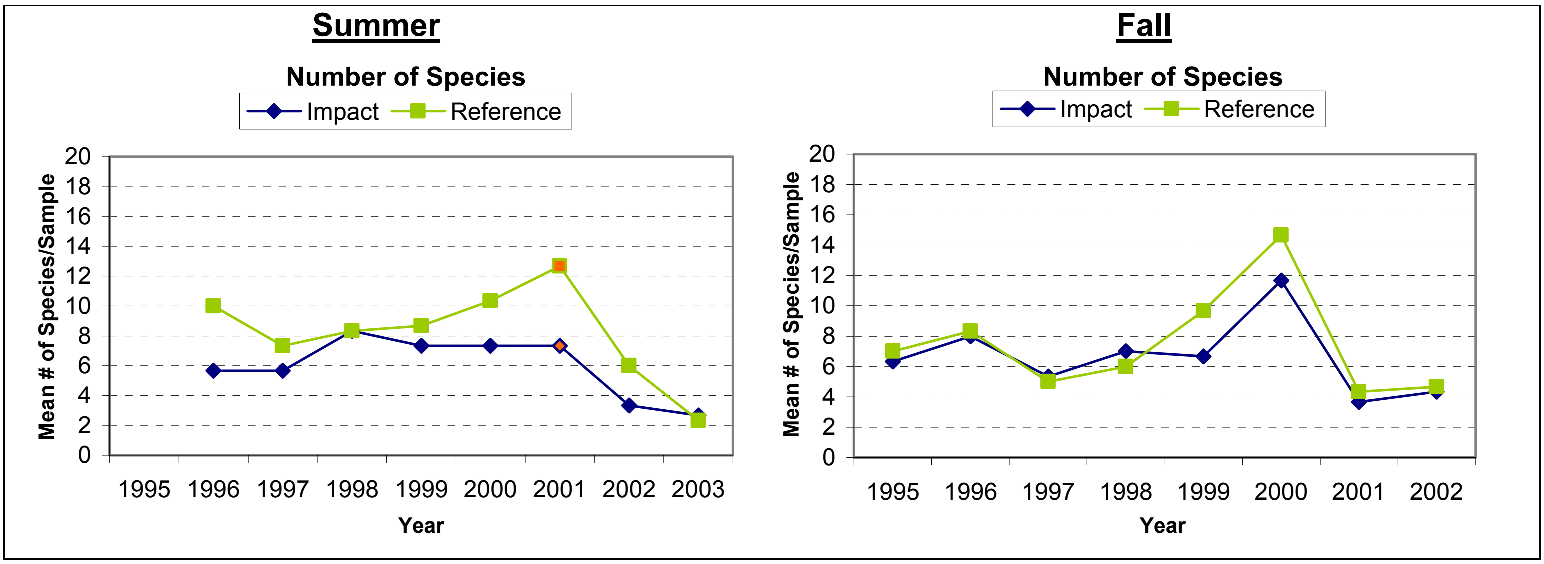


Figure 23. Mean number of species present in Blind Slough samples, summer versus fall, 1995-2003.

Analysis of the benthic populations at the Blind Slough facility indicates that the environmental impact of the salmon rearing activities at this site are slight and do not persist. The organic material being input to the environment at this location is being absorbed by the environment with a temporary increase of the population, predominantly the *Oligochaeta*. When the input of organic material ceases, the population decreases to background levels. The data indicates that the impact is not great enough to impact other population parameters such as species diversity, nor is there any indication that species have disappeared.

Upper Deep River, Walter Kato's

There are two SAFE net pen facilities in Deep River, Washington. This facility is located about a half mile upstream from the Washington State Highway #4 bridge over Deep River. This site is moderately well flushed. It is within the zone of tidal influence with current flowing upriver on an incoming tide and downriver on an outgoing tide. The river is about 75 meters wide here.

The sediment is organically rich with a lot of plant material and woody debris. The TOC at the Reference station was 4.09 percent and 3.47 percent at the end of the growing seasons in the years 2002 and 2003 respectively. The TOC was 2.64 percent and 4.08 percent at the Impact station at the end of the growing seasons in the years 2002 and 2003 respectively. Production at this station has increased over the years of operation but it is still below the level at which a permit would be required, so no mixing zone has been established. Benthic macro invertebrate samples are collected from the Impact station located under the net pens and from a Reference station.

As indicated in Figure 24 below, the population density is usually higher at the Impact station than at the Reference station at the end of the fish rearing season. The summer of 2000 presents the only exception to this. Population densities at the two stations are about the same by the time samples are collected in the fall each year. This indicates that the organic matter added to the sediment over the growing season has been absorbed.

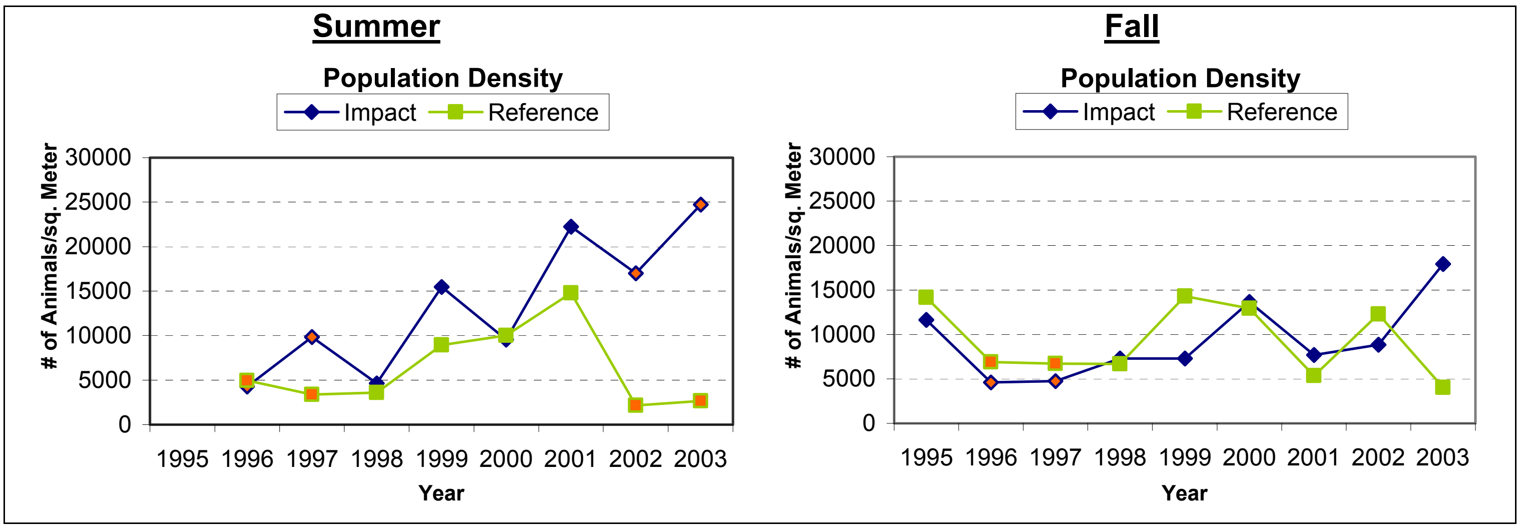


Figure 24. Macro invertebrate population density at the Upper Deep River facility, summer versus fall, 1995-2003.

The differences between the Reference station and the Impact station in the summer samples tends to be small during the earlier sampling years, although significant differences are detectable due to small sample variability. Over the last few years the population density at the Impact station is tending to increase significantly over that of the Reference station at the end of the growing season. This is probably due to an increase in the fish rearing activity, but it could indicate a build up of organic material. This is probably not the case since the fall samples do not show this pattern. The fall samples indicate that the macro invertebrate population is no longer responding to organic enrichment. While this increase in population density may not be a trend it should be monitored closely in the future.

The sediments at this net pen site are organically rich as is a common characteristic of the sediments in sloughs and bays on the lower Columbia River. *Oligochaeta* (worms) are ubiquitous in these fresh water environments. They often make up the most numerous taxon present in these sediments. This is the case at this Deep River net pen facility.

Since *Oligochaeta* process sediment to extract the organic material to meet their nutritional needs, their numbers often increase with the addition of organic material from the fish rearing activities. This is the case at this facility, as is indicated in the following Figures comparing overall population density to *Oligochaeta* population density. The *Oligochaeta* make up the largest percentage of the population, and they drive the increase in population density that occurs at the end of the fish rearing season.

As is indicated by Figure 25 of the *Oligochaeta* population below, it is the decline in *Oligochaeta* population after the rearing season in 2000 that resulted in the overall population decline at the Impact station that year.

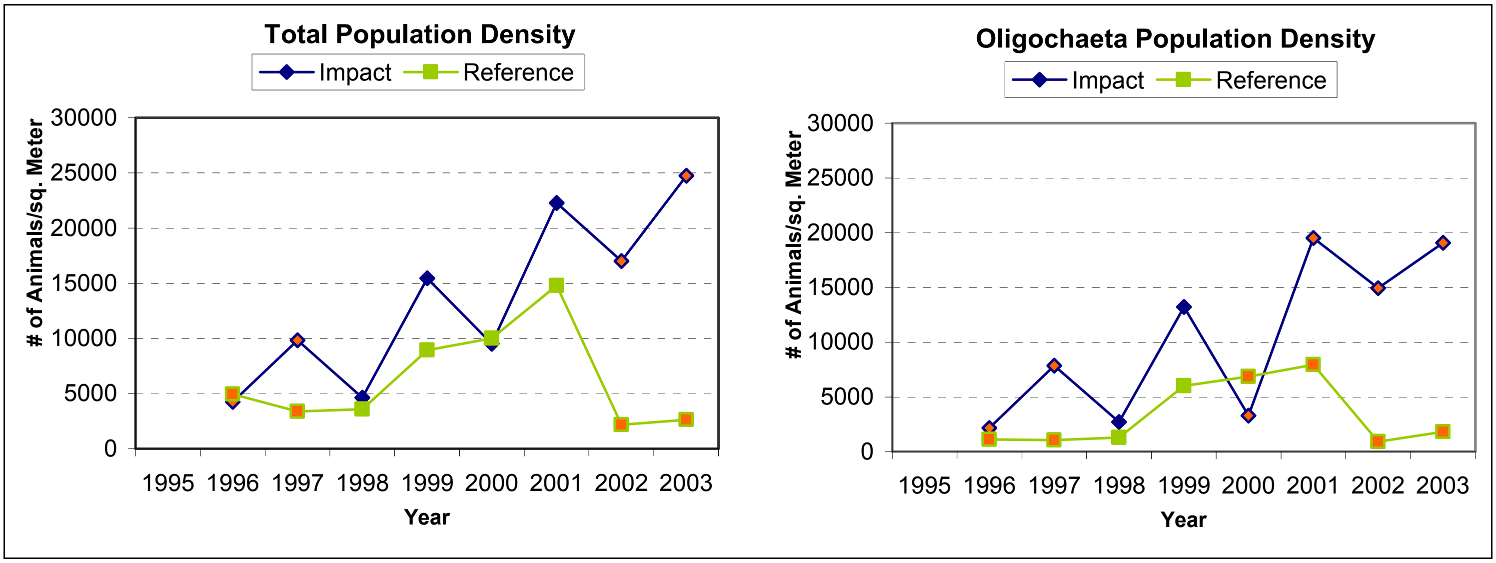


Figure 25. Summer population density of Oligochaeta compared to total population at Upper Deep River facility, 1995-2003.

