Caged Mussel Pilot Study
Port Alice Mill, Vancouver Island
EEM Program

FINAL REPORT

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ANOVA	Analysis of variance
ASTM	American Society for Testing and Materials
BCRI	BC Research, Inc.
BOT	beginning of test
CI	condition index
CPPA	Canadian Pulp and Paper Association
DFO	Department of Fisheries and Oceans
DO	dissolved oxygen
EC	Environment Canada
EDR	Exposure-dose-response
EEM	Environmental Effects Monitoring
EOT	end of test
EVS	EVS Environment Consultants, Inc.
FSEWG	Fish Survey Expert Working Group
HRGC	High resolution gas chromotography
HRMS	High resolution mass spectrophotometry
IOS	Institute of Ocean Sciences
MAFF	Ministry of Agriculture, Fisheries and Food
PCDD	polychlorinated dibenzo-p-dioxins
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
SPMDs	semipermeable membrane devices
SQT	sediment quality triad
SSL	Spent sulphite liquor
TBT	tributyltin
TCDD	tetrachloro dibenzo-p-dioxin
TCDF	tetrachloro dibenzofuran
TMS	trimethylsilyl
TSS	total suspended solids
US EPA	US Environmental Protection Agency
WAWW	whole-animal wet-weight

1.0 EXECUTIVE SUMMARY

The caged bivalve methodology is being considered as an alternative to the Fish Survey component of Environmental Effects Monitoring (EEM) requirement at Canadian pulp and paper mills. It could be a valuable assessment tool, specifically at those locations where standard fish surveys were not successful in Cycle 1. For example, uncertain exposure was listed as a problem or confounding factor with the majority of marine and estuarine fish surveys in Cycle 1 (FSEWG, 1997). Another problem was catching sufficient numbers of even one sentinel fish species. The EEM decision tree for the Fish Survey (Figure 1 in Environment Canada, 1997) recognized that at some mills increased effort or a redesigned Fish Survey could resolve Cycle 1 problems and these mills would continue with a standard fish survey. At mills where environmental constraints led to alternative approaches in the decision, the caged bivalve approach could be an option.

Current EEM regulations recognize the importance of evaluating both effluents and conditions in receiving waters to protect Canadian fish, fish habitat and the use of fisheries resources. Monitoring with caged bivalves helps bridge the gap between laboratory bioassays and traditional field monitoring by combining elements of experimental control and environmental realism. *In situ* studies with caged bivalves facilitates controlled field monitoring (e.g., large numbers of animals, a small size range, identical pre-exposure history) and the formulation of testable hypotheses. These studies can be designed to address site-specific conditions, which facilitates quantifying both exposure and effects, especially at mills where a traditional survey has been unsuccessful.

In 1997, Environment Canada, Department of Fisheries and Oceans, and the Canadian Pulp and Paper Association jointly funded a pilot study to test the feasibility, scientific value, and applicability of using caged bivalves as an EEM tool for locations where the standard fish survey would not likely yield interpretable results. The approach measured mussel survival, bioaccumulation, and growth after *in situ* exposure to sulphite pulp mill effluent for 68 days. The pilot-scale *in situ* field study with caged mussels (*Mytilus edulis*) was conducted in Neroutsos Inlet, British Columbia from August 5 through October 14, 1997.

Effects results showed increased mussel growth with increased distance from the mill effluent diffuser (i.e., decreased exposure). Percent lipids increased and percent water decreased along the same gradient. Both of these biochemical endpoints support the growth results and suggest better mussel condition with increasing distance from the mill. A similar gradient was not evident with other variables such as temperature or chlorophyll-a. Although there were significant depth effects which were probably attributable to differences in temperature and dissolved oxygen, the primary factors associated with effects over distance were spent sulphite liquor and dissolved oxygen. Both of these factors are related to the mill effluent.

A statistically significant difference in mussel growth among sites was detected when the absolute difference was only 10 percent. Efforts are underway to quantify the range in statistical power with various applications of this method and relate these statistically significant differences to environmental significance. This will result in defining effects on individuals or at least a range of effects that may be related to population effects for potential application in EEM. This and other recent caged mussel field studies and data analysis will contribute to the definition of a significant effects level.

This report summarizes methods, rationale, and historical monitoring with caged bivalves, methods used to conduct the pilot study, results of the pilot study, and application of *in situ* caged bivalve studies to answer EEM questions.

1.0 SOMMAIRE À L'INTENTION DE LA DIRECTION

La méthode des bivalves en cage est considérée comme une solution de remplacement à l'étude des poissons exigée dans le cadre du Suivi des effets environnementaux (SEE) dans les usines canadiennes de pâtes et papiers. Elle pourrait être un outil d'évaluation précieux, en particulier aux endroits où les études des poissons standard ont échoué au premier cycle. Par exemple, dans la majorité des études des poissons effectuées en mer et en estuaire dans le premier cycle, l'incertitude quant à l'exposition a été relevée comme un problème ou un facteur de confusion (FSEWG, 1997). La capture d'un nombre suffisant d'une même espèce de poisson sentinelle a été un autre problème. L'arbre de décision du SEE pour l'étude des poissons (figure 1, Environnement Canada, 1997) a permis d'établir que des efforts accrus à certaines usines ou une modification de l'étude des poissons pourraient régler les problèmes relevés dans le premier cycle; et ces usines pourraient continuer avec une étude des poissons standard. Dans le cas des usines qui, en raison de contraintes environnementales, ont dû adopter d'autres approches décisionnelles, la méthode des bivalves en cage pourrait être une solution.

La réglementation actuelle concernant le SEE reconnaît l'importance de l'évaluation des effluents et des conditions des eaux réceptrices pour protéger le poisson, l'habitat du poisson et l'utilisation des ressources halieutiques au Canada. La surveillance effectuée à l'aide de bivalves en cage permet de réduire l'écart entre les bioessais en laboratoire et la surveillance sur le terrain classique en combinant des éléments du contrôle expérimental et des conditions environnementales réelles. Des études *in situ* avec des bivalves en cage facilitent la surveillance pratique en conditions contrôlées (p. ex. un grand nombre d'animaux, une petite plage de taille, des antécédents de pré-exposition identiques) et la formulation d'hypothèses vérifiables. Ces études peuvent être conçues pour l'étude des conditions propres à un site, qui facilitent la mesure de l'exposition et des effets, en particulier pour les usines où l'étude des poissons n'a pas été concluante.

En 1997, Environnement Canada, Pêches et Océans Canada et l'Association canadienne des pâtes et papiers ont subventionné conjointement une étude pilote pour vérifier la faisabilité, la valeur scientifique et l'applicabilité de l'utilisation des bivalves en cage comme outil de SEE pour les endroits où l'étude des poissons standard ne donnerait probablement pas de résultats interprétables. On a mesuré la survie, la bioaccumulation et la croissance chez les moules après une exposition *in situ* aux effluents d'une usine de pâte au bisulfite pendant 68 jours. L'étude pilote *in situ* avec des moules (*Mytilus edulis*) en cage a été menée dans le bras Neroutsos (Colombie-Britannique), entre le 5 août et le 14 octobre 1997.

Les résultats concernant les effets ont montré une croissance accrue des moules lorsque l'on s'éloigne du point de diffusion des effluents de l'usine (diminution de l'exposition). Dans le même gradient, on a observé une augmentation du pourcentage des lipides et une diminution du pourcentage d'eau. Ces deux mesures terminales biochimiques appuient les résultats concernant la croissance et semblent indiquer que les conditions de croissance des moules s'améliorent à mesure que l'on s'éloigne de l'usine. Un gradient semblable n'était pas évident avec d'autres variables comme la température et la chlorophylle-*a*. Des effets évidents liés à la profondeur étaient probablement attribuables à des différences dans la température et la concentration d'oxygène dissous, mais les principaux facteurs associés aux effets par rapport à la distance étaient la liqueur de bisulfite usée et l'oxygène dissous. Ces deux facteurs sont liés aux effluents de l'usine.

La croissance des moules entre les sites présentait une différence statistiquement importante alors que la différence absolue n'était que de 10 pour cent. Des travaux sont en cours pour calculer l'étendue de la plage de la puissance statistique avec différents applications de cette méthode et relier ces différences statistiquement significatives à l'importance écologique. Ces données permettront de préciser les effets sur les individus ou au moins une plage d'effets qui peuvent être liés aux effets sur la population en vue d'une application potentielle pour le SEE. Cette étude, ainsi que d'autres études pratiques récentes menées à l'aide de moules en cage, et l'analyse des données contribueront à l'établissement du niveau d'effets importants.

Le présent rapport résume les méthodes, la justification et les travaux de surveillance déjà menés à l'aide de bivalves en cage, les méthodes utilisées pour réaliser l'étude pilote, les résultats de cette étude pilote et l'application des études *in situ* de bivalves en cage pour répondre aux questions du SEE.

2.0 INTRODUCTION

2.1 Canadian Workshops on EEM Fish Survey Alternatives

Government, industry, and consultants experienced difficulty sampling and interpreting data from adult fish surveys required by federal regulations for Environmental Effects Monitoring (EEM) of pulp and paper mills during Cycle I (1993-1996). Particularly in the marine environment, there were several cases where appropriate fish could not be collected in sufficient numbers (FSEWG, 1997). In other instances, data interpretation was problematic due to fish mobility and uncertain exposure to pulp mill effluent. In February of 1997, government and industry met with environmental monitoring specialists in Dartmouth, Nova Scotia to discuss alternatives to the EEM Adult Fish Survey (Courtenay et al. 1998). In April of 1997, a second workshop was held in Sidney, British Columbia (BC) to further discuss the utility of field studies with caged bivalve. As a result, a pilot *in situ* field study with caged bivalves was proposed to evaluate as a suitable alternative to the adult fish survey. These workshops were followed by a series of conference calls and planning meetings with government, industry, and consultants to discuss the details of the pilot study. Originally, both east and west coasts were considered as locations for this pilot study. Due to time constraints and other logistical issues, it was decided to conduct the first pilot study in British Columbia. It was cooperatively funded by Environment Canada, the Canadian Pulp and Paper Association (CPPA), and the Department of Fisheries and Oceans (DFO). An east coast pilot study was subsequently conducted in Pictou Harbor (Andrews and Parker 1999).

2.2 Caged Bivalve Monitoring at Canadian Mills & Related Industries

Historically, caged bivalves have been used to monitor pulp and paper mills in freshwater and marine environments. Freshwater caged bivalve studies emphasized bioaccumulation of chemicals in tissues. Their use for monitoring trace contaminants in Canadian waters began as early as 1980 by the Ontario Ministry of the Environment in the Niagara River (Kauss et al. 1981, Richman 1992). Standardized methods for Canadian monitoring were proposed as early as 1986 (Creese et al. 1986).

Many different species have been used successfully in a variety of countries. In Canada, the freshwater mussel *Elliptio complanata* has been used extensively to evaluate chemical bioavailability, particularly in the St. Lawrence area (Metcalfe and Hayton 1989). One of the first comprehensive biomonitoring studies using *Elliptio complanata* was conducted by Kauss and Hamdy (1985) for organochlorines in the St. Clair and Detroit Rivers.

A detailed biomonitoring study of the Niagara River in 1987 showed that caged mussels (*Elliptio complanata*) accumulated tetrachloro dibenzo-p-dioxin (TCDD) and tetrachloro dibenzofuran (TCDF) that were proportional to concentrations of these compounds in both resident biota (*Cladophora*, spottail shiners) and sediment (Anderson et al. 1991). Another study conducted in the Rainy River, Ontario indicated that mussels are sensitive biomonitors of polychlorinated dibenzo-p-dioxins (PCDDs). Several PCDD sources were identified, including two Kraft pulp and paper mills, a wood waste disposal site, and a sewage treatment plant. The PCDD congener distribution pattern in mussel tissues was similar to that of the suspended sediments in the mill effluent (Hayton et al. 1990). Further sensitivity was shown where dioxins (including TCDD originating from the mills) in mussel tissues collected 60 km downstream of the mills were at or above the "no-effect level" of 3 pg/g (Newell et al. 1987, Hayton and Hollinger 1989).

Metcalfe and Hayton (1989) compared leeches and mussels as biomonitors for chlorophenol pollution and concluded that leeches were superior, but the 3-week exposure period for mussels may have been inadequate. In a later study on Canagagigue Creek, it was demonstrated that mussels exposed for 6 weeks accumulated twice the concentration of dioxins in their tissues as those exposed for only three weeks. The Ontario Ministry of Environment (1996) has used caged mussels to establish baseline chemical concentrations to evaluate the effectiveness of process changes.

In contrast to the freshwater studies, marine caged bivalve studies in British Columbia have emphasized effects measurements without supporting tissue chemistry data. Wu and Levings (1980) showed reduced growth rates in transplanted mussels in the vicinity of a kraft mill outfall. Quayle (1964) conducted two oyster transplant experiments in the vicinity another bleached kraft mill outfall, but the results were inconclusive. Only water samples and condition factors were measured, tissue residues were not. Other studies at the same mill using wild oysters found an inverse relationship between tissue concentrations of zinc and distance from the mill (Anderson 1977). An inverse relationship was also found between oyster condition and tissue concentrations of zinc in that study. This was one of the first examples of combining exposure and effects measurements in Canada. Recently, Grout and Levings (2001) related tissue concentrations of copper and zinc to mussel survival and growth in the vicinity of a copper mine in British Columbia.