As the Oligochaeta numbers increase, this taxonomic group makes up a larger percentage of the population at the Impact station than at the Reference station. This increases the percent of the population composed of the dominant species as indicated in Figure 26. below.

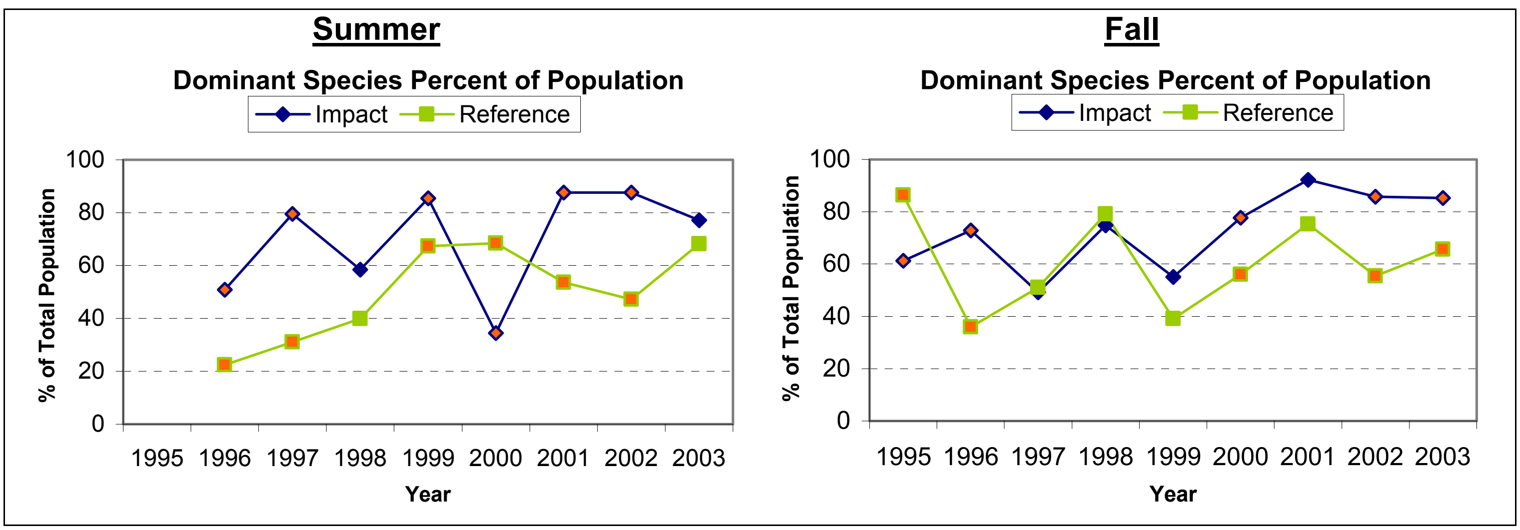


Figure 26. Percent of the total population that is composed of the dominant species at the Upper Deep River facility, summer versus fall, 1995-2003.

Since the *Oligochaeta* population density did not increase at the Impact station between the fall of 1999 and the end of the rearing season in 2000, the percent of the population composed of *Oligochaeta* was the lowest of any year so far. The population density of other taxonomic groups increased at this time as indicated in Figure 27. below. This is probably due to a lack of competition from the *Oligochaeta.*

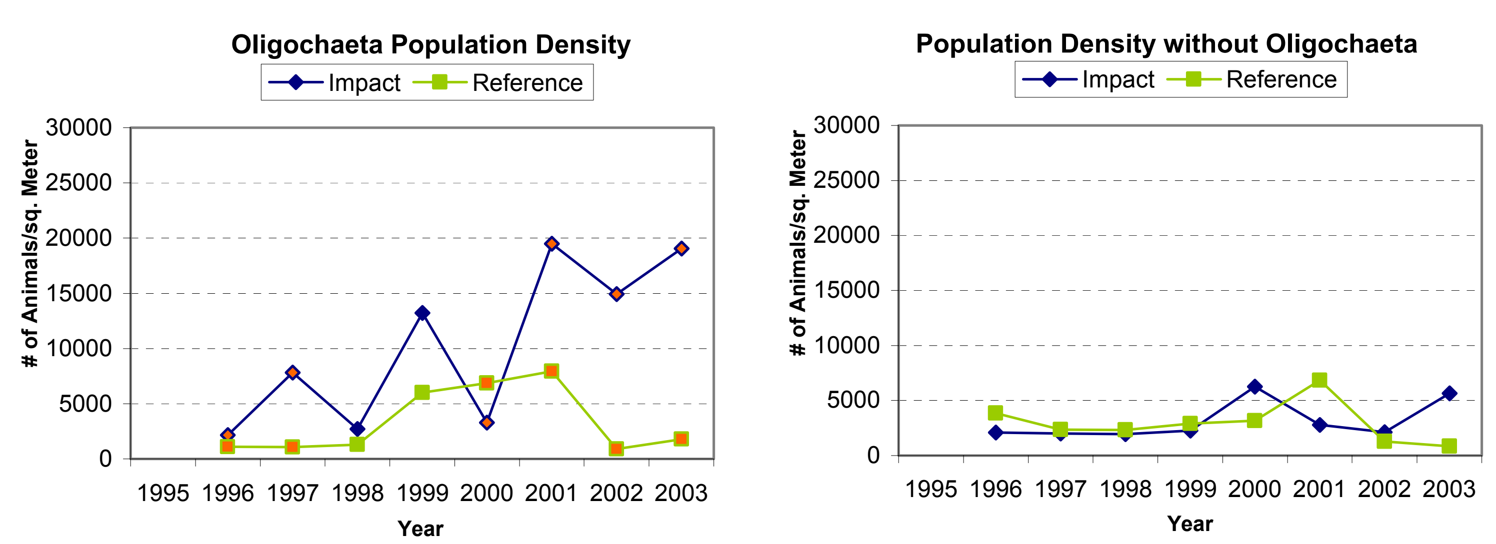


Figure 27. Comparison of the *Oligochaeta* population to all other taxa at the Upper Deep River facility, 1995-2003.

Analysis of the benthic populations at the Walter Kato Deep River facility indicates that the infusion of organic material resulting from the salmon rearing activities at this site are absorbed by the environment. This is indicated by the increase in the benthic population and the subsequent decrease after several months of inactivity. The organic material being input to the environment is being absorbed by benthic macro invertebrates, principally by the *Oligochaeta*.

The data indicates that the impact is not great enough to impact other population parameters such as species diversity, nor is there any indication that species have disappeared.

Salmon production levels at this facility may be increased in the future. If this occurs the production levels may necessitate a discharge permit which will require the establishment of a mixing zone and more extensive environmental monitoring.

Lower Deep River, Robert Fauver's

This is the second net pen facility in Deep River, Washington. This facility is located about a half mile downstream from the Washington State Highway #4 bridge over Deep River, about one mile downstream of the other Deep River site at Walter Kato's. Like the other Deep River site, this site is also moderately well flushed and the river is wider here, about 100 meters wide. It is also within the zone of tidal influence with current flowing upriver on an incoming tide and downriver on an outgoing tide. Fish were first added to the net pens at this site in the fall of 1997.

The sediment is also similar to that at the other Deep River facility and is organically rich with a lot of plant material and woody debris. The TOC at the Reference station was 4.09 percent and 3.47 percent at the end of the growing seasons in the years 2002 and 2003 respectively. The TOC was 2.46 percent and 5.78 percent at the Impact station at the end of the growing seasons in the years 2002 and 2003 respectively. Production at this station has also increased over the years of operation, but it is still below the level at which a permit would be required, so no mixing zone has been established.

The benthic macro invertebrate population structure at this station is similar to that at the other Deep River site as Figure 28. indicates.

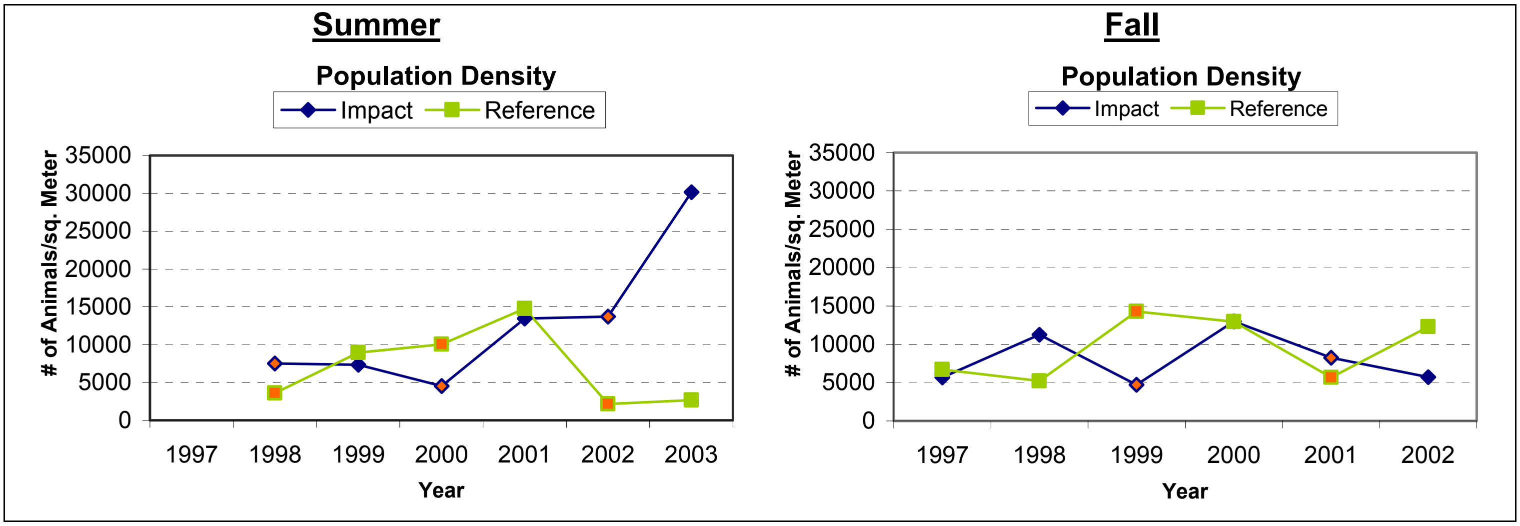


Figure 28. Macro invertebrate population density at Lower Deep River facility, summer versus fall, 1997-2003.

In the earlier years of operation the production was low and no trend is apparent at the level of resolution provided by this monitoring effort. When a statistically significant difference occurs the population at the Reference station is often more dense than at the Impact station. However, as the production increased, a trend is emerging with the population at the Impact station increasing over that at the Reference station by a large margin. No such trend is present in the population in the fall. The more dense population is as likely to occur at the Reference station as it is to occur at the Impact station in the fall, and the difference between the two stations is small, indicating that the organic material that had enriched the sediments at the Impact station has been depleted.

Oligochaeta is the dominant taxonomic group at this site, as it is at the other Deep River site. *Oligochaeta* processes sediment to meet their nutritional needs, and their numbers often increase with the addition of organic material to the sediment. This is the case at this facility as is indicated by Figure 29. comparing overall population density to *Oligochaeta* population density. The *Oligochaeta* make up the largest percentage of the population, and they drive the increase in population density that occurs after the fish rearing season.

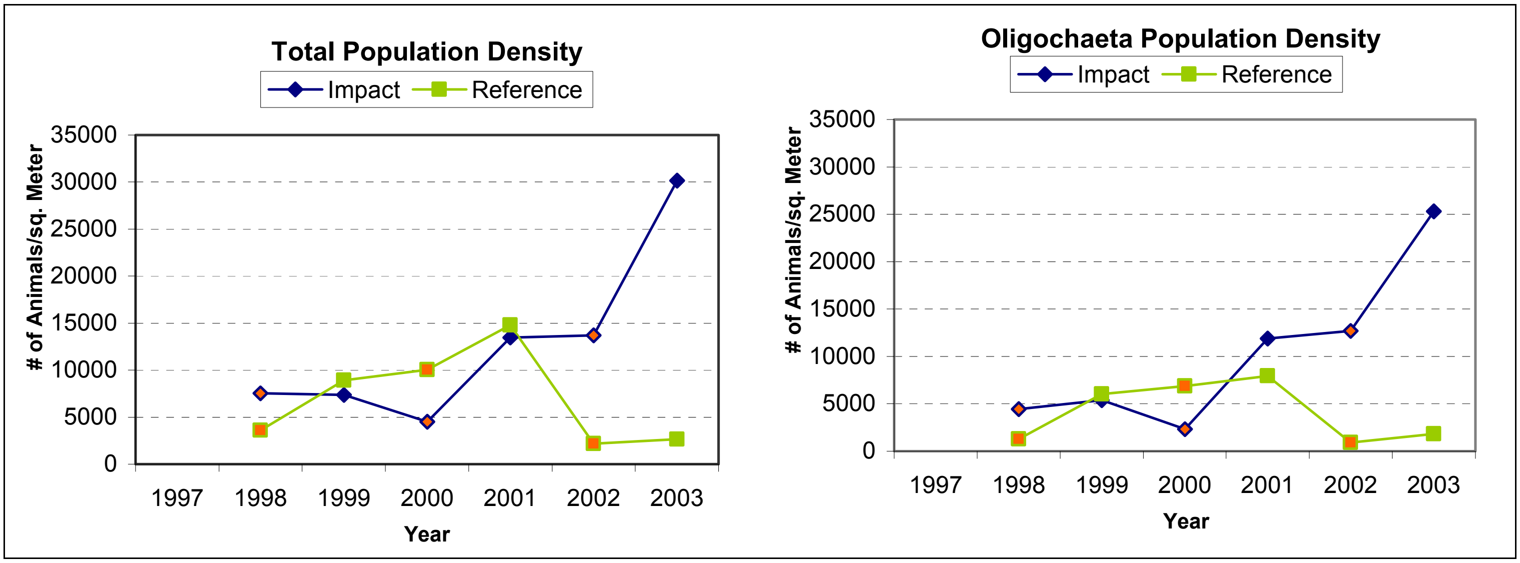


Figure 29. Summer population density of *Oligochaeta* compared to total population at Lower Deep River facility, 1997-2003.

The *Oligochaeta* population density correlates closely with the overall population, but it more accurately reflects the organic enrichment occurring. The density of the *Oligochaeta* population is greater at the Impact station than at the Reference station each year except in the summer of 1999, when the Reference population density is slightly greater, and in the summer of 2000 when the *Oligochaeta* population shows the same decrease at the Impact station at this Deep River facility as it did at the other Deep River facility.

The trend of one taxonomic group dominating the population to a greater extent at the Impact station than at the Reference station, especially a taxon like *Oligochaeta*, is a measurable response to the fish rearing activities. Figure 30. shows that the dominant species, *Oligochaeta*, is usually more dominant at the Impact site than it is at the Reference site at the end of the fish rearing season in every year except 2000. In 2000 there was a decline in the *Oligochaeta* population at both Deep River Impact stations. The cause of this decrease has not been ascertained.

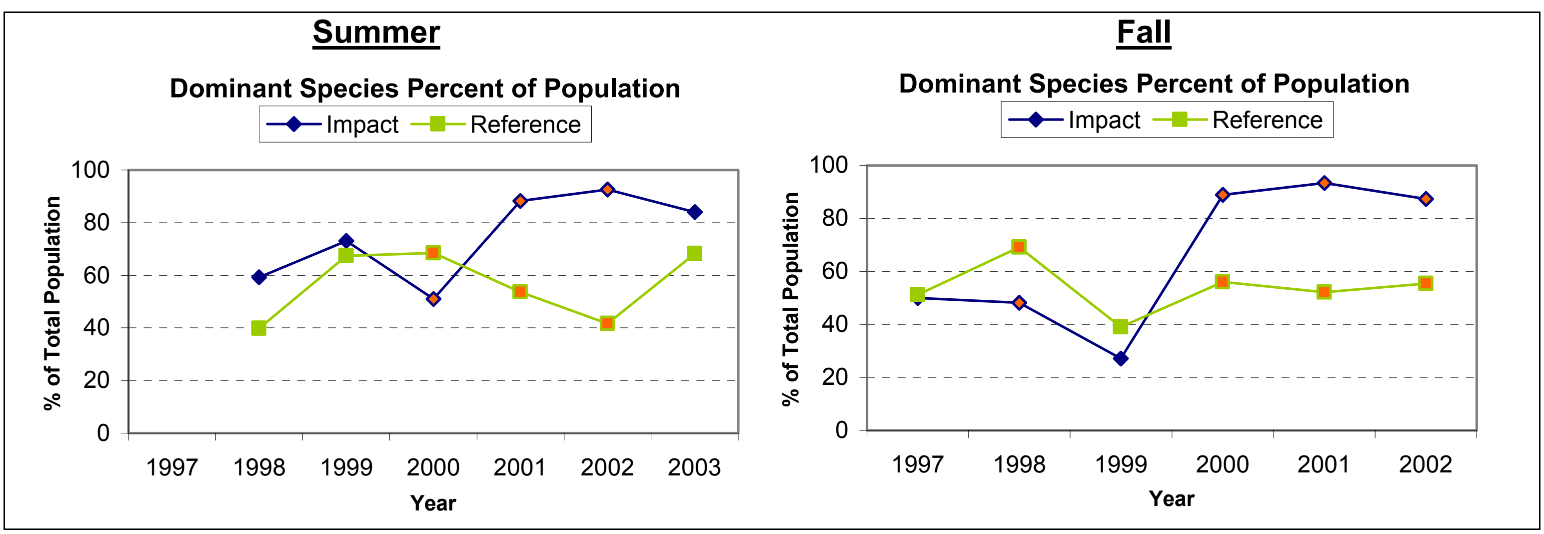


Figure 30. Percent of the total population that is composed of the dominant species at the Lower Deep River facility, summer versus fall, 1997-2003.

In the fall, after the year 1999, they have increased the extent to which they dominate the overall population at the Impact site. Since the previous Figures of the overall population size decreases in the fall, as does the population of *Oligochaeta*, this may be a seasonal affect. However, this should not be assumed.

Figure 31 shows the number of species present at the Impact and Reference stations in the summer at the end of the growing season, and in the fall just before the next growing season begins and after several months of inactivity.