The use of caged mussels was first suggested as one of the core marine monitoring elements of EEM in 1990 at the 17th Annual Aquatic Toxicity Workshop in Vancouver, BC (Parker et al. 1991). Two *in-situ* tests were suggested: a 4-day caged fish test to assess lethality, tainting, and bioconcentration of chemicals, and a 21-day caged mussel (*Mytilus* sp.) test to assess bioconcentration and bioaccumulation by invertebrates. As stated in Parker et al. (1991), "Tests of these types have been performed for many years by government and consultants." Two of the plenary presentations at the same meeting described the use of caged mussels as bioindicators of tributyltin (TBT) (Salazar and Salazar 1991) and the application of caged mussels as part of "real time" monitoring in decision making for dredging projects (Nelson 1991).

2.3 *Caged Bivalve Monitoring at Mills in Other Countries*

Caged bivalves have been used as indicators of exposure and indicators of effects in Finland, France, New Zealand, Australia, and the US. For example, two studies conducted at a pulp and paper mill in Alaska using caged mussels showed reduced growth rates and elevated concentrations of dioxins and furans in soft tissues of mussels transplanted to sites adjacent to the mill (EVS 1996 1997, Salazar et al. 1997). Examples of using freshwater bivalves include the use of *Corbicula fluminea* to evaluate effluents from a wood treatment facility discharged to the San Joaquin River, California (Hayward et al. 1996), *Anodonta cygnea* to evaluate extractable organic halogens in effluents discharged into the Ton River in France (Hayer and Pihan 1996), and *Hydridella menziesi* to assess accumulation and depuration of resin acids in effluent discharged to a freshwater pond in New Zealand (Burggraaf et al. 1996). Finland has the largest data set for monitoring bioavailable chemicals associated with pulp mill effluents, where they have been using the caged bivalve approach since 1984 (Herve 1991, Herve et al. 1988 1996).

2.4 *Wild Bivalve Monitoring for EEM Cycle 1*

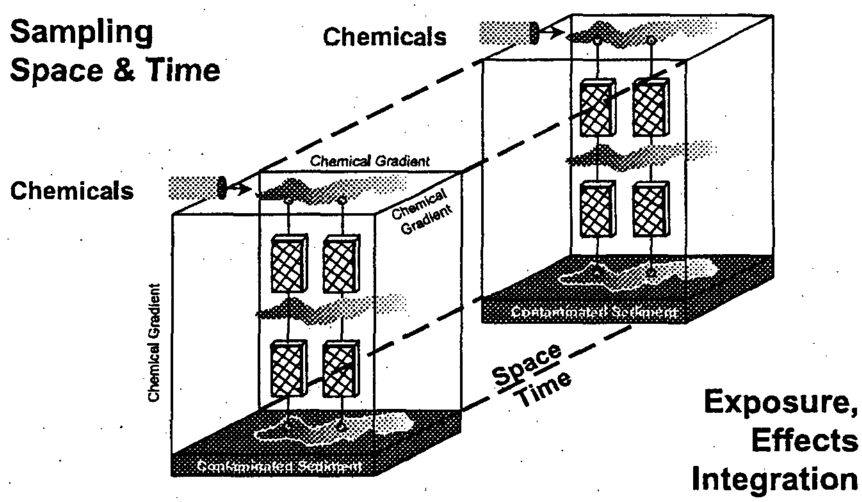
Hatfield Consultants Ltd. monitored condition of natural bivalve populations at several BC mills as part of EEM in Cycle 1, including wild mussels at the Port Alice mill, the location of this pilot study. Measured condition index in wild bivalves was used as an estimate of effects. Exposure was not directly confirmed by measuring mill-associated chemicals in mussel tissues, although mussels were collected from areas known to contain mill effluent. In general, results have shown that the smallest mussels were found nearest the mill but that these populations have been recovering due to process improvements (Hatfield Consultants Ltd. 1997). In the Hatfield study, it was difficult to collect wild mussels in the same size range from different locations. This increased the uncertainty in quantifying and comparing mussel condition across sites due to the variability in the condition index metric and the effects of size on condition index.

2.5 *Conceptual Framework for Using Caged Bivalves for EEM*

During the 1980's when marine mussel monitoring was being developed as a strategic part of many environmental monitoring programs, bivalves were primarily used as a chemical monitoring tool. Many still think of pollution in terms of chemical endpoints, but the ultimate concern in most environmental monitoring is adverse biological effects (Addison 1996). Waldock et al. (1996) emphasized the importance of distinguishing the use of bioindicators to quantify exposure, and bioindicators to quantify adverse biological effects. The conceptual framework using caged bivalves as an EEM monitoring tool can include both a bioaccumulation and a bioeffects component. This framework provides the basis to assess effects of chemicals from pulp and paper mill effluents and not their mere presence in various environmental compartments.

Caging bivalves facilitates monitoring individual organisms and sampling an increased matrix of space and time, in a cost-effective manner. Bivalves of a uniform size and exposure history can be strategically situated in the water column or sediments along known and/or suspected gradients of chemical contamination in three dimensional space and time (Figure 1). At each transplant location, the bivalves integrate the effects of exposure under environmentally realistic (ambient) conditions, for known periods of exposure. Biologically-integrated monitoring results are obtained by measuring bioaccumulation (e.g., tissue chemistry) for exposure at internal receptors (dose) and growth for effects (response).

Temporal & Spatial Monitoring Model for Caged Bivalves



Advantages

- Control & realism
- Outside natural populations
- Defined exposure period
- Physical or chemical gradients
- Manipulative experiments

Applications

- Site-specific differences
- Temporal/spatial variability
- Short & long-term trends
- Source identification
- Dose-response estimates

Figure 1. Temporal and spatial monitoring model for caged bivalves. Sampling space and time with bivalve transplants along gradients of chemical contamination. Two suspected sources, two sites, two depths, and two sampling intervals (beginning and end of exposure) are shown in this example

A number of investigators have emphasized the importance of an integrated assessment strategy (Chapman 1996, Hall 1996, Diamond et al. 1994, Chapman et al. 1992). An integrated sediment quality triad (SQT) was developed for assessing sediment quality using toxicity tests, sediment chemistry, and benthic community structure (Long and Chapman 1985). Their original discussion included bioaccumulation as a major element in the triad (Chapman and Long 1983), and Mearns (1985) emphasized the importance of bioaccumulation in his exposure-uptake-effects triad. Using the risk assessment framework and the triads from Chapman and Long (1983) and Mearns (1985) as templates, Salazar and Salazar (1995a, 1996, 1998) developed an *exposure-dose-response* (EDR) triad (Figure 2). The EDR triad emphasizes the importance of monitoring chemicals in external media, chemicals in tissues, and biological effects to support an integrated risk assessment strategy. The advantages and potential applications of this approach are shown in Figure 2.

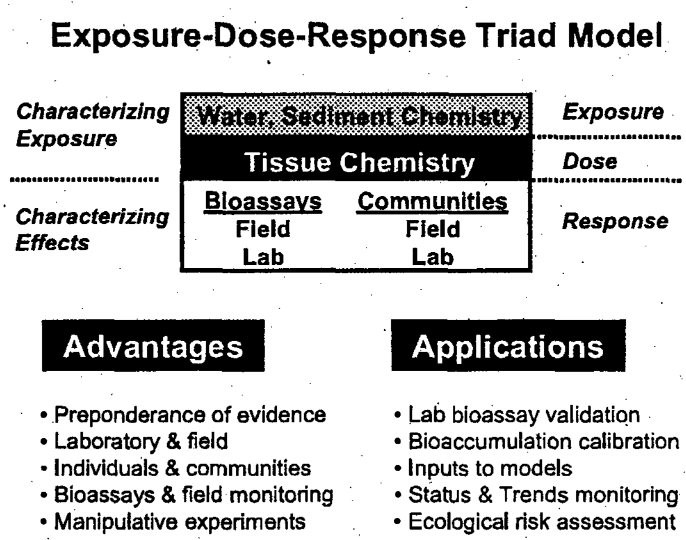


Figure 2. Exposure-dose-response triad model.
Shows the link between chemicals in the environment, in tissues, and associated adverse biological effects.

Interaction between natural factors (e.g., temperature, food availability) and effluent exposure affects bioaccumulation and growth, as shown in Figure 3. This generic model was originally developed for marine bivalve monitoring of TBT antifouling coatings (Salazar and Salazar 1996), but could be applied to most biomonitoring programs, including pulp and paper mill effluents. The key to calibrating the bivalve bioindicator is separating the effects of natural and biological factors from the effects of contaminants associated with the effluent. There is evidence showing that tissue burdens of toxic chemicals can affect biological responses such as growth and that biological responses can affect the bioaccumulation process. These interactions should be assessed to reduce the uncertainty in ecological monitoring and help interpret biological relevance.

Increased emphasis has been placed on the use of controlled field bioassays (Parrish et al. 1988, Green et al. 1985). The caged bivalve approach combines the advantages of experimental control from laboratory bioassays (i.e., defined exposure period, facilitation of effects measurements) and the environmental realism of traditional field monitoring (i.e., experiments are conducted *in-situ*). Even if bioaccumulation in natural populations of bivalves were measured to characterize exposure, it would not be clear if the tissue chemistry represented the last day, week, month, or year. This and natural factors complicate interpretation of effects measurements of wild bivalve populations. With a defined exposure period, a caged bivalve monitoring program allows more meaningful comparisons of biological effects (e.g., decreased growth, increased moisture content, decreased lipids) with respect to tissue burdens of mill-associated chemicals (i.e., internal dose) and natural versus mill-related parameters in the environmental media (i.e, external exposure). Comparisons can be made between beginning and end-of-test (i.e., temporal) and among different sites along an exposure gradient (i.e, spatial).

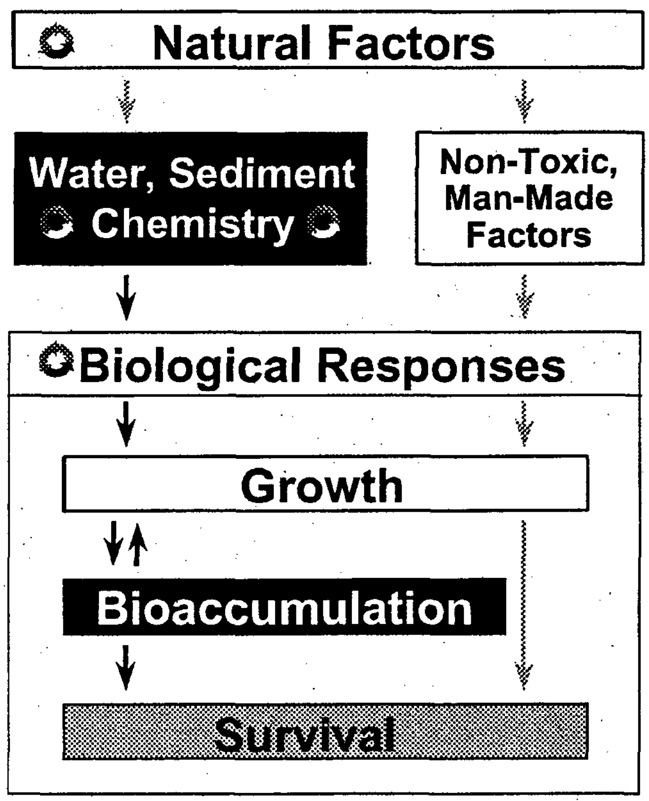


Figure 3. Natural factors/chemical monitoring model for caged bivalves. This model shows the influence of natural factors, chemicals and non-toxic man-made factors (e.g. habitat alteration) on biological responses. Natural factors, chemical concentrations, and biological responses can also be cyclical. Double arrows are shown between bioaccumulation and growth to indicate interactions.

2.6 *Refined Protocol Studies using Caged Bivalves*

Although caged bivalve studies have been used for over 10 years, the approach and field logistics continue to be refined. The following are considered significant refinements in the methodology. 1) A cage design that ensures equal exposure to all test animals; this facilitates controlled experimentation in the field and can be coupled with a well-defined exposure period. 2) A minimum size range of approximately 5 to 10 mm for the beginning-of-test bivalves reduces the variability in both exposure and effects measurements. 3) Concurrent measurements of bioaccumulation and bioeffects in the same organism provide data that can be used for both monitoring and predictive purposes (e.g., modeling). 4) Repetitive monitoring of individuals increases the discriminating power of the test. This generic, refined approach has been used in over 40 studies with over 50,000 bivalves including 15 different species in freshwater, marine, and estuarine environments from the intertidal zone to a depth of 70 meters (Salazar and Salazar 1995a,b, 1997,a,b,c, 1998, Salazar et al. 1995, Applied Biomonitoring 1999).

3.0 STUDY OBJECTIVES

3.1 Technical Objectives and Study Design

The primary objective of this pilot study was to evaluate the feasibility and scientific value of using caged mussels as an EEM tool for evaluating biological effects associated with pulp and paper mill effluents. This was accomplished in part by demonstrating that mussels survived and grew after an exposure period lasting from 68 days. The study design consisted of transplanting mussels from a clean source to areas near the mill effluent and allowing the mussels sufficient time to accumulate bioavailable substances and to respond to exposure conditions. It included multiple exposure and effects measurement endpoints in mussels as well as ancillary measurements of natural and mill-related factors that affect these endpoints (i.e., temperature, salinity, dissolved oxygen, chlorophyll-a, nutrients, particulate matter, and spent sulphite liquor). Specific objectives of this study were to measure effects and exposure endpoints in caged mussels suspended in the water column of Neroutsos Inlet along a decreasing chemical gradient originating from the Port Alice pulp mill diffuser, to test whether caged bivalves would survive and grow after a 68-day exposure period, and to determine whether exposure and effects endpoints showed differences along the exposure gradient (i.e., among stations) and if these differences could be related to the concentrations of mill effluent.