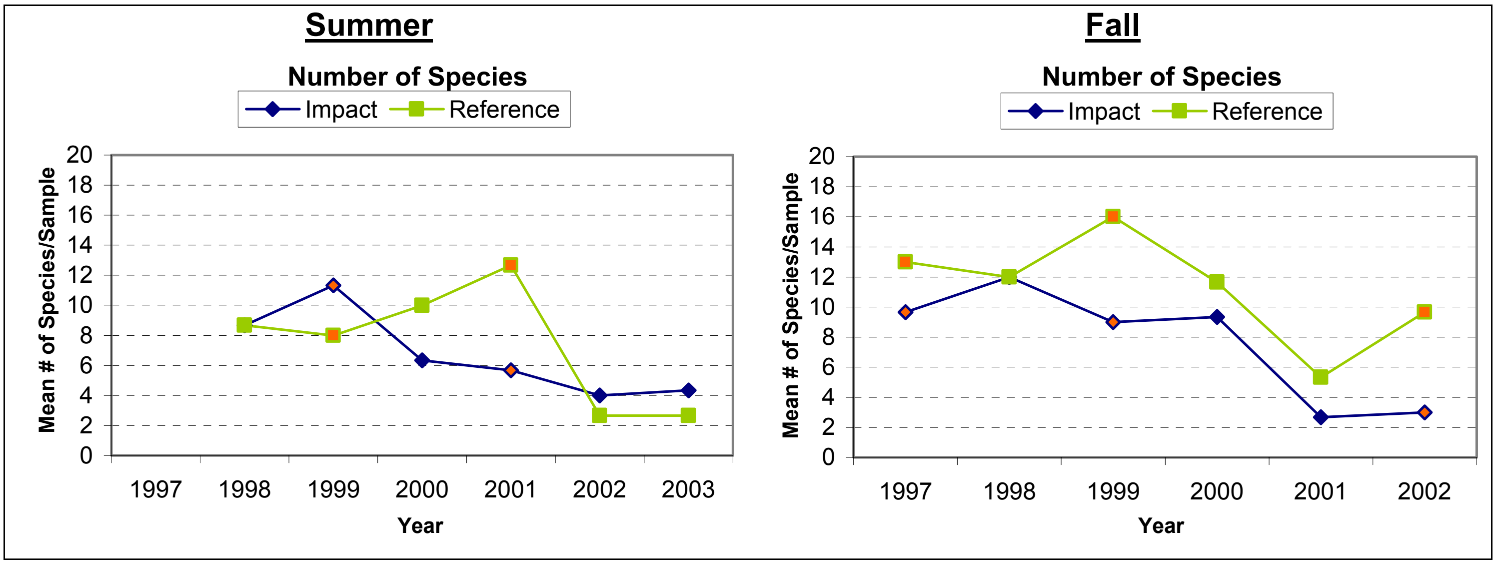


Figure 31. Mean number of species present at the Lower Deep River facility, summer versus fall, 1997-2003.

While significant differences occur between the Reference station and the Impact station there is no apparent trend in the summer population. However, the fall population shows the Reference station to have more species present in all of the last four years and significantly greater taxa richness in two of the last four years. The presents of fewer species at the Impact station than at the Reference station could indicate an environmental impact.

The population density data indicates that the environmental impact at this site is small and does not persist. However, the species dominance data and the taxa richness data suggests that there may be an impact that persists, or that only appears well after the fish rearing activity has ceased. These trends are unusual and it is necessary to see if they persist.

Steamboat Slough

Steamboat Slough is a side channel of the mainstream of the Columbia River between Price Island and the Washington shore, and it is open to the Columbia River at both ends. The salmon net pen facility is located about 200 meters upstream from the confluence of Skamokawa Creek, Steamboat Slough and the Columbia River. It is influenced by Skamokawa Creek and the Elochoman River but the main influence is from the strong tidal currents of the Columbia River. This situation is not conducive to the imprinting and homing instincts of the fish and returns to this facility have been poor. It is expected that this facility will be abandoned.

The strong tidal currents do not allow for much deposition and the sediments in Steamboat Slough are sandy with TOC levels lower than at other net pen sites. The TOC at the Reference site was 0.45 percent and 0.46 percent at the end of the growing seasons in the years 2002 and 2003 respectively. The TOC was 0.34 percent and 0.43 percent at the Impact site at the end of the growing seasons in the years 2002 and 2003 respectively. Production at this facility is below the level that would require a discharge permit.

Fish were first added to these net pens in the spring of 1998. They spent a shorter time in the pens this year than usual as they are normally added to the pens in the fall, and released in the late spring, usually in May. In later years fish were added and released following the usual schedule. Samples collected in the summer of 1998 and the following fall were collected before fish were added to the net pens, and they are baseline samples.

As indicated in Figure 32 the benthic macro invertebrate population size at the Impact station does not increase relative to that at the Reference station. There is no clear pattern, the population at the Reference station is sometimes larger than at the Impact station. While significant differences occur between the Reference station and the Impact station, either one may have the larger population in a given year.

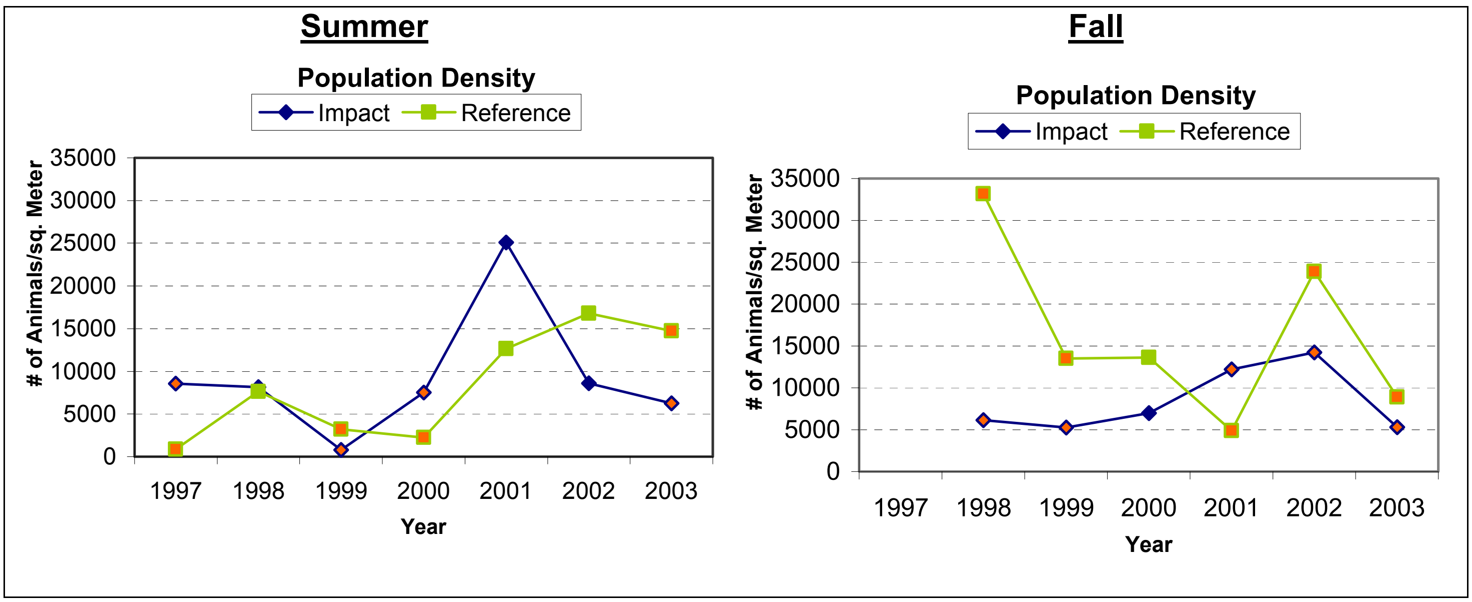


Figure 32. Macro invertebrate population density at the Steamboat Slough facility, summer versus fall, 1997-2003.

The composition of the population is diverse at both the Reference station and the Impact station. Two taxonomic groups are usually most dominant, *Oligochaeta* (worms) and The amphipod *Americorophium salmonis*. Several other taxonomic groups are also well represented. As a result the dominant species makes up a percentage of the population below 60 percent at both stations in the summer samples.

There is very little difference between the Reference station and the Impact station in percent dominance of the most dominant species at the end of the growing season or in the fall after a period of inactivity, as shown in Figure 33 below. When significant differences occur, the Reference station often has a larger percent of the benthic macro invertebrate population composed of one taxon. Also dominance is often greater at both stations in the fall, which may be a seasonal phenomenon.

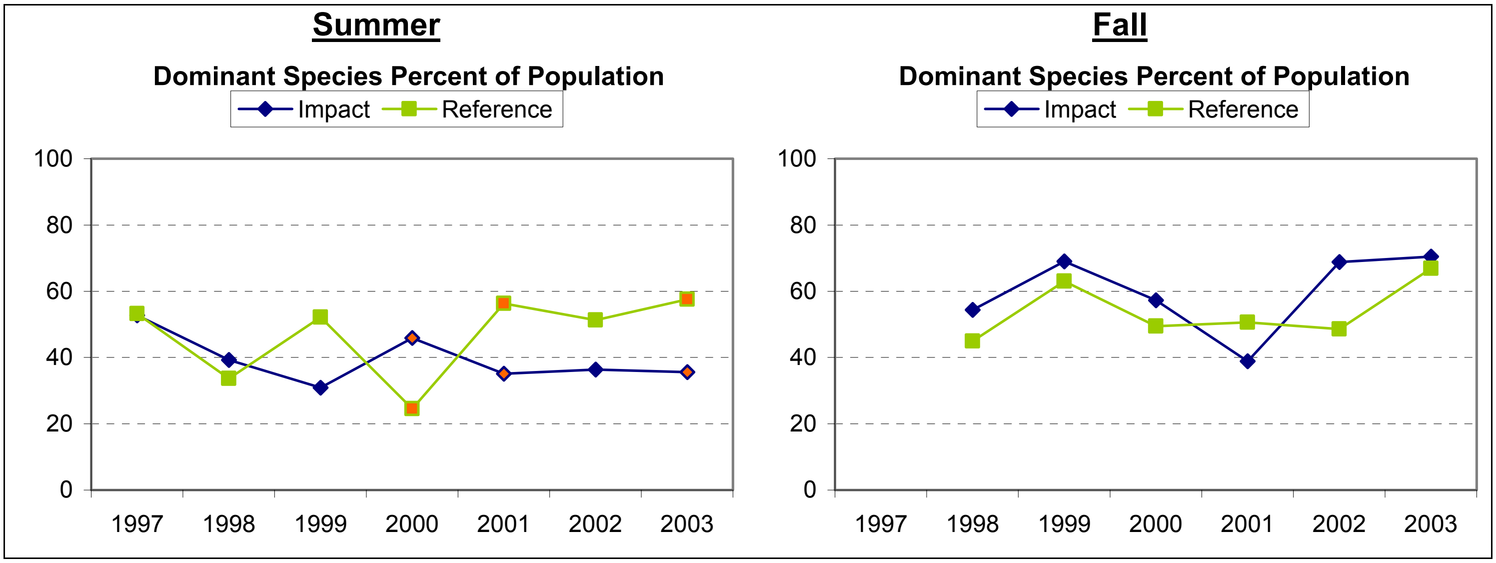


Figure 33. Percent of the total population that is composed of the dominant species at the Lower Deep River facility, summer versus fall, 1997-2003.

Figure 34 indicates that there is little difference between the Reference station and the Impact station in the number of species that make up the macro invertebrate populations in either the summer or the fall. There is no pattern in this population parameter.

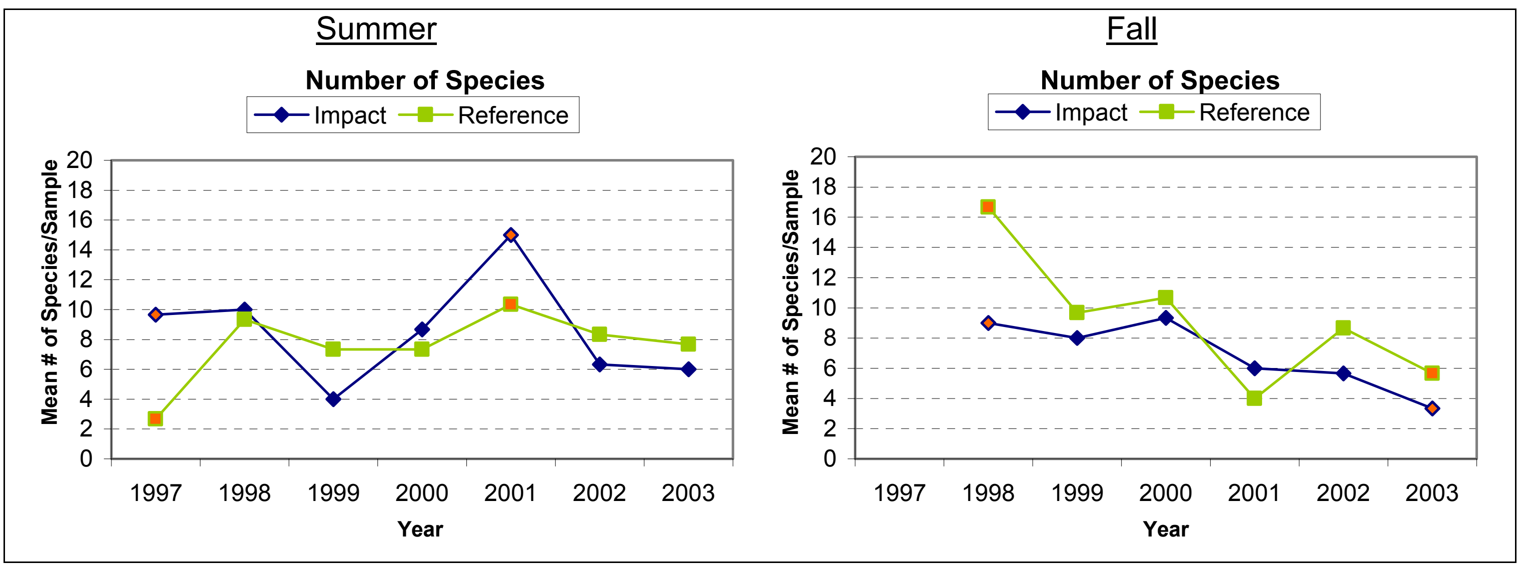


Figure 34. Mean number of species present in Steamboat Slough facility samples, summer versus fall, 1997-2003.

Due to the low production level and the high degree of tidal flushing there is no environmental impact at this site that is detectable at the level of resolution provided by this monitoring program.

SUMMARY OF THE ENVIRONMENTAL IMPACT

The SAFE Project operates at production levels that are relatively low compared to other net pen fish rearing operations where environmental problems have raised concerns. This is because the fish are not raised to marketable size in the net pens, instead they are released when they smolt and migrate out to sea. Since the fish are not usually held in the net pens all year, this allows for a period of recovery of the area from the slight impacts that are detected, primarily organic enrichment. When fish have been held at a facility all year it has been on an experimental basis, and so far it has only involved a small number of fish.

The Perimeter stations that have shown some impact that is not due to differences in benthic substrate are the stations at the Youngs Bay, Yacht Club facility that lie in the direction of the current, and these show only a slight increase in organic enrichment. With only two years of samples it is a little too soon to determine if a trend exists. Further sampling will help to clarify the situation at these stations.

WATER QUALITY PARAMETERS

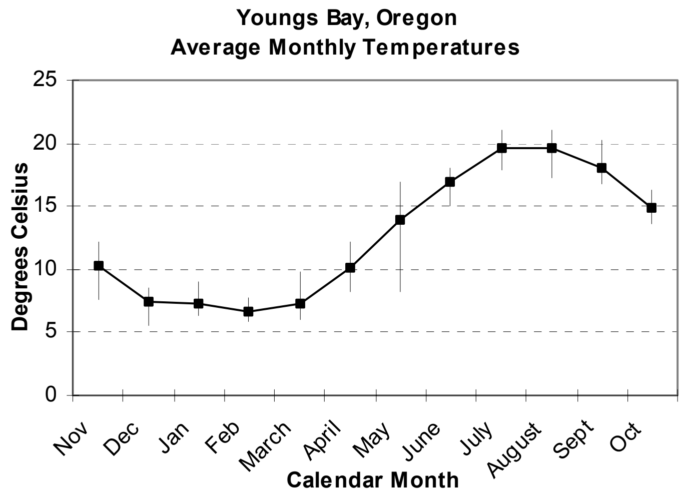
Documenting the ongoing suitability of the environment for the rearing of salmon at the various SAFE facilities is a component of this environmental monitoring program. To this end the HydrolabJ Surveyor 3 Datalogger with an H_2O Datasond, or the HydrolabJ Surveyor 4A Datalogger with a Surveyor 4 Datasond are deployed at each water body where net pen facilities are located as described in the Materials and Methods section.

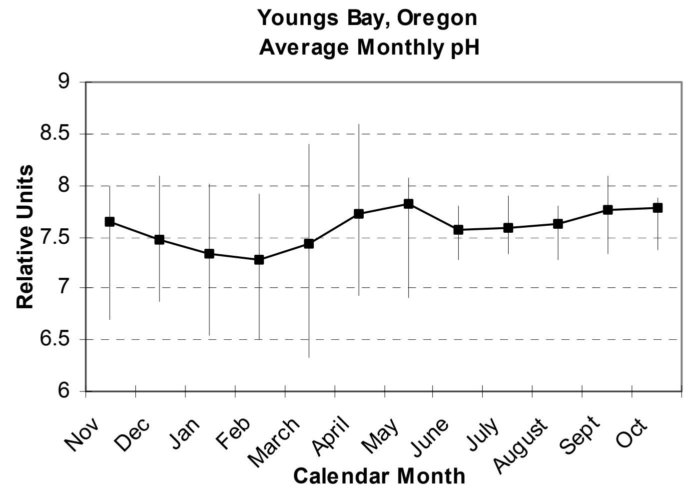
An instrument is deployed at each site every month for a 24-hour period. These instruments record temperature, dissolved oxygen, pH, turbidity and specific conductance. The instrument is placed about 2 meters below the water surface, between the net pens. The water bodies that have two net pen facilities, Youngs Bay and Deep River, are only monitored at one location.

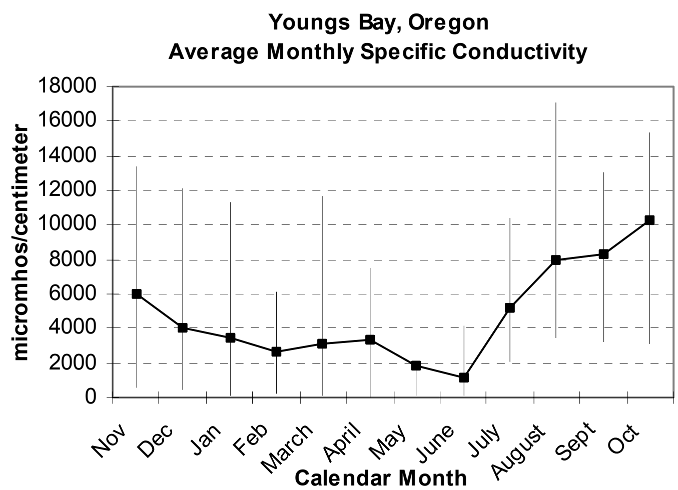
The following Figures summarize the data collected over the years during which fish were reared in the various net pen facilities. Each page displays the water quality for one of the water bodies. Each Figure displays one of the water quality parameters. The Figures show the average measurement of all of the years that data was collected for each month of the year. At each data point the vertical bars show the maximum and the minimum range that occurred during that month over the years.