3.2 Practical Objectives — Technology Transfer

The second objective of the caged mussel pilot study was technology transfer to address concerns regarding the commercial availability of the method to the consultants employed by the mills for EEM. The following groups participated in the pilot study and received varying degrees of basic training in this field bioassay: Applied Biomonitoring, BC Research Inc. (BCRI), Environment Canada, EVS Environment (EVS), G3 Consulting Ltd., Hatfield Consultants Ltd., Institute of Ocean Sciences (IOS), Paine, Ledge & Associates, Paprican, Polaris Marine, and environmental staff of the western Pulp Limited Partnership Port Alice Mill. Polaris Marine provided the engineering and fabrication of the floats, anchors and lines, boat, diver, and other personnel for deployment and retrieval, and considerable support throughout the planning and execution of the caged mussel pilot study.

4.0 SUMMARY OF STUDY METHODS

The methods used in this *in situ* pilot study to evaluate effluent exposure by measuring bioaccumulation and bioeffects by measuring mussel growth were based on American Society for Testing and Materials (ASTM) approved standard guidelines prepared by Salazar and Salazar (2001). The method has been applied in a variety of locations; e.g. San Diego Bay, CA (Salazar and Salazar 1996), Port Valdez, AK (Applied Biomonitoring 1999), Ward Cove, AK (EVS Consultants 1996, 1997), Harbor Island, WA. (Salazar et al. 1995), Sinclair Inlet WA (URS Consultants 1994), Delaware Bay, DE (Salazar and Salazar 1997a), and the Sudbury River in Massachusetts (Salazar et al. 1996).

4.1 Mussel Measurement Endpoints

Survival and growth were the two measurement endpoints used to evaluate effects; bioaccumulation was used to evaluate exposure. Survival was measured as the number of dead individuals, separate from those that appeared to be missing. Four metrics were used to evaluate growth: whole-animal wet-weight (WAWW), tissue weight, shell length, and shell weight. Bioaccumulation was assessed using the tissue concentrations (i.e., internal dose) for the chemicals of concern (see Section 4.9.2).

Percent water and percent lipids were measured as another indicator of mussel condition. The effects endpoints were paired with tissue and water chemistry, as indicators of exposure, to help interpret the results and to demonstrate the utility of this approach as an effective monitoring tool for the EEM program.

4.2 Null Hypotheses

The pilot study was designed to test the following null hypotheses:

Null Hypothesis #1: There is no difference in growth (as estimated by changes in whole-animal wet-weight, shell length, tissue weight, or shell weight) among stations along an exposure gradient.

Null Hypothesis #2: There is no difference in accumulation of chemicals of concern (as determined by tissue burdens) among stations along an exposure gradient.

Null Hypothesis #3: There is no relationship between *other measurement endpoints* in bivalves and exposure to mill-associated chemicals.

4.3 Physical Setting and Station Locations

The Port Alice Mill, a Western Pulp Limited Partnership operation, was selected as the test site for four reasons: (1) The mill volunteered to participate in the pilot study; (2) Their Adult Fish Survey in EEM Cycle I did not provide useful information; (3) The mill is removed from other potential sources of contamination (e.g., sewage effluents and industrial discharges); and (4) Wild mussels were collected from the area in previous surveys. Representatives of the Port Alice Mill showed an interest in testing alternate monitoring techniques since fish surveys were not successful in Cycle 1. English sole, the primary sentinel species for the Adult Fish Survey were not found in either near-field or reference areas. Sufficient numbers of Slender sole were collected in the near-field area but not in the reference area. No other finfish species were collected that could be considered suitable as sentinel species for future EEM fish surveys (Hatfield Consultants Ltd. 1997).

The Port Alice Mill is located near the head of Neroutsos Inlet in the Northwestern section of Vancouver Island, BC (Figure 4). There are no other sources of industrial chemicals in the vicinity. The study area for EEM Cycle I included both near-field and far-field sampling areas (Figure 5), which were defined in the EEM pre-design phase (Hatfield Consultants Ltd. 1994). Near-field sites were located from the head of Neroutsos Inlet north to the vicinity of Teeta Creek on the western shore to Rumble Beach on the eastern shore. Far-field sites were located in outer Neroutsos Inlet (Hatfield Consultants Ltd. 1997). The following conclusions were reached during the Hatfield study regarding the effluent: (1) Dispersal is both down the inlet toward Quatsino Sound and up the inlet to the Cayeghle Creek estuary at the head of Neroutsos Inlet; (2) The highest concentrations are along the eastern shore and in mid-channel rather than along the western shore; (3) Dispersion down-inlet occurs more frequently at or near the surface; (4) Dispersion up-inlet occurs more frequently below the surface between 2 and 6 meters; and (5) Concentrations of 1 percent or greater occurred as far up-inlet as the Cayeghle Creek estuary (approximately 4 km up-inlet from the mill diffuser) and as far down-inlet as Teeta Creek (approximately 4 km down-inlet from the mill diffuser), although infrequently (Hatfield Consultants Ltd. 1997). Independent measurements by the Department of Fisheries and Oceans have confirmed the generic effluent dispersion patterns and depth distributions (Dario Stucchi, IOS, personal communication).

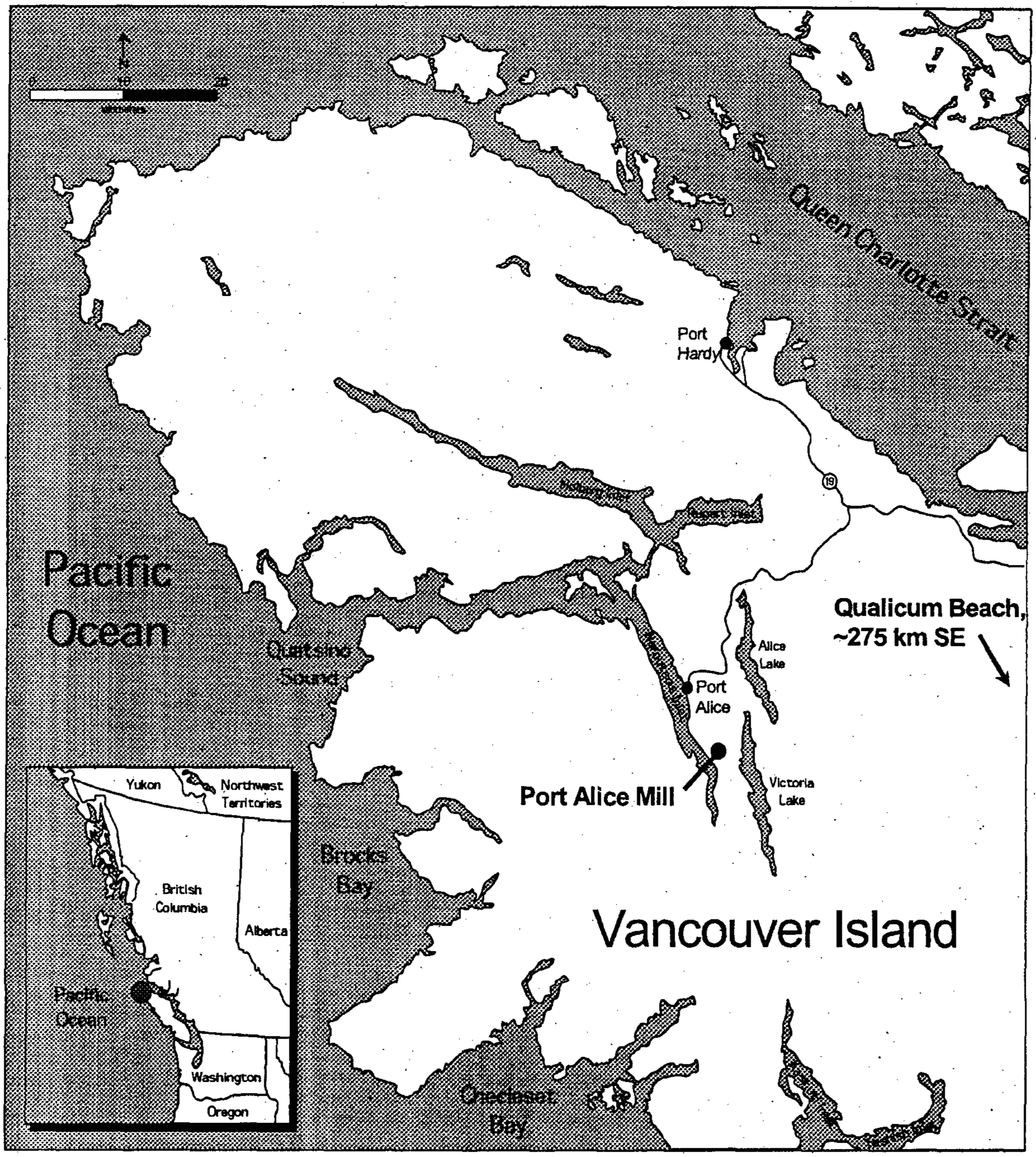


Figure 4. Site map. Shows Pacific northwest area (inset), Vancouver Island, and the location of the Port Alice pulp mill on Neroutsos Inlet.

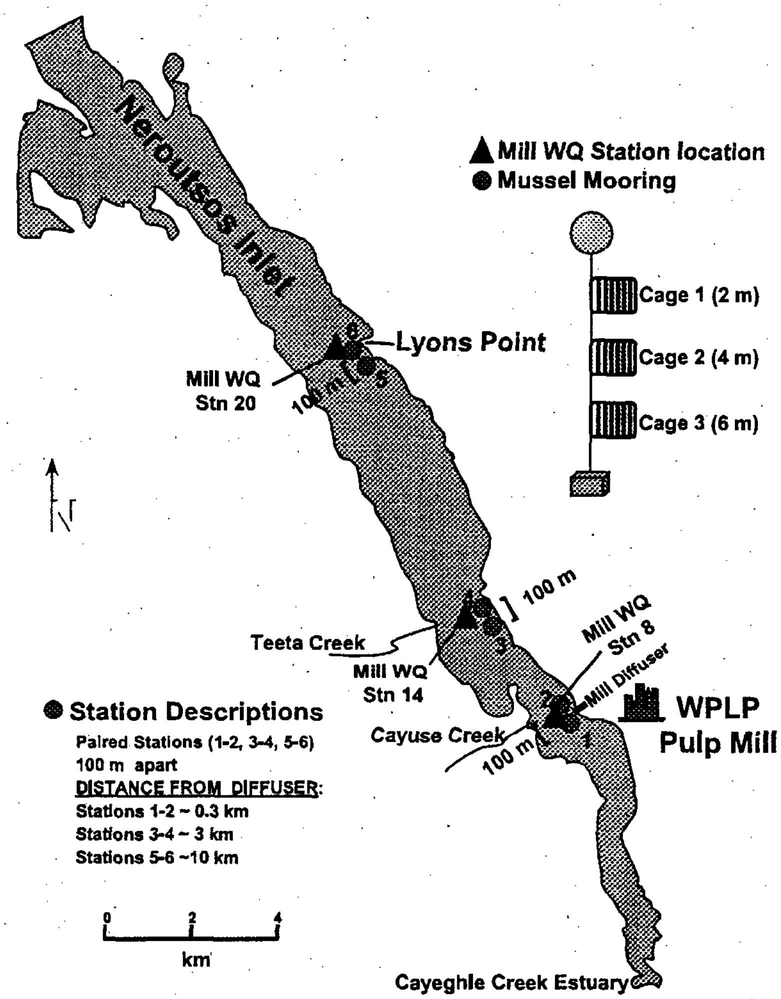


Figure 5. Neroutsos Inlet. Map showing caged mussel stations and Port Alice pulp mill.

4.4 Sampling Stations

Mussels were deployed at six stations in Neroutsos Inlet (Figures 5, 6). The stations were selected to assist in determining whether mussels could survive and grow, and show differences in exposure and effects endpoints among stations along a decreasing chemical gradient from the mill diffuser. Station numbering began at the station closest to the mill and increased with distance from the diffuser. Table 1 provides the approximate coordinates for each mussel station and the position relative to the diffuser and other mussel stations.

Table 1. Approximate coordinates and positions of mussel stations in Neroutsos Inlet.

Mussel Station	Approximate Coordinates	Position
1	50°23.10'N, 127°27.45' W	100 m SE of Mussel Station 2
2	50°23.20'N, 127°27.50' W	300 m NW from mill diffuser, across from Cayuse Creek
3	50°24.30'N, 127°28.95' W	100 m SE of Mussel Station 4
4	50°24.40'N, 127°29.00' W	3 km NW of mill diffuser, across from Teeta Creek
5	50°27.40'N, 127°31.20' W	100 m SE of Mussel Station 6
6	50°27.45'N, 127°31.00' W	10 km NW of mill diffuser, near Lyons Point

The stations were situated such that Stations 1, 3, and 5 were 100 m from Stations 2, 4, and 6, respectively so that a pair of stations (i.e., those 100 m apart) may be considered as replicates for statistical purposes. The mussel deployment stations were in the vicinity of areas previously monitored by the mill for water quality. The mill water quality stations and the mussel stations were relatively close together, but the water quality stations were located in mid-channel compared to the mussel stations which were located close to shore (Figure 5). Mussel Stations 1 and 2 corresponded to Port Alice water quality monitoring Station 8. Mussel Stations 3 and 4 corresponded to Port Alice water quality monitoring Station 14. Mussel Stations 5 and 6 corresponded to Port Alice water quality monitoring Station 20. Due to the inherent difficulties in selecting a true control or reference station, the stations furthest removed from the mill were not referred to as "control" or "reference" stations.

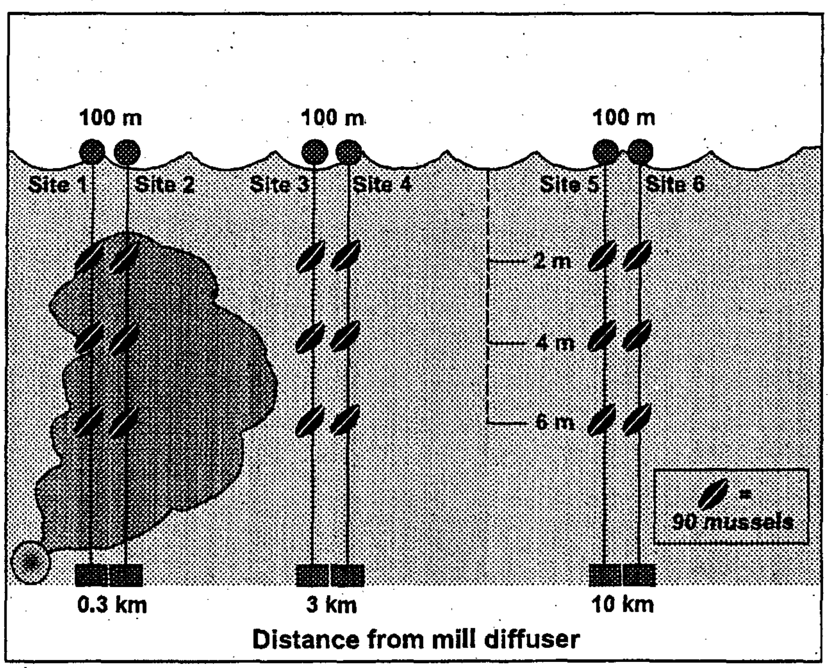


Figure 6. Port Alice caged mussel deployment configuration.

Station coordinates were identified by Hatfield Consultants and the scientific authority; station position was implemented by Polaris Marine. Cages were placed at depths of 2, 4, and 6 m below the surface to correspond to water quality sampling depths at each station and depths where the effluent plume was expected in the vicinity of the mill (Figures 5, 6). The plume distribution and sampling depths were based on preliminary discussions and data presented by Dario Stucchi (IOS) and Hatfield Consultants. The cages were anchored at approximately 15-20 m water depth. Figure 7 shows the detailed configuration of the deployment hardware.

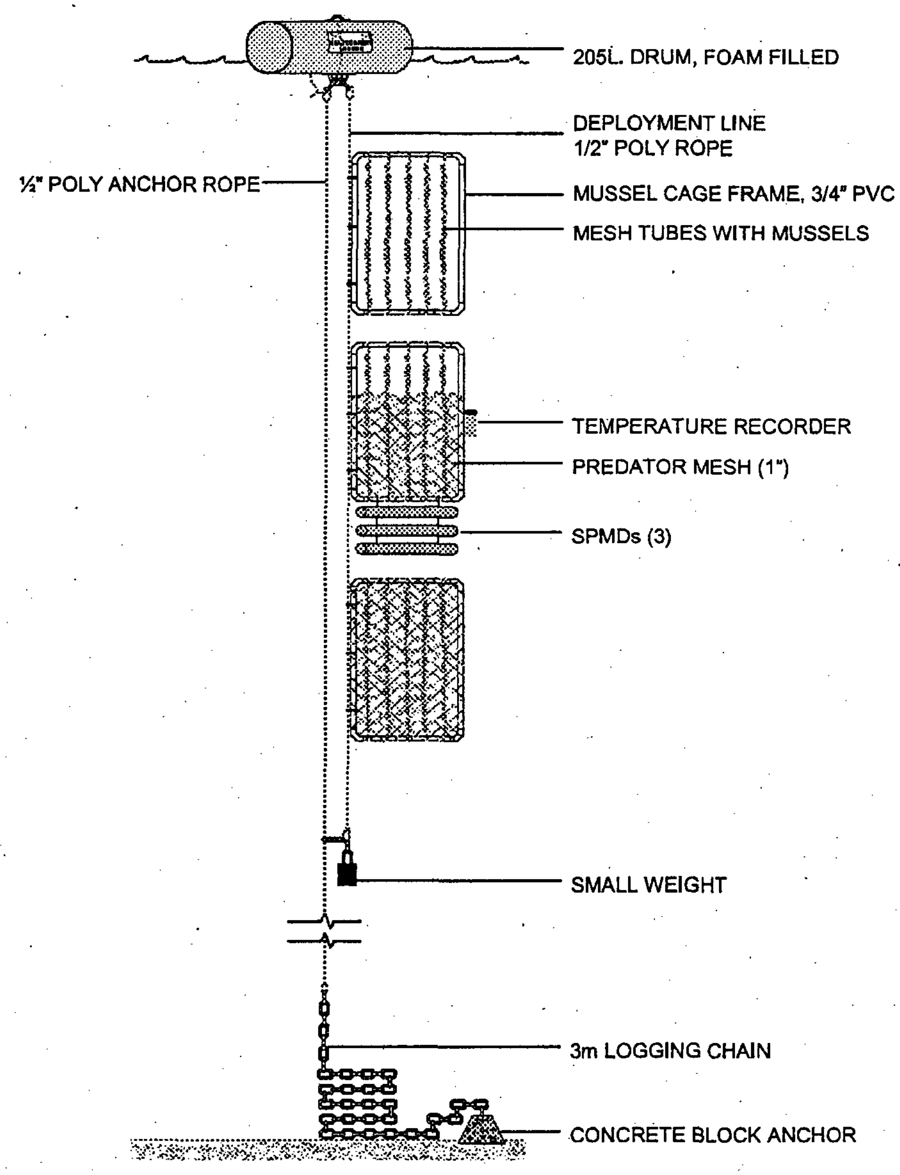


Figure 7. Deployment hardware.

4.5 Mussel Collection, Sorting, Initial Measurements and Distribution

Mussels were obtained from Island Scallops on Vancouver Island in the Georgia Strait, near Qualicum Beach, BC. This area has previously been identified as an uncontaminated source of mussels by several local experts. Approximately 7,000 mussel spat were held in tanks at the Island Scallops facility prior to purchase. These *Mytilus edulis* spat were sent from the east coast for grow out in BC. *Mytilus edulis* was used as the test species for the following reasons: (1) this species is not indigenous to the area and the spawning cycle for *Mytilus edulis* from Island Scallops is during the winter (Rob Saunders, Island Scallops, personal communication) which is outside of the deployment period; (2) *Mytilus edulis* is not affected by low salinity conditions; (3) it does not experience neoplasia and summer mortality as does *Mytilus trossulus*; (4) comparability between east coast and west coast monitoring will be facilitated; and (5) much of the laboratory research and field survey data compiled on *Mytilus edulis* can be utilized. A permit was secured for the transplant study from the BC Ministry of Agriculture, Fisheries and Food (MAFF) due to concerns regarding the potential spread of exotic species and diseases within the shellfish industry. A federal and/or provincial permit will likely be necessary for any caged bivalve monitoring conducted as part of EEM.

All beginning-of-test mussel processing activities occurred at the Ben-Bow Inn, Qualicum Beach, BC on Vancouver Island. The pre-sort was conducted on picnic tables on the back lawn (Figure 8A). The fine sort and distribution into bags was conducted in the motel room. During this pre-sorting phase, the stock supply of mussels was held without water or ice in large tubs; sorted mussels were placed into buckets containing seawater and ice packs (i.e., wet ice sealed in ziploc bags). Ice packs were used to maintain water temperatures near 13°C (Figure 8B). Data were recorded manually in addition to the digital record (Figure 8B). After sorting and distribution to the mesh bags as shown in Figures 9 and 10A, the mussels were placed into ice chests containing ice packs to minimize stress and exposure to high temperatures. Processing began at approximately 11:00 am and was finished at approximately 7:00 pm, requiring a total of about 8 hours.

Shell length (longest axis, generally from the anterior end near the beak to the leading posterior end) was used to sort and select mussels for this study. Shell length was determined with vernier calipers. Initially, mussels were pre-sorted into 1-mm size groups. Mussels provided by Island Scallops were between 2 and 30 mm shell length; with the majority < 10mm. During the presort, mussels in the 14- to 25-mm size range were retained as this size range represented a compromise between the smallest mussels with the highest growth rates and the largest mussels with the most tissue for chemical analysis, and the smallest sized mussel that would be retained by the mesh netting used in this study. Mussels with shell lengths less than 14.0 mm could slip through the mesh. The final size range (14 to 21 mm) was based on the largest number of animals in contiguous size groups. However, because there were not as many mussels within the 14 to 21 mm range as originally anticipated by Island Scallops, it was necessary reduce the number of mussels per cage from 100 to 90.

A. Rough sort before initial measurements: Sorting mussels by size group

B. Data Recording and Equilibration

1. Recording data manually as backup of digital record.

2. Water equilibration for whole-animal wet-wt.

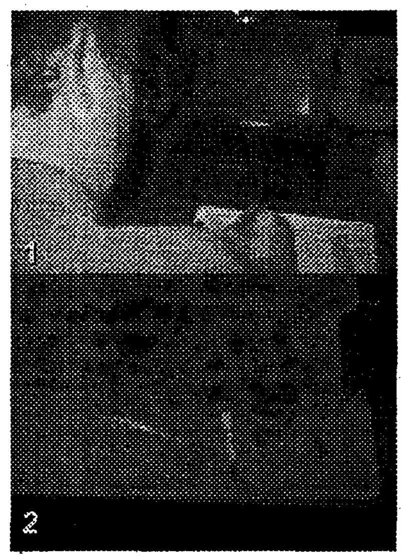


Figure 8. (A) Rough sort before initial length and whole-animal wet-weight measurements. (B) Equilibration and data recording.

Once the final size range was identified, the animals were remeasured for initial length (to the nearest 0.01 mm) with digital calipers connected to a notebook computer, weighed for initial whole-animal wet-weight (to the nearest 0.01 g) on an electronic balance also connected to a notebook computer, and distributed to the mesh tubes. The distribution process used (Salazar and Salazar 2001) ensures an even distribution of mussels across stations based on size (Figure 9). Only live animals that were fully closed, or those that closed immediately upon physical stimulation were used.

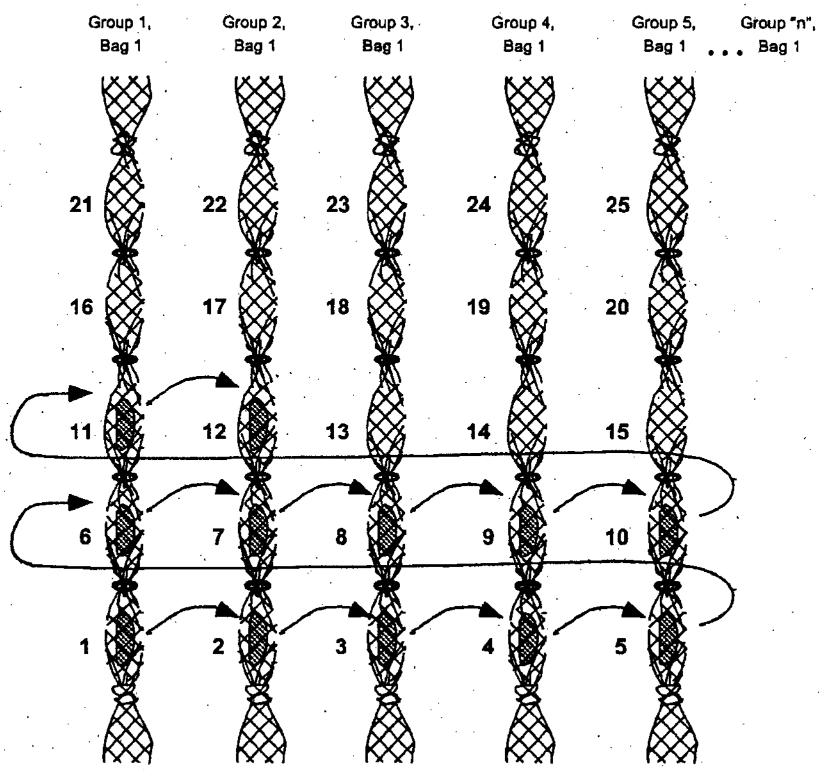


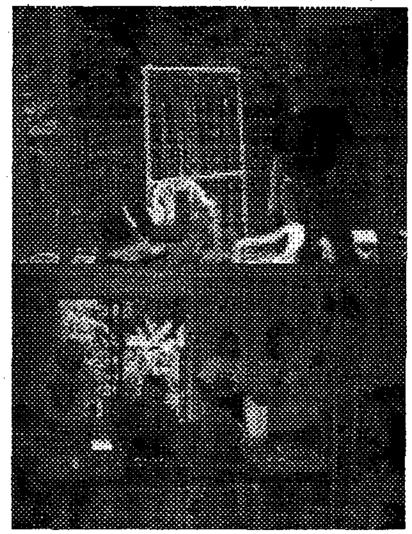
Figure 9. Mussel distribution process. Used to ensure similar sizes of mussels among cages at the beginning of the test.