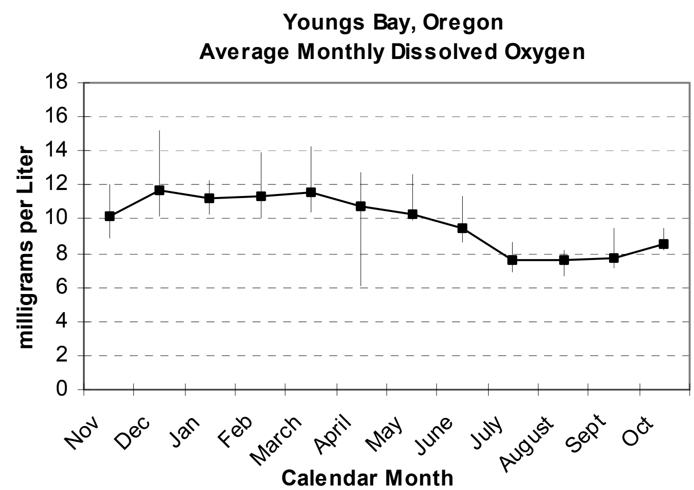
All of the physicochemical parameters measured are within the healthy tolerance range of the salmon being reared in the net pens by this project. Only the summer temperatures sometimes reach levels that may be stressful to salmon, but these occur during months when fish are usually not being hel

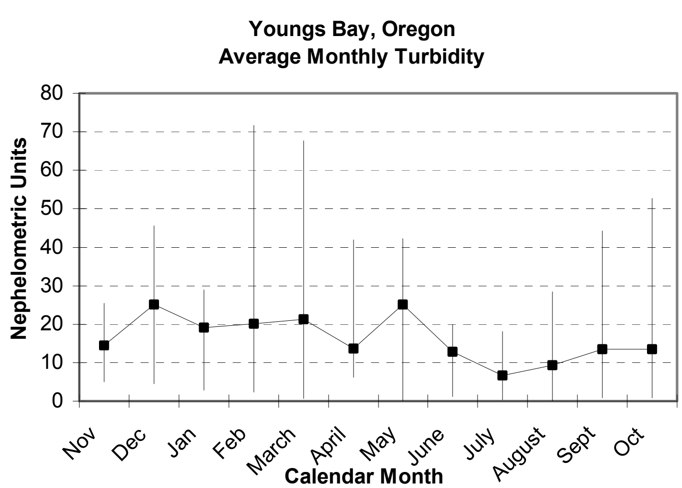
Youngs Bay, Oregon, Physicochemical Parameters, Data collected from 1994 to 2003

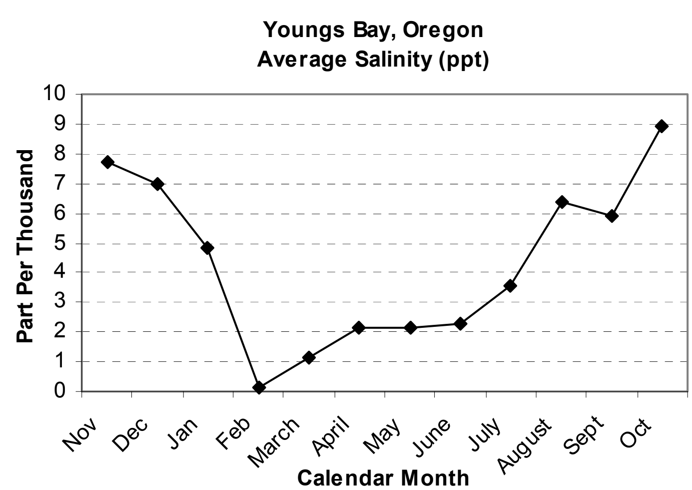






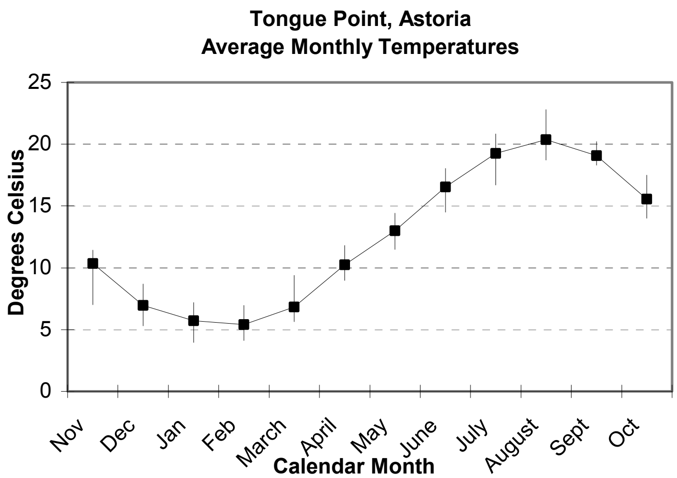


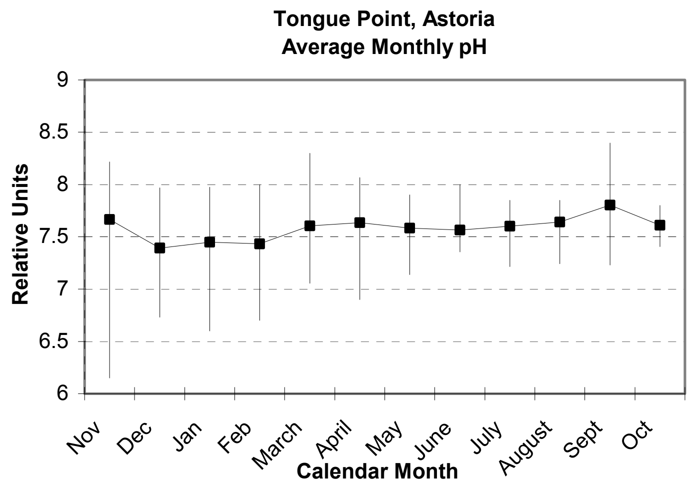


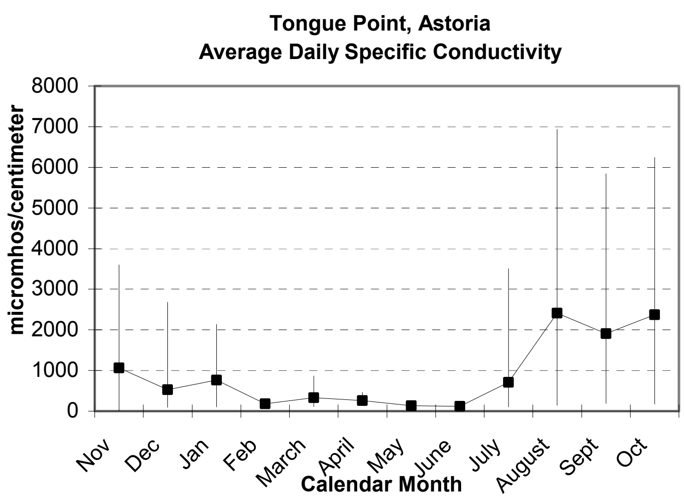


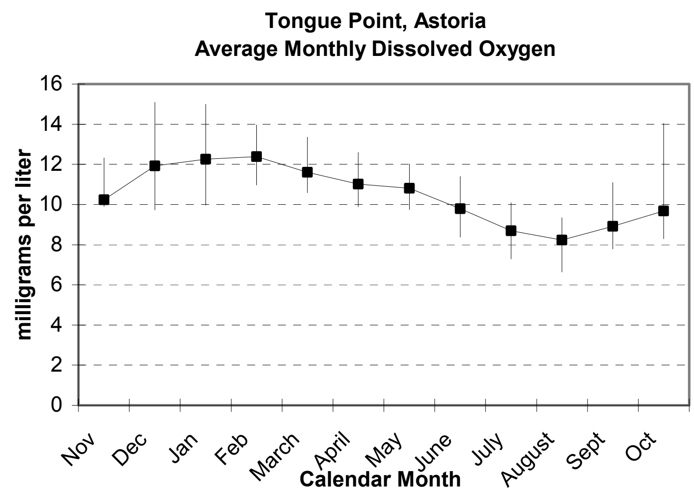
Note: Salinity measurements were taken starting in November 2002, only at Youngs Bay, Oregon due to the brackish environment that exists at this site.

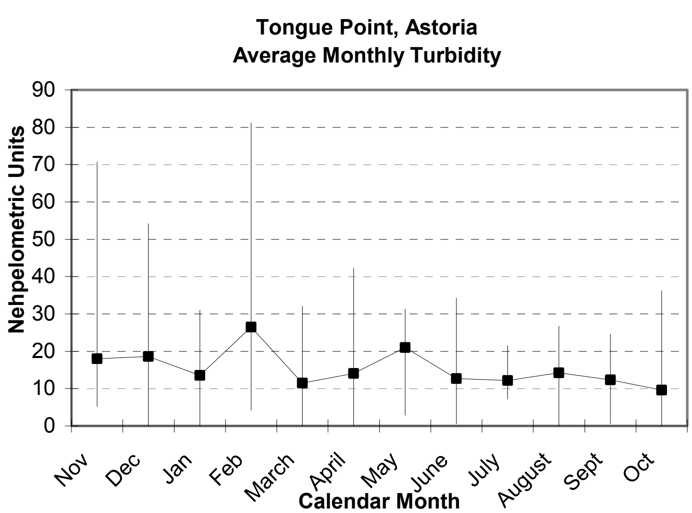
Tongue Point, Oregon, Physicochemical Parameters, Data collected from 1994 to 2003