Tubes of fine mesh plastic netting (approximately 10 cm diameter, 5 mm mesh size) were used to hold the mussels during the deployment period. Mussels were situated in the mesh netting with one individual per cell, for a total of 18 animals per tube. Nylon cable ties were used to create cells and separate individuals. The mesh netting permits optimum exposure to environmental conditions; sufficient space was provided between cable ties to permit valve opening, growth, and movement by the mussel. The "one animal per cell" approach was used to permit measuring growth effects on an individual-by-individual basis. Five tubes, each containing 18 mussels, were prepared for each cage, for a total of 90 mussels per cage. Three cages were prepared for each station. Three replicates of 130 mussels each were used to measure time zero (T_0) percent moisture, percent lipids and concentrations of mill-related chemicals. Samples were frozen prior to chemical analysis. Initial tissue weights (g-wet) and shell weights (g-wet) were obtained from a subsample of these 390 mussels. However, due to the small size and time constraints, only 15 mussels were used to estimate initial tissue and shell weights.

After all beginning-of-test processing was completed, the bagged mussels were taken by row boat to approximately 300 m offshore where they were attached to a mooring overnight holding. The mussels were continuously submerged in seawater during this holding period.

A. Initial Measurement Setup

Mesh bags, PC, balance, calipers



Measurement teams

<u>2 teams of 3 each</u>
Recorder
Stuffer
Cable-tie installer

B. Caging Bagged Mussels

Attaching mussel bags to PVC frames
Attaching predator mesh

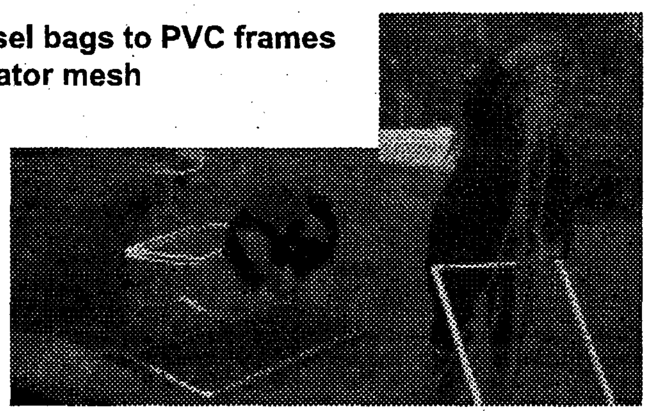


Figure 10. A. Initial measurement set up. B. Caging bagged mussels: attaching bagged mussels to PVC frames and attaching predator mesh around caged mussels.

4.6 Deployment

The next morning, the bagged mussels were retrieved and placed in an ice chest containing packs of wet ice. During all phases of transport, mussels were held in this ice chest without seawater to eliminate stress associated with insufficiently oxygenated water. Packs of ice were used to maintain cool temperatures and minimize temperature stress. Mussels were transported via aircraft to Port Hardy they by car to Port Alice where the mesh tubes containing mussels were removed from the ice chest and secured to rigid polyvinyl chloride (PVC) frames with large nylon cable ties and rope (Figure 7, 10B). The PVC frames, or mussel cages, were wrapped with heavy-duty plastic mesh (approximately 2.5 cm mesh size) to discourage predators. A total of 18 cages were prepared, three to be deployed at each of six stations. While on shore, three cages were attached to each deployment line with large nylon cable ties so that the cages were situated at 2-, 4- and 6-m below the surface. One deployment line was prepared for each station. The temperature monitors and semipermeable membrane devices (SPMDs) were also attached to the deployment arrays at this time (see Sections 4.8.1 and 4.8.4, respectively). The completed deployment arrays were then taken to the stations by boat where they were attached to previously deployed anchors and buoy lines (Figure 11A). All deployment activities were assisted by Polaris Marine.

4.7 Test Duration

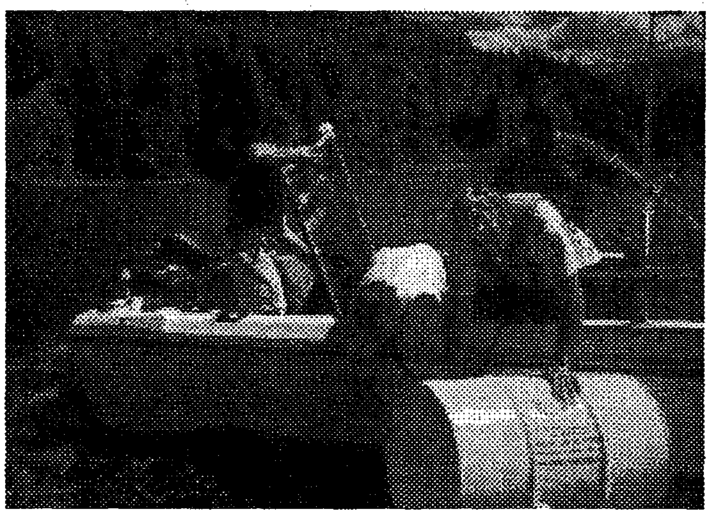
Caged mussels were deployed on August 7, 1997 and retrieved on October 14, 1997, representing a 68-day (9.7-week) exposure period. The length of the exposure period was based on time constraints imposed by the approaching mussel spawning period, decreasing temperatures and weather conditions, and the fact that the mill was shutting down for routine maintenance. The mill shut down on October 11, 1997, during the last week of exposure although an additional day of water quality monitoring was conducted on October 14, 1997, the day the mussel cages were retrieved.

4.8 Supplemental Measurements

4.8.1 Water Temperature

The effects of environmental factors on mussel growth and reproduction have been well documented. Temperature and food availability are probably the most critical variables. Water temperatures at the 4-m depth for each station were recorded at approximate 15 minute intervals over the 68-day period using one continuously recording temperature monitor (HoboTemp, Onset Computer Corporation) per station. The temperature monitor was attached to the deployment line adjacent to the middle mussel cage (Figure 7). To test for differences in temperature at the three deployment depths, two additional temperature monitors were attached to the array for Station 3; one at the 2-meter depth and one at the 6-meter depth. At the end of the test, temperature data were downloaded from the logging devices.

A. Deploying Cages from Floats: 2, 4, & 6 meters



B. Preparing Mussels for End-of-Test Measurements

1. Removing mussels from bags
2. Removing tissues

Figure 11. A. Deploying cages from floats at the beginning of the test. B. Preparing mussels for end-of-test measurements.

4.8.2 *Water Quality Measurements*

The project obtained additional water quality data (i.e., temperature, dissolved oxygen (DO), spent sulphite liquor (SSL), colour, and salinity) from the Port Alice Mill as part of their routine monitoring program. These parameters were measured mid-channel near the caged mussel stations twice a week between August 5 and October 14, 1997. Water Quality Stations 8, 14, and 20 were situated near mussel Stations 1-2, 3-4, and 5-6, respectively.

Other water quality parameters were measured by Environment Canada at the beginning (August 7-9, 1997), middle (September 16, 1997), and end of the exposure period (October 14-15, 1997). Salinity, dissolved oxygen (DO), chlorophyll-a, nutrients, total organic carbon, and total suspended solids (TSS) were measured at each caged mussel station and cage depth. DO was measured *in situ* with a YSI DO meter (model 58) and probe on a 50-m cable. Water for the remaining analyses was collected with a 3-L van Dorn water sampler deployed from the side of the vessel at Mussel Stations 1-2, 3-4, and 5-6. Sample handling and analytical methods for each parameter are provided in Appendix L.

4.8.3 *Semipermeable Membrane Devices*

SPMDs were deployed at each station to provide additional water chemistry data to compare with mussel tissue chemistry and evaluate the utility of lipid bags as an indicator of exposure. Recent studies have shown that SPMDs preferentially accumulate the lower molecular weight organic chemicals (Peven et al. 1996, Prest et al. 1992, 1995a,b). Some studies have shown that there may be less variability in the SPMDs and that the response may be more linear (Huckins et al. 1990, 1993). However, in every case where accumulation by SPMDs and mussels has been compared, the results have been different, suggesting that the two systems are measuring different compartments of the exposure pathway (Peven et al. 1996, Prest et al. 1992, 1995a,b). For example, chemicals sorbed on suspended particulate matter are more easily accumulated by mussels than through the SPMD membrane. Also, chemicals measured from SPMDs may not be detected in mussel tissues or measured at lower concentrations because some chemicals may be metabolized by mussels or not biologically available. No results were obtained from the SPMDs because at some points, the bags developed holes and the sampling media was lost.

4.9 Retrieval and End-of-test Measurements

4.9.1 *Mussel Growth Measurements*

All mussel cages were successfully retrieved on October 14, 1997, after a 68-d exposure. Retrieval operations were assisted by Polaris Marine. The cages were detached from the deployment lines and the individual bags removed from the PVC frames. The mussels were placed into an ice chest containing bags of ice and transported by aircraft to the IOS facility in

Sidney, BC. As during deployment, the mussels were transported without seawater. Due to adverse weather conditions, the mussels did not arrive at the IOS facility until 4 pm. Four workers measured roughly half the animals during the next 10 hours. End-of-test measurements included removing the test mussels from the bags, placement in compartmentalized trays to keep track of their order in the cage, measurement of shell length, WAWW, tissue removal (Figure 11), and measurement of soft tissue weight and shell weight for each live individual. The same instruments and units were used as at the start of the test (see Section 4.5). The unprocessed mussels, still in their mesh bags, were suspended off the IOS pier for overnight holding and processed the next day. Approximately 10 more hours were required to complete the end-of-test processing. The number of dead and missing animals was recorded for each station. Dead animals were identified by empty shells; mussels were determined "missing" if there was no individual in the assigned cell in the mesh tube. For purposes of data analysis, dead and missing were both considered dead.

For each cage, tissues from all live mussels (i.e., only animals that closed upon physical stimulation) were pooled for chemical analysis. Gaping animals, with intact tissues that did not close upon physical stimulation were considered dead. The pooled tissues from one cage formed one replicate for chemical analysis. All equipment (i.e., shucking knives and the aluminum foil covering the cutting boards) used during tissue extraction was thoroughly cleaned before processing a new batch (i.e., replicate) according to the following process: wash with Liquinox, rinse with hot tap water, rinse with acetone, rinse with hexane. Prior to processing a station, all staff thoroughly washed their hands with Liquinox. Gloves were not worn during the shucking process to reduce the potential for injury due to slippery hands and handling wet mussels. Thin-bladed stainless steel knives were used to slice the mussels in half and remove the soft tissues. After severing the interior muscles, the stainless steel knife was used to separate soft tissue from shell. The severed mussel was held in such a position that the excess liquid was allowed to drain. The soft tissues were kept on the shell during extraction and after complete separation. The shell was used as a "holding dish" until tissue weights were made. A weigh pan was made from decontaminated aluminum foil. The soft tissues were placed on the weigh pan using the original shucking knife.

When all tissues of a "replicate" were weighed, the tissues were transferred from the weigh pan to certified clean sample jars provided by IOS. The sample jar was tightly capped, affix with a prepared label, and placed in the refrigerator. The aluminum foil weigh boat and cutting board cover were discarded after all tissues of a given replicate were shucked and weighed. All shucking equipment was decontaminated before proceeding to next sample. Tissue samples were homogenized within 24 hours by IOS personnel. A small portion (i.e., 7 to 9 g) was removed from each sample to analyze percent moisture and lipid content. The rest of the sample was then frozen at -20°C until chemical analysis.

4.9.2 Chemical Availability Assessment

To quantify the bioavailability of chemicals related to mill effluent, the soft tissues of exposed mussels were chemically analyzed for PAHs, plant sterols, and resin acids. The target compounds for this study were:

- PAHs: Retene, Fichtelite.
- Sterols: Cholesterol, Campesterol, beta-Sitosterol, Stigmasterol.
- Resin Acids: Pimaric acid, Sandaracopimaric acid, Isopimaric acid, Palastric acid, Abietic acid, Neoabietic acid, Dehydroabietic acid (DHA).

The chemical analyses, including the percent lipids and percent moisture, were done by Dr. Michael Ikonomou (IOS). Although there was a question whether these particular chemicals would be accumulated at elevated concentrations within mussel tissues, mussels have accumulated many hydrophobic organic chemicals by a factor of 1,000,000 (McCarty and Mackay 1993). Therefore, where mill-related chemicals have not been detected in water or other environmental compartments at elevated concentrations, they could still be accumulated by the mussels.

IOS developed a high resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS)-based method to detect resin acids, sterols, retene and fichtelite from a single 10g aliquot of a tissue sample.

Prior to this study, IOS had established analytical methods for the determination of sterols, retene, and resin acids in effluents and in sediments. For each sample two analyses were performed; one for the determination of resin acids and one for the determination of sterols and retene. These involved different extraction, sample-workup protocols and HRGC/HRMS analysis. For the HRGC/HRMS analysis the resin acids were derivatized to their corresponding esters using diazomethane and the sterols were derivatized to their corresponding ethers using trimethylsilyl (TMS). Analytical methods for sterols in tissues are summarized in Appendix K.

However, a fully functional HRGC/HRMS-based analytical method for the determination of these compounds in tissue samples was unavailable. The IOS lab has an liquid chromatography/electrospray ionization-mass spectrometry (LC/ESI-MS) method for the analysis of DHA and metabolites in fish bile and plasma, but this method does not provide enough specificity to determine all the target analytes in a single extract. The development of a comprehensive HRGC/HRMS-based analytical method to simultaneously determine all the target analytes from of a single aliquot of a tissue sample was necessitated by the minimum amount of sample available for a large number of chemical analysis.

4.10 Data Analyses

The statistical models applicable to this field study are shown in Figure 12. The model, a nested design, involves three locations, each with two replicated moorings and each mooring contained three cages situated at depths of 2, 4, and 6 m below the surface. A nested analysis of variance (ANOVA) is the statistical approach for this design. However, to meet the study objective of evaluating the feasibility and scientific value of using caged mussels as an EEM monitoring tool for evaluating biological effects, the design was simplified for the effects portion of the analysis by considering only individual moorings (i.e., stations) and paired moorings (i.e., paired stations). A one-way ANOVA (alpha = 0.05) was used to test for differences among stations and paired moorings. If statistically significant differences were found, Student-Newman-Keuls Multiple Comparison test was used to identify the different stations.

4.10.1 Effects Data

Biological effects from exposure to chemicals potentially discharged in the Port Alice pulp mill effluent were assessed by comparing mussel survival and changes in growth among individual stations and among pooled (paired) stations. Four primary metrics were used to assess growth: shell length, WAWW, tissue weight (wet tissue weights were converted to dry tissue weights using the percent water measured on each pooled sample by cage), and shell weight. Additional metrics used to evaluate mussel condition included condition index, percent water, and percent lipids. Condition indices (CI) were calculated as dry tissue weight/shell weight. Only WAWW and shell length were measured for each individual at the start of the test. The change (i.e., increase or decrease) over time could only be determined for these two metrics. Using a 68-day or 9.7 week exposure period, growth rates were calculated as:

$$(\text{Measurement}_{\text{final}} - \text{Measurement}_{\text{initial}})/9.7 \text{ weeks.}$$

At the beginning of the test, mussels were of a uniform size. Therefore, it was assumed that the average tissue weight and shell weight were also similar among stations. Based on this assumption, the end-of-test tissue weights and shell weights were evaluated for statistical differences. Differences were assumed to have occurred during the test period.

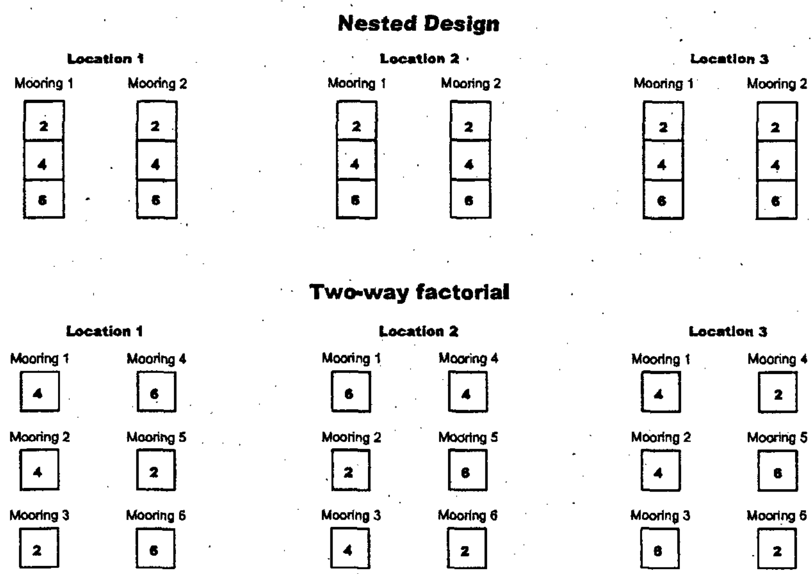


Figure 12. Diagram of statistical models showing nested and factorial designs.

4.10.2 Water Quality, Tissue Chemistry, and Water Temperature Data

The water quality and tissue chemistry data were analyzed by individual stations, by pooled (paired) stations, and by depth using a one-way ANOVA. In some analyses, it was necessary to perform the Kruskal-Wallis test, the non-parametric equivalent to the ANOVA, because of the limited amount of water data collected. A multiple range test (Student-Newman-Keuls for parametric; Dunn for non-parametric) was used to identify the different stations.

Water temperatures at each station were recorded at approximate 15 minute intervals over the 68-day period using one *in situ* computerized data logger per station (HoboTemp, Onset Instruments). Data were downloaded from the logging devices using the instruments' data recovery software. The following three null hypotheses were tested:

1. There was no difference in daily average temperature by stations,
2. There was no difference in the weekly temperature range by stations,
3. There was no difference in daily average temperature by depth.

Daily average temperatures and weekly temperature ranges were calculated for Stations 1 through 6 using the temperature data at the 4-m depth. These data were used to answer hypotheses 1 and 2. Differences in temperature with depth were evaluated by calculating daily average temperatures at the 2- and 6-m depths for Station 3 only. A one-way ANOVA or its non-parametric equivalent, the Kruskal-Wallis test, was used to test for differences. A multiple range test (Student-Newman-Keuls for parametric; Dunn for non-parametric) was used to identify the different stations. All analyses were conducted at alpha = 0.05.

4.10.3 Environmental Relevance

In addition to analyzing the mussel survival and growth data for statistical differences, the data were assessed for environmental significance using the guidelines described in the proposal and work plan for the *in situ* monitoring study with caged mussels at Port Valdez (Applied Biomonitoring 1999). Using a weight-of-evidence approach, adverse environmental effects are more probable if, in addition to the treatment being statistically less than the reference, the absolute difference between treatment and reference is $\geq$ 10-25 percent. Because no stations were considered "control" or "reference" stations, the data were compared to each other to determine if differences could be detected and if relationships could be established with distance from the mill. Regression analyses were used to confirm the relationship between sets of variables.

5.0 RESULTS

The results of the pilot study are provided below. Separate summaries are provided for survival (Table 2), mussel effects metrics (Table 3A), and statistical results (Table 3B). Data reports for raw measurements and calculated mussel metrics are provided as Appendices A through I. Raw tissue chemistry results are provided as Appendix J.

5.1 Data Quality Review

Based on external appearance, the mussels showed relatively rapid growth rates and good condition. Based on the appearance of internal tissues, most tissue masses were relatively large and some individuals showed developing reproductive tissues. All mussel growth data were usable for this report. For shell length, outliers would be end-of-test measurements that resulted in negative shell growth. For whole-animal wet-weight, outliers would be end-of-test measurements that resulted in a weight loss of more than 0.5 g-wet. No data were considered outliers, and none were excluded from the data set. All tissue chemistry and water quality data were considered usable for this report. The temperature data were "trimmed" at the beginning and end of each data file so that the monitoring period was the same for each station.

5.2 Mussel Survival

End-of-test survival was based on the number of individuals present at the end of test compared to the number deployed; the number not present were either missing or dead. In most studies, the shells of dead individuals usually remain within the mesh netting allowing an accurate account of mortality. It is possible that some of the smaller live mussels or small empty mussel shells slipped through the mesh netting during the early stages of deployment making it difficult to distinguish between dead and missing individuals at the end of the test. In Appendices A through I, missing and dead individuals are designated "M" and "D" respectively. Based on the number of live mussels present at the end of the test, survival was high and ranged from 91 to 99 percent for individual cages (Table 2). Average survival by station ranged from 93 to 96 percent, with a grand mean of approximately 95 percent. The survival data were analyzed for differences among stations using a contingency table. No significant differences (alpha = 0.05) were detected.

Table 2. End-of-test percent survival for mussels (N = 270 at T_0)

Depth	Sta 1	Sta 2	Sta 3	Sta 4	Sta 5	Sta 6	Grand Mean
2 m	91	94	94	94	94	94	
4 m	93	97	93	96	96	93	
6 m	96	96	99	93	96	97	
Mean	**93%**	**96%**	**96%**	**94%**	**95%**	**95%**	**94.8%**
Std. Dev.	2.2%	1.1%	2.9%	1.1%	0.6%	1.7%	
Total N	249	256	258	254	257	255	

Table 3A. Summary of mussel metrics used to quantify effects – by station and pooled station

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Grand Mean	Pooled Stations Sta 1 & 2	Sta 3 & 4	Sta 5 & 6
Initial Length (mm)										
mean	**17.05**	**17.03**	**17.03**	**17.08**	**17.05**	**16.97**	**17.0**			
min	14.77	14.62	14.63	14.56	14.64	14.65				
max	20.98	20.96	20.93	20.79	20.65	20.92				
stdev	1.49	1.42	1.51	1.44	1.48	1.49				
count	270	270	270	270	270	270				
2SE	0.181	0.173	0.184	0.175	0.180	0.181				
EOT Length (mm)										
mean	**29.15**	**28.66**	**29.56**	**29.63**	**29.85**	**29.84**	**29.4**	**28.9**	**29.6**	**29.8**
min	16.00	16.37	14.96	17.79	15.90	17.07		16.0	15.0	15.9
max	39.58	38.05	38.76	39.56	39.57	39.03		39.6	39.6	39.6
stdev	4.77	4.72	4.60	4.48	4.82	4.63		4.7	4.5	4.7
count	249	256	258	254	257	255		505	512	512
2SE	0.605	0.589	0.573	0.562	0.602	0.579		0.42	0.40	0.42
Percent Change	71.1	68.4	73.7	73.2	75.0	76.1	75.2			
Length Growth Rate (mm/wk)										
mean	**1.24**	**1.20**	**1.29**	**1.28**	**1.31**	**1.32**	**1.27**	**1.22**	**1.28**	**1.32**
min	0.03	0.13	0.01	0.10	0.10	0.13		0.03	0.01	0.10
max	2.15	2.05	2.10	2.03	2.35	2.22		2.15	2.10	2.35
stdev	0.47	0.46	0.46	0.45	0.48	0.44		0.46	0.45	0.46
count	249	256	258	254	257	255		505	512	512
2SE	0.060	0.057	0.058	0.056	0.060	0.056		0.041	0.040	0.041
Initial WAWW (g-wet)										
mean	**0.50**	**0.49**	**0.50**	**0.50**	**0.50**	**0.49**	**0.50**			
min	0.27	0.26	0.27	0.27	0.24	0.24				
max	0.99	0.91	0.99	0.95	0.99	0.96				
stdev	0.15	0.13	0.15	0.14	0.15	0.14				
count	270	270	270	270	270	270				
2SE	0.018	0.016	0.018	0.018	0.018	0.017				
EOT WAWW (g-wet)										
mean	**2.67**	**2.55**	**2.79**	**2.80**	**2.89**	**2.93**	**2.77**	**2.61**	**2.80**	**2.91**
min	0.44	0.51	0.35	0.57	0.45	0.53		0.44	0.35	0.45
max	5.33	5.81	5.26	5.99	5.93	6.46		5.81	5.99	6.46
stdev	1.02	1.00	1.05	1.02	1.16	1.07		1.01	1.04	1.12
count	249	256	258	254	257	255		505	512	512
2SE	0.129	0.125	0.131	0.128	0.145	0.134		0.090	0.092	0.099
Percent Change	457	433	477	474	490	511	498			
WAWW Growth Rate (mg/wk)										
mean	**224**	**212**	**236**	**236**	**246**	**251**	**234**	**218**	**236**	**248**
min	6	22	2	14	13	11		6	2	11
max	488	505	470	534	543	597		505	534	597
stdev	101	98	103	101	115	105		99.4	102.4	110.1
count	249	256	258	254	257	255		505	513	512
2SE	12.8	12.2	12.9	12.6	14.3	13.1		8.8	9.0	9.7
EOT Tissue Weight (g-wet)										
mean	**0.69**	**0.66**	**0.72**	**0.66**	**0.74**	**0.81**	**0.71**	**0.68**	**0.69**	**0.78**
min	0.06	0.15	0.08	0.14	0.15	0.15		0.06	0.08	0.15
max	1.37	1.47	1.62	1.48	1.72	1.89		1.47	1.62	1.89
stdev	0.25	0.24	0.29	0.25	0.33	0.32		0.25	0.27	0.32
count	249	256	258	254	256	256		505	512	512
2SE	0.032	0.030	0.036	0.031	0.041	0.040		0.022	0.024	0.029