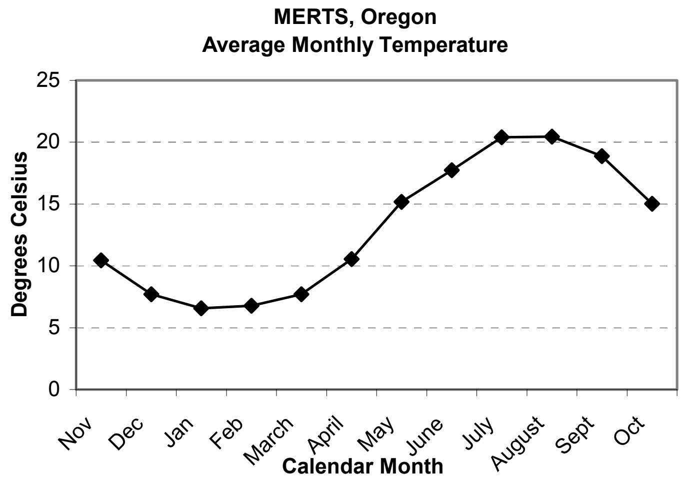


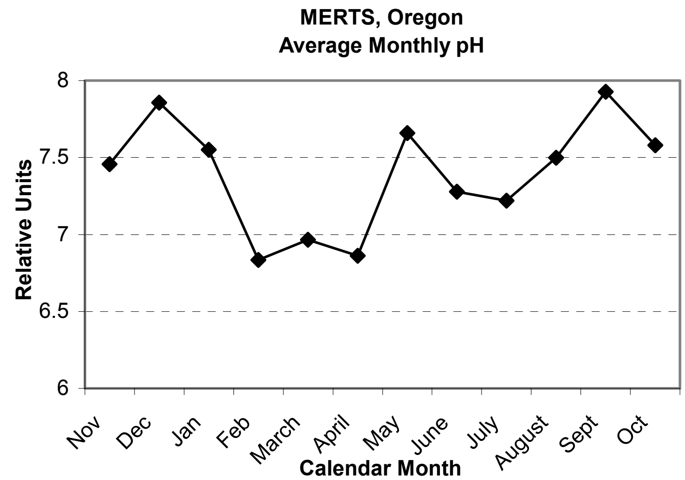


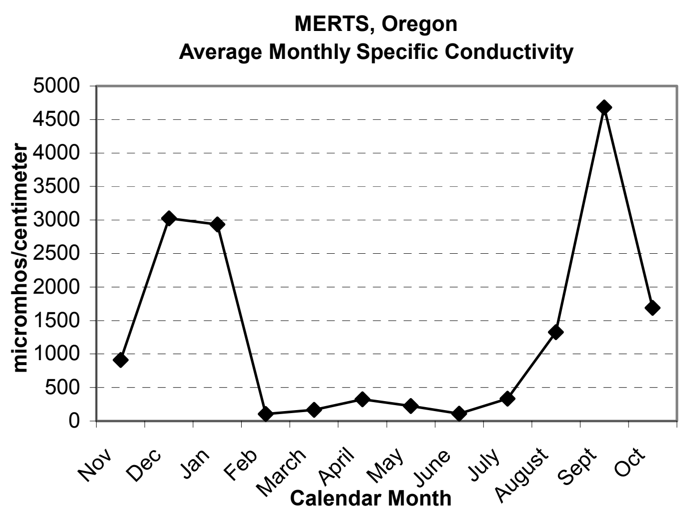


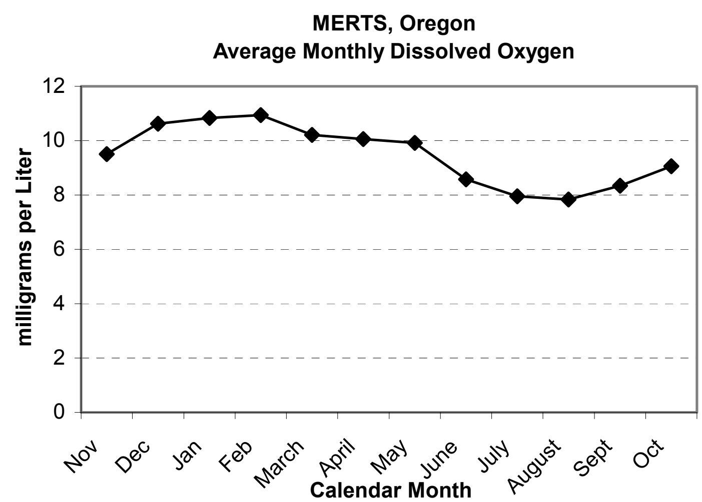


Marine and Environmental Research and Training Station (MERTS), Oregon, Physicochemical Parameters



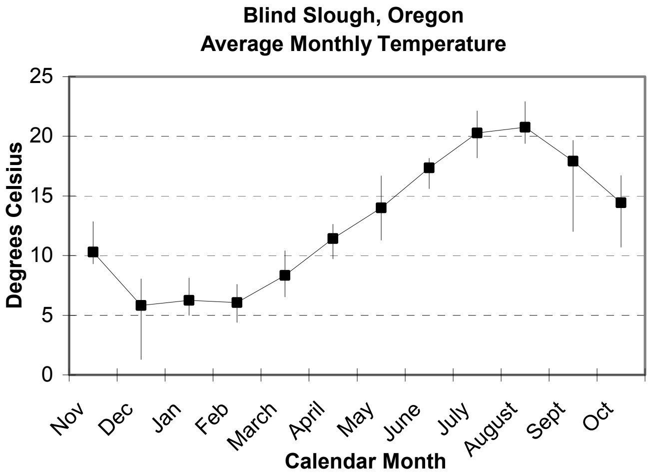


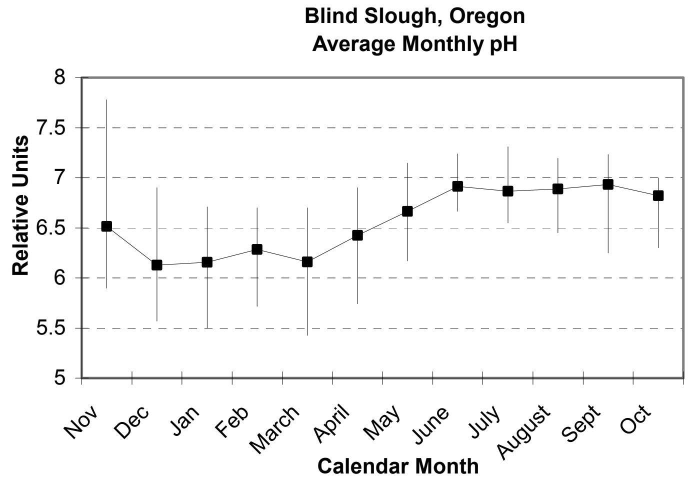


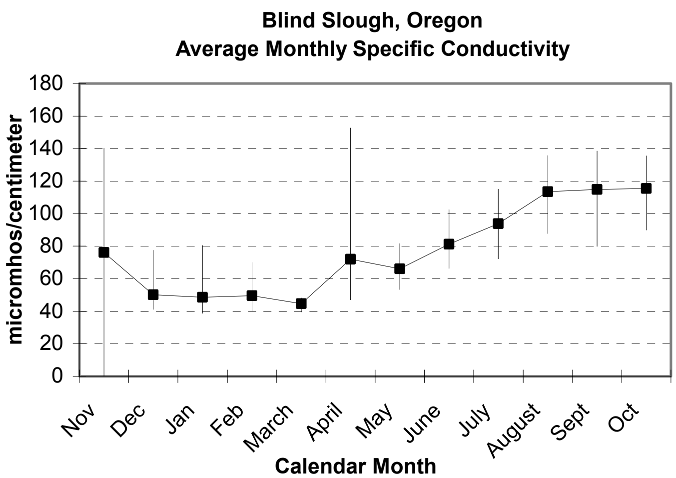


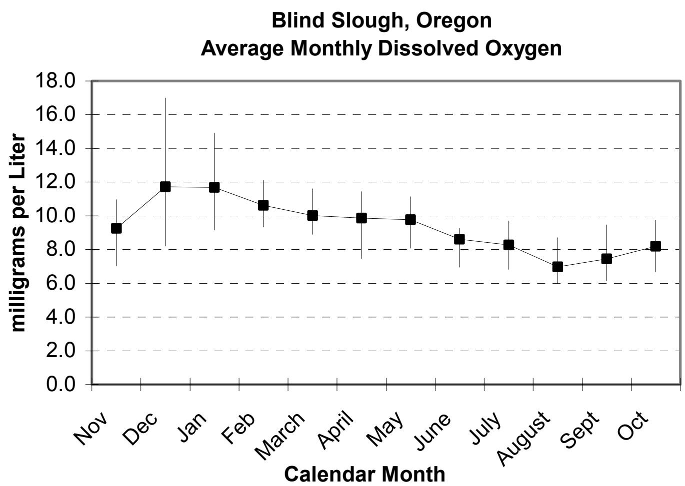
Note: sampling at this location began in June 2002. No turbidity data is displayed due to sensor failure.

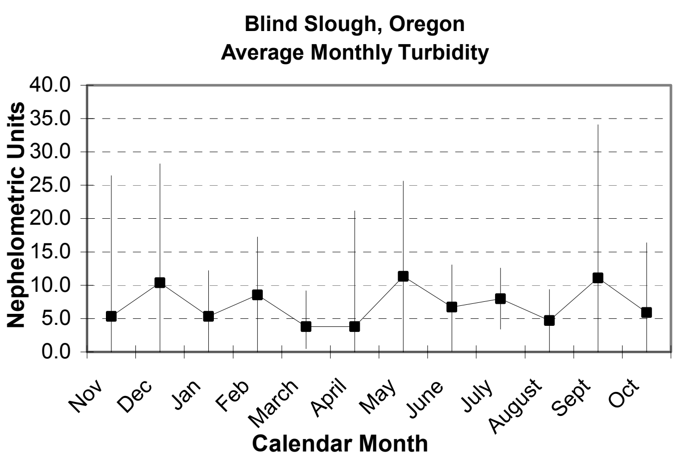
Blind Slough, Oregon, Physicochemical Parameters, Data collected from 1994 to 2003