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Grand Mean	Pooled Stations Sta 1 & 2	Sta 3 & 4	Sta 5 & 6
EOT Tissue Weight (g-dry)										
mean	**0.142**	**0.136**	**0.150**	**0.147**	**0.168**	**0.180**	**0.154**	**0.139**	**0.149**	**0.174**
min	0.01	0.03	0.02	0.03	0.03	0.04		0.012	0.017	0.032
max	0.28	0.31	0.32	0.31	0.36	0.44		0.309	0.325	0.443
stdev	0.05	0.05	0.06	0.06	0.07	0.08		0.052	0.061	0.073
count	249	256	258	254	256	256		505	512	512
2SE	0.01	0.01	0.01	0.01	0.01	0.01		0.005	0.005	0.006
EOT Shell Weight (g-wet)										
mean	**0.91**	**0.91**	**0.98**	**0.94**	**0.96**	**1.00**	**0.95**	**0.91**	**0.96**	**0.98**
min	0.15	0.22	0.17	0.23	0.20	0.14		0.15	0.17	505
max	1.73	1.84	1.89	1.98	1.90	2.03		1.84	1.98	0.005
stdev	0.31	0.31	0.32	0.31	0.33	0.33		0.31	0.32	0.34
count	248	256	257	254	256	252		504	511	508
2SE	0.040	0.039	0.040	0.039	0.042	0.042		0.03	0.03	0.03
Condition Index (dry)										
mean	**0.157**	**0.15**	**0.151**	**0.155**	**0.173**	**0.178**	**0.16**	**0.154**	**0.153**	**0.175**
min	0.047	0.092	0.060	0.078	0.089	0.091		0.047	0.060	0.089
max	0.418	0.237	0.291	0.308	0.297	0.309		0.418	0.308	0.300
stdev	0.035	0.025	0.036	0.032	0.034	0.038		0.030	0.034	0.035
count	248	256	257	254	255	252		503	511	506
2SE	0.0045	0.0031	0.0045	0.0040	0.0042	0.0047		0.0027	0.0030	0.0031
Percent Lipids										
mean	**0.97**	**1.04**	**1.14**	**1.15**	**1.54**	**1.41**	**1.21**	**1.00**	**1.14**	**1.48**
min	0.94	1.03	1.01	0.94	1.38	1.17		0.94	0.94	1.17
max	1.00	1.05	1.35	1.47	1.82	1.68		1.05	1.47	1.82
stdev	0.03	0.01	0.18	0.28	0.24	0.26		0.05	0.21	0.23
count	3	3	3	3	3	3		6	6	6
2SE	0.035	0.012	0.212	0.327	0.281	0.295		0.04	0.17	0.19
Percent Water										
mean	**79.41**	**79.54**	**79.18**	**77.61**	**77.04**	**78.05**	**78.47**	**79.5**	**78.4**	**77.5**
min	79.12	79.00	77.61	73.83	74.95	76.54		79	73.83	74.95
max	79.62	80.33	80.58	79.52	78.88	79.43		80.33	80.58	79.43
stdev	0.26	0.70	1.49	3.28	1.98	1.45		0.48	2.43	1.65
count	3	3	3	3	3	3		6	6	6
2SE	0.300	0.806	1.723	3.783	2.283	1.673		0.39	1.99	1.34

Table 3B. Summary of statistical results on mussel metrics used to quantify effects By pooled station

Mussel Growth Endpoint	Pooled Station 1-2	Pooled Station 3-4	Pooled Station 5-6
Weight Growth Rate (mm/wk)	218	236	248
Length Growth Rate (mm/wk)	1.22	1.28	1.32
EOT WAWW (g-wet)	2.61	2.80	2.91
EOT Length (mm)	28.9	29.6	29.8
EOT Shell Weight (g-wet)	0.91	0.96	0.98
EOT Tissue Weight (g-dry)	0.139	0.149	0.174
EOT Tissue Weight (g-wet)	0.68	0.69	0.78
EOT Condition Index	0.154	0.153	0.175
EOT Percent Lipid	1.00	1.14	1.48
EOT Percent Water	79.5	78.4	77.5

Stations with a continuous underline = statistically similar grouping; no underline = station only similar to itself

5.3 *Shell Length*

At the start of the test, individual shell lengths ranged from 14.6 to 21.0 mm; mean shell length for each of the six stations was between 17.0 and 17.1 mm (Table 3; Appendix A). Shell length increased at all stations during the exposure period, with an approximate 75.2 percent increase in mean length across stations. End-of-test shell lengths for individuals ranged from 15.0 to 39.6 mm; mean by station ranged from 28.7 to 29.9 mm (Figure 13; Table 3; Appendix B); the overall. The lowest mean end-of-test lengths were found for mussels deployed at Station 2; the highest were at Stations 5 and 6. The end-of-test shell length data were suitable for a parametric analysis without transformation. End-of-test shell lengths were statistically similar for mussels at most stations: shell length at Station 2 was less than at Stations 5 and 6.

The end-of-test length data were also analyzed on a paired station basis using parametric statistics. End-of-test lengths at Pooled Stations 1 and 2 were significantly smaller than at Pooled Stations 3 and 4 and Pooled Stations 5 and 6. Respective mean end-of-test lengths for these three paired stations were 28.9, 29.6, and 29.8 mm (Table 3).

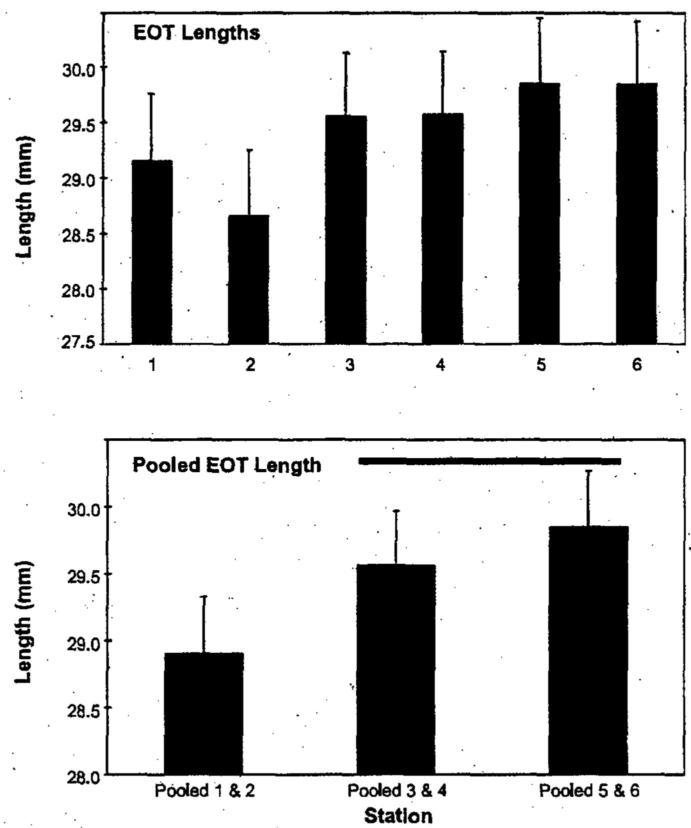


Figure 13. End-of-test lengths by station and pooled station. Statistically similar stations are grouped with a horizontal bar.

Summary of Statistical Analyses: End-of-Test Lengths

Station Comparisons

Station:	1	2	3	4	5	6
Length (mm)	29.2	28.7	29.6	29.6	29.9	29.8
29.2	1					
28.7		2			*	*
29.6			3			
29.6				4		
29.9					5	
29.8						6

Pooled Station Comparisons

Station:	1-2	3-4	5-6
Length (mm)	28.9	29.6	29.8
28.9	1-2	*	**
29.6		3-4	
29.8			5-6

* = $p < 0.05$
** = $p < 0.01$
*** = $p < 0.001$

The lowest length growth rate, 1.20 mm/wk, was found for mussels deployed at Station 2; the highest, 1.32 mm/wk, at Station 6 (Figure 14, Table 3). The length growth rate data (Appendix C) were analyzed with parametric tests without transformation. Length growth rates were statistically similar for mussels at most stations: length growth rate at Station 2 was less than at Stations 5 and 6.

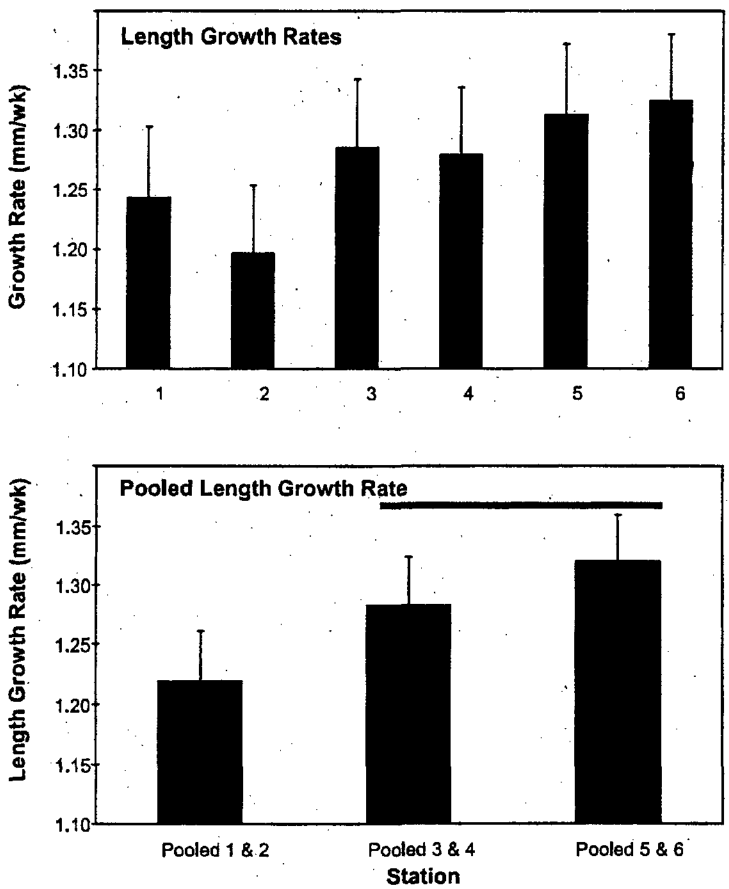


Figure 14. Length growth rates by station and pooled station. Statistically similar stations are grouped with a horizontal bar.

The length growth rate data were also analyzed on a paired station basis using parametric statistics. Length growth rates at Pooled Stations 1 and 2 were significantly less than at Pooled Stations 3 and 4 and Pooled Stations 5 and 6. Respective mean length growth rates for these three paired stations were 1.22, 1.28, and 1.32 mm/wk (Table 3).

Summary of Statistical Analyses: End-of-Test Length Growth Rates

Station Comparisons

Station:	1	2	3	4	5	6
Δ Length mm/wk	1.24	1.20	1.29	1.28	1.31	1.32
1.24	1					
1.20		2			*	*
1.29			3			
1.28				4		
1.31					5	
1.32						6

Pooled Station Comparisons

Station:	1-2	3-4	5-6
Δ Length mm/wk	1.22	1.28	1.32
1.22	1-2	*	**
1.28		3-4	
1.32			5-6

* = $p < 0.05$
** = $p < 0.01$
*** = $p < 0.001$

5.4 *Whole-animal Wet-weight (WAWW)*

At the start of the test, individual WAWW ranged from 0.24 to 0.99 g; mean whole-animal wet-weight by station ranged from 0.49 to 0.50 g-wet (Table 3, Appendix D). WAWW increased at all stations during the exposure period, with an average increase in WAWW across stations of approximately 500 percent. The range in end-of-test WAWW by individuals was 0.35 to 6.46 g-wet; mean end-of-test WAWW by station ranged from 2.55 to 2.93 g-wet (Figure 15, Table 3, Appendix E). The lowest mean end-of-test WAWWs were found for mussels deployed at Station 2; the highest were at Station 6. The end-of-test WAWW data were suitable for a parametric analysis without transformation. End-of-test WAWWs were statistically similar for mussels at most stations: WAWWs at Station 2 were significantly less than at Stations 3, 4, 5, and 6.

The end-of-test WAWW data were also analyzed on a paired station basis using parametric statistics. End-of-test WAWWs at Pooled Stations 1 and 2 were significantly less than at Pooled Stations 3 and 4 and Pooled Stations 5 and 6. Respective mean end-of-test WAWWs for these paired stations were 2.61, 2.80, and 2.91 g-wet (Table 3).

The lowest mean WAWW growth rates, 212 mg/wk, were found for mussels deployed at Station 2; the highest, 251 mg/wk, at Station 6 (Figure 16; Table 3). WAWW growth rates (Appendix F) were analyzed with parametric tests without transformation. Statistically significant differences were found between the following stations: WAWW growth rates at Station 1 were significantly lower than at Station 6, and WAWW growth rates at Station 2 were significantly lower than at all stations, except Station 1.

WAWW growth rates were also analyzed on a paired station basis using parametric statistics.

WAWW growth rates at Pooled Stations 1 and 2 were significantly less than at Pooled Stations 3 and 4 and Pooled Stations 5 and 6. Respective mean WAWW growth rates for these three paired stations were 218, 238, and 248 mg/wk.