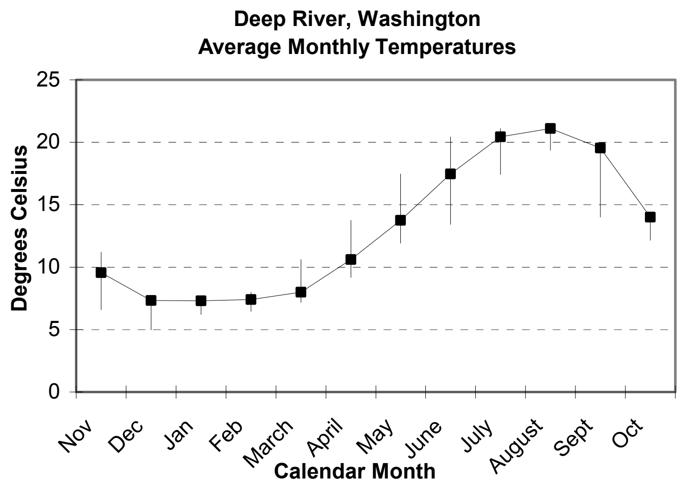


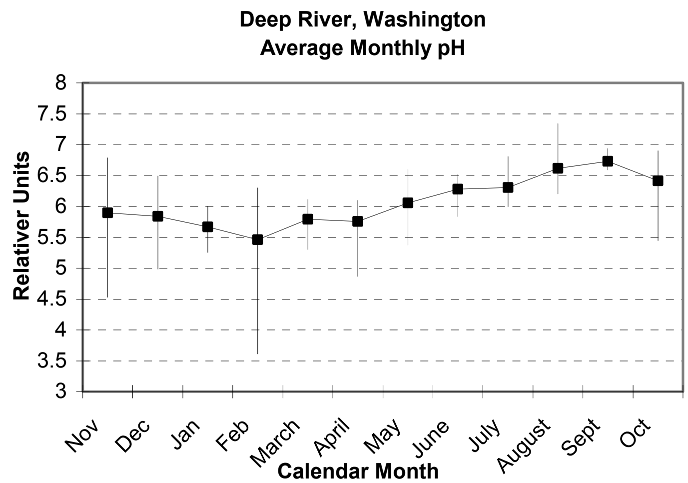


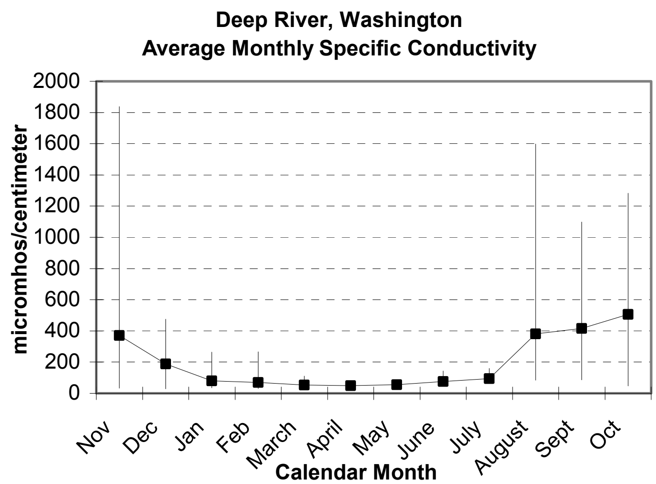


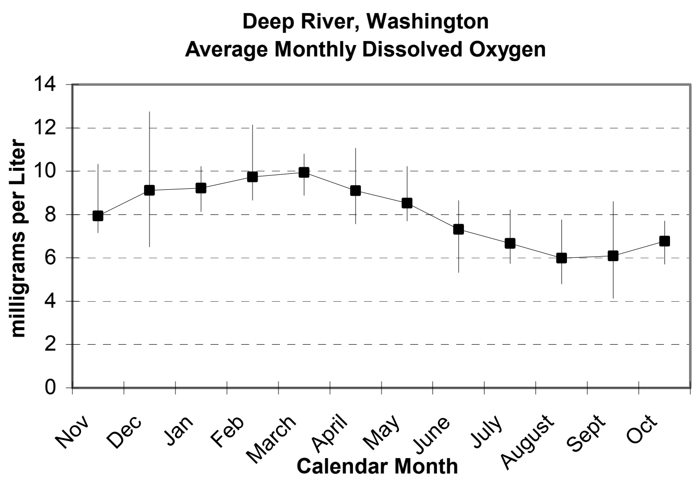


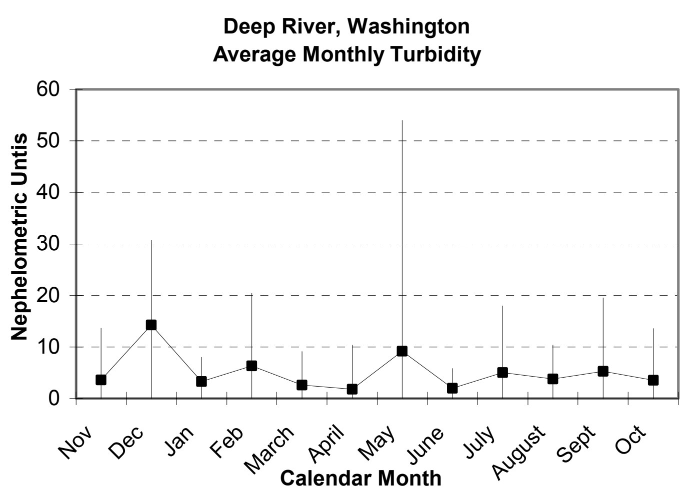
Deep River, Washington, Physicochemical Parameters, Data collected from 1994 to 2003



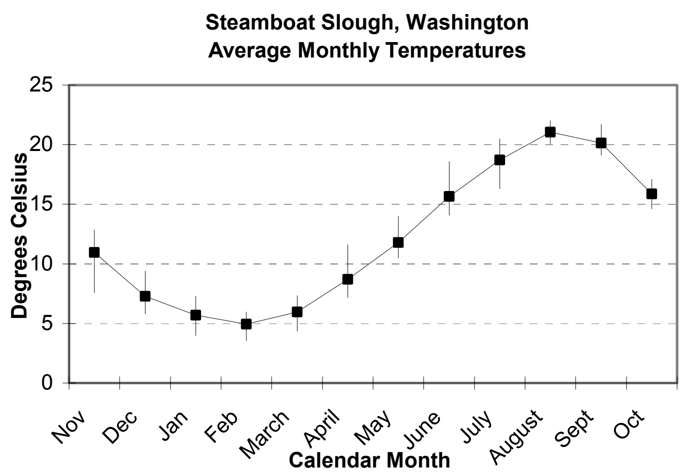


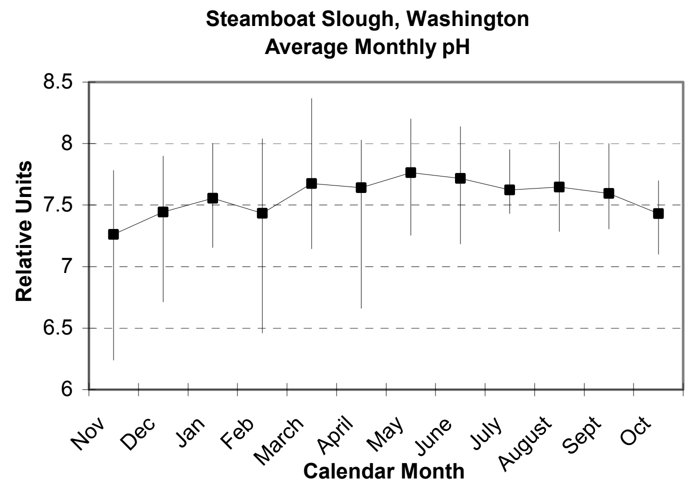


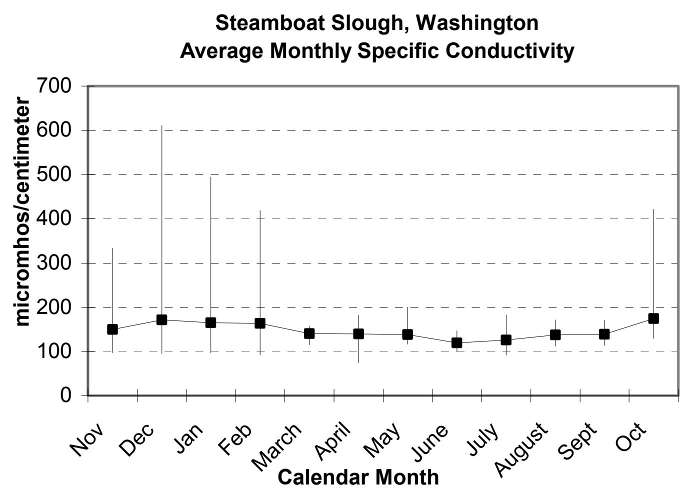


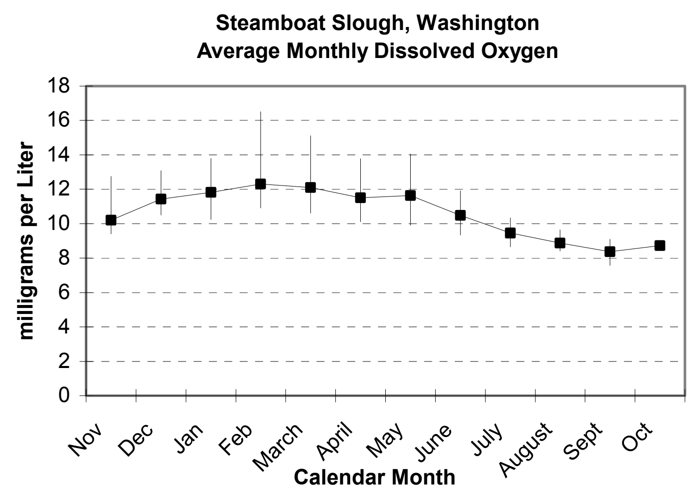


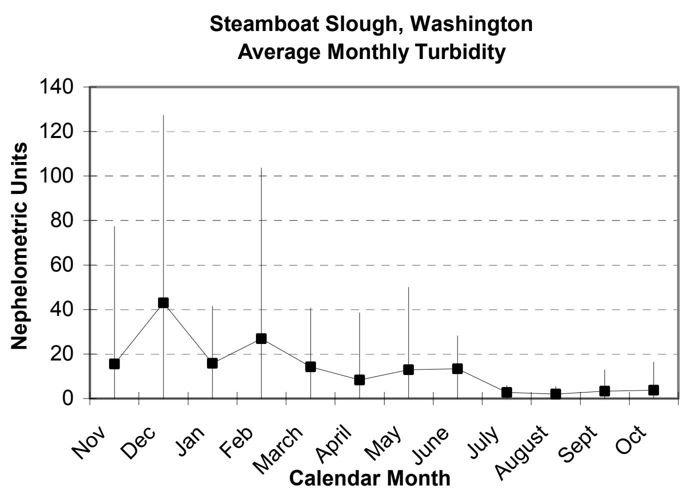
Steamboat Slough, Washington, Physicochemical Parameters, Data collected from 1994 to 2003











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