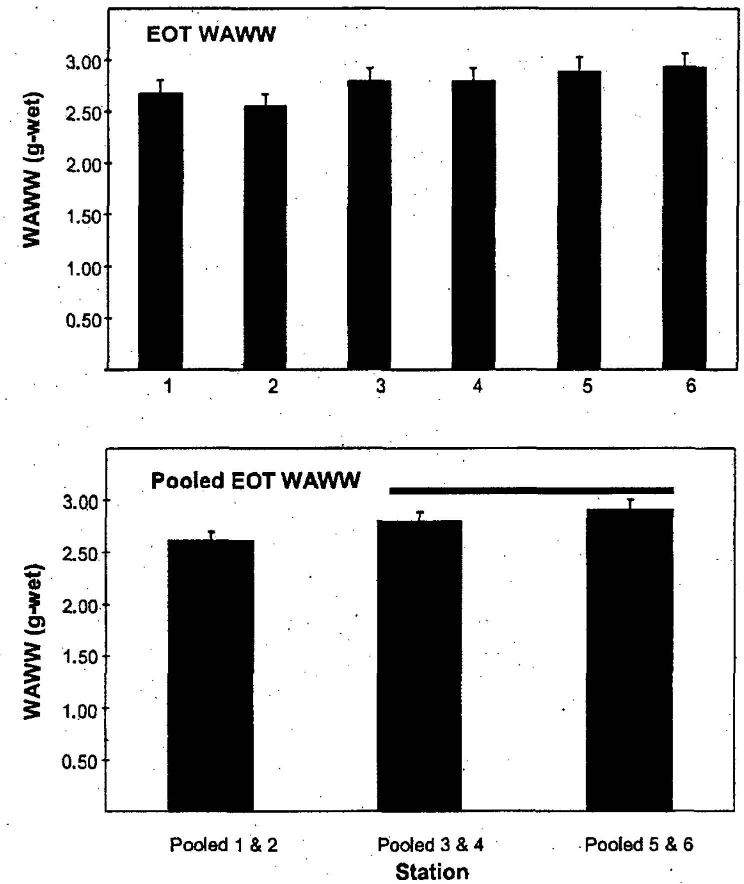


Figure 15. End-of-test whole-animal wet-weights (WAWWs) by station and pooled station. Statistically similar stations are grouped with a horizontal bar.

Summary of Statistical Analyses: End-of-Test WAWW (g-wet)

Station Comparisons

Station:	1	2	3	4	5	6
WAWW	2.67	2.55	2.79	2.80	2.89	2.93
2.67	1					
2.55		2	*	*	**	***
2.79			3			
2.80				4		
2.89					5	
2.93						6

Pooled Station Comparisons

Station:	1-2	3-4	5-6
WAWW	2.61	2.80	2.91
2.61	1-2	**	***
2.80		3-4	
2.91			5-6

* = $p < 0.05$
** = $p < 0.01$
*** = $p < 0.001$

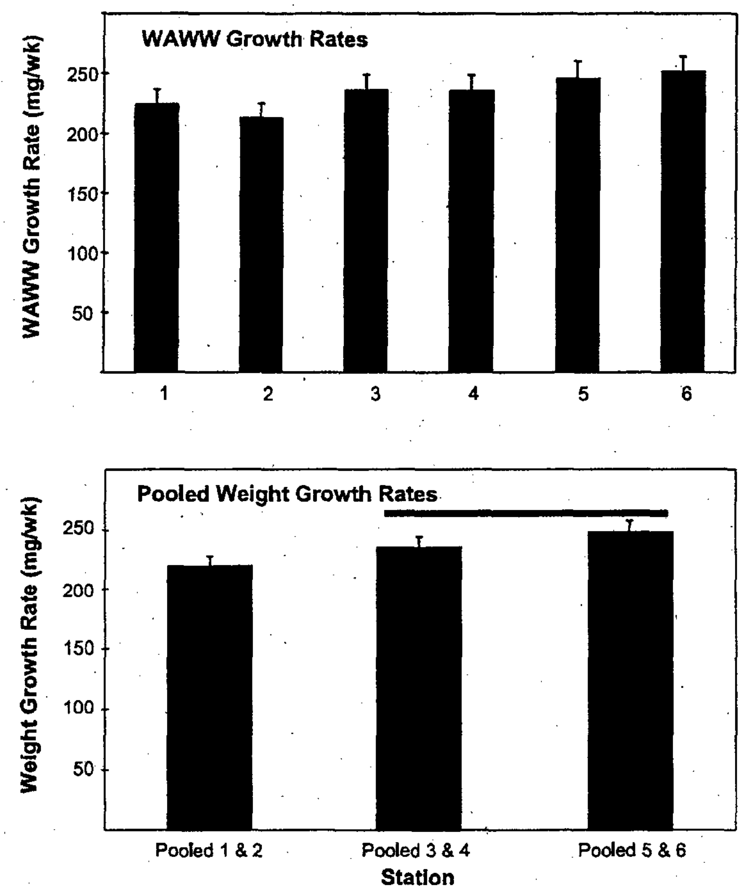


Figure 16. Whole-animal wet weight (WAWW) growth rates by station and pooled station. Statistically similar stations are grouped with a horizontal bar.

Summary of Statistical Analyses: End-of-Test WAWW Growth Rates

Station Comparisons

Station:	1	2	3	4	5	6
WAWW GR mg/wk	224	212	236	236	246	251
224	1					*
212		2	*	*	**	***
236			3			
236				4		
246					5	
251						6

Pooled Station Comparisons

Station:	1-2	3-4	5-6
WAWW GR mg/wk	218	236	248
218	1-2	**	***
238		3-4	
248			5-6

* = $p < 0.05$
** = $p < 0.01$
*** = $p < 0.001$

5.5 *End-of-Test Tissue Weights*

Wet Tissue Weights

Mean wet tissue weight at the start of the test was estimated at 0.24 g-wet. This estimate was based on the tissue weights measured for the mussels used for T_0 tissue chemistry analyses. End-of-test wet tissue weights by individuals ranged from 0.06 to 1.89 g-wet; mean tissue weights by station ranged from 0.66 to 0.81 g-wet (Figure 17A, Table 3, Appendix G). The lowest mean end-of-test wet tissue weight, 0.66 g-wet, was found at Stations 2 and 4; the highest, 0.81 g-wet, at Station 6. The end-of-test wet tissue weight data were suitable for a parametric analysis without transformation. Several statistical differences among stations were found for end-of-test tissue weights: Station 1 ≠ Station 6; Station 2 ≠ Stations 3, 5, and 6; Station 3 ≠ Stations 4, 6; Station 4 ≠ Stations 5, 6; and Station 5 ≠ Station 6.

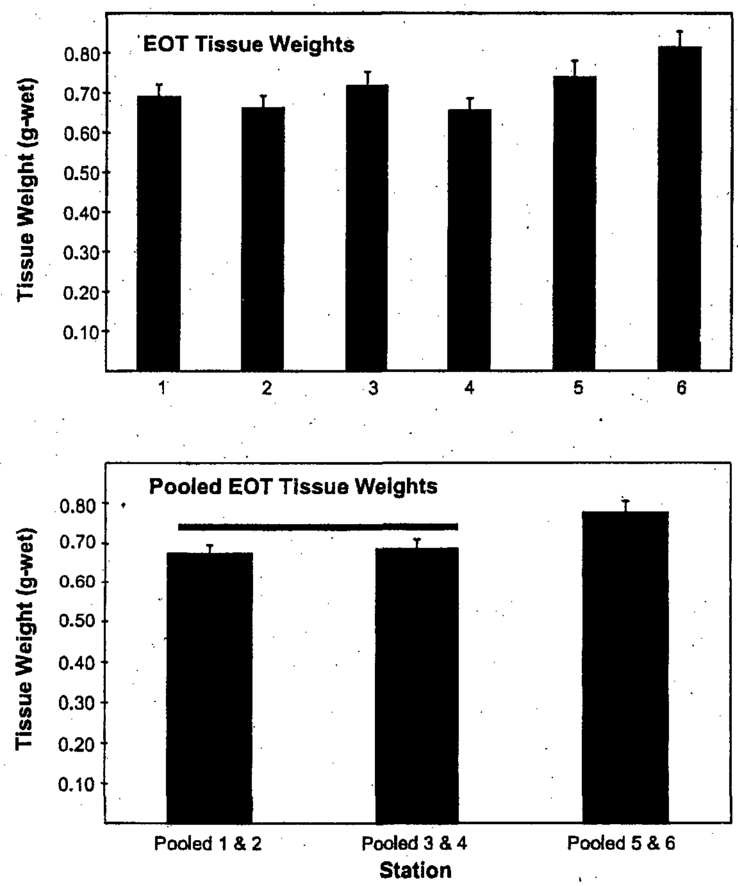


Figure 17A. End-of-Test (EOT) wet tissue weights (g-wet) by station and pooled station. Statistically similar stations are grouped with a horizontal bar.

The wet tissue weight data were also analyzed on a paired station basis using parametric statistics. EOT tissue weights at Pooled Stations 1 and 2 and Pooled Stations 3 and 4 were significantly lower than those at Pooled Stations 5 and 6. Respective mean EOT tissue weights for these three paired stations were 0.68, 0.69, and 0.78 g-wet (Table 3).

Summary of Statistical Analyses: End-of-Test Wet Tissue Weights (TW)

Station Comparisons

Station:	1	2	3	4	5	6
TW (g-wet)	0.69	0.66	0.72	0.66	0.74	0.81
0.69	1					***
0.66		2	*		**	***
0.72			3	*		**
0.66				4	**	***
0.74					5	**
0.81						6

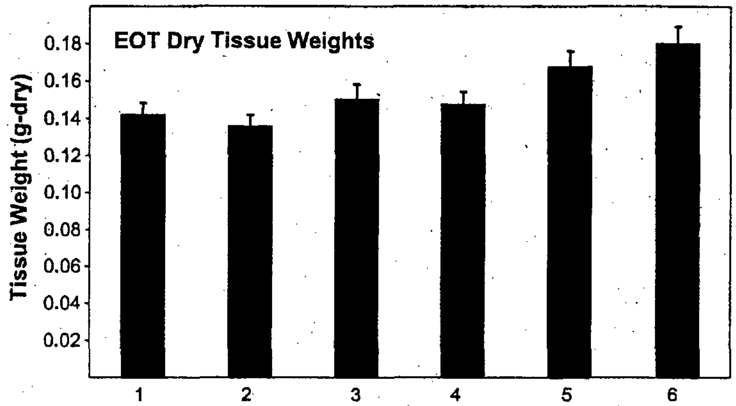
Pooled Station Comparisons

Station:	1-2	3-4	5-6
TW (g-wet)	0.68	0.69	0.78
0.68	1-2		***
0.69		3-4	***
0.78			5-6

* = $p < 0.05$
** = $p < 0.01$
*** = $p < 0.001$

Dry Tissue Weights

End-of-test dry tissue weights by individuals ranged from 0.01 to 0.44 g-dry; mean tissue weights by station ranged from 0.136 to 0.180 g-dry (Figure 17B, Table 3). The lowest mean end-of-test dry tissue weight was found at Station 2 and the highest at Station 6. The end-of-test wet tissue weight data were suitable for a parametric analysis without transformation. Several statistical differences among stations were found for end-of-test dry tissue weights: Station 1 ≠ Stations 5, 6; Station 2 ≠ Stations 3, 5, and 6; Station 3 ≠ Stations 5, 6; Station 4 ≠ Stations 5, 6; and Station 5 ≠ Station 6.



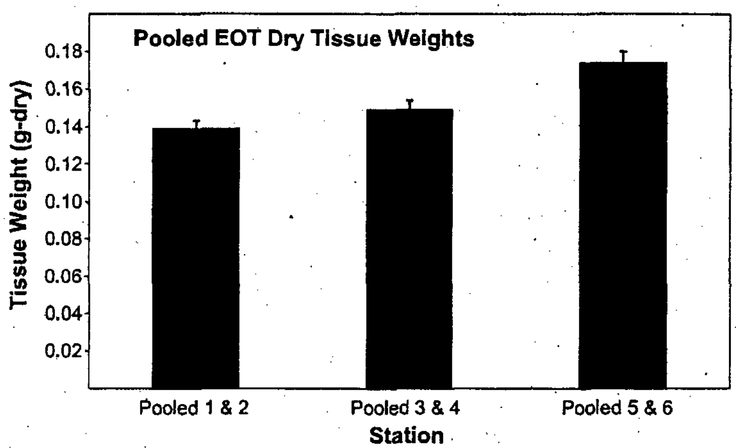


Figure 17B. End-of-Test (EOT) dry tissue weights (g-dry) by station and pooled station. Statistically similar stations are grouped with a horizontal bar.

The dry tissue weight data were also analyzed on a paired station basis using parametric statistics. EOT dry tissue weights were significantly different among all Pooled Stations. Respective mean EOT tissue weights for these three paired stations were 0.139, 0.149, and 0.174 g-dry (Table 3).

Summary of Statistical Analyses: End-of-Test Dry Tissue Weights (TW)

Station Comparisons

Station:	1	2	3	4	5	6
TW (g-dry)	0.142	0.136	0.150	0.147	0.168	0.180
0.142	1				***	***
0.136		2	*		**	***
0.150			3		**	***
0.147				4	***	***
0.168					5	*
0.180						6

Pooled Station Comparisons

Station:	1-2	3-4	5-6
TW (g-dry)	0.139	0.149	0.174
0.139	1-2	*	***
0.149		3-4	***
0.174			5-6

* = $p < 0.05$
** = $p < 0.01$
*** = $p < 0.001$

5.6 *End-of-Test Shell Weights*

T_0 shell weight for the mussels used for tissue chemistry analyses was not measured because of time constraints. End-of-test shell weights for individuals ranged from 0.15 to 2.03 g; mean end-of-test shell weights by station ranged from 0.91 to 1.01 g (Figure 18; Table 3, Appendix H). The lowest mean end-of-test shell weight was found for mussels deployed at Station 2; the highest at Station 6. The end-of-test shell weight data were suitable for a parametric analysis without transformation. Shell weights for mussels at Stations 1 and 2 were significantly lower than at Station 6.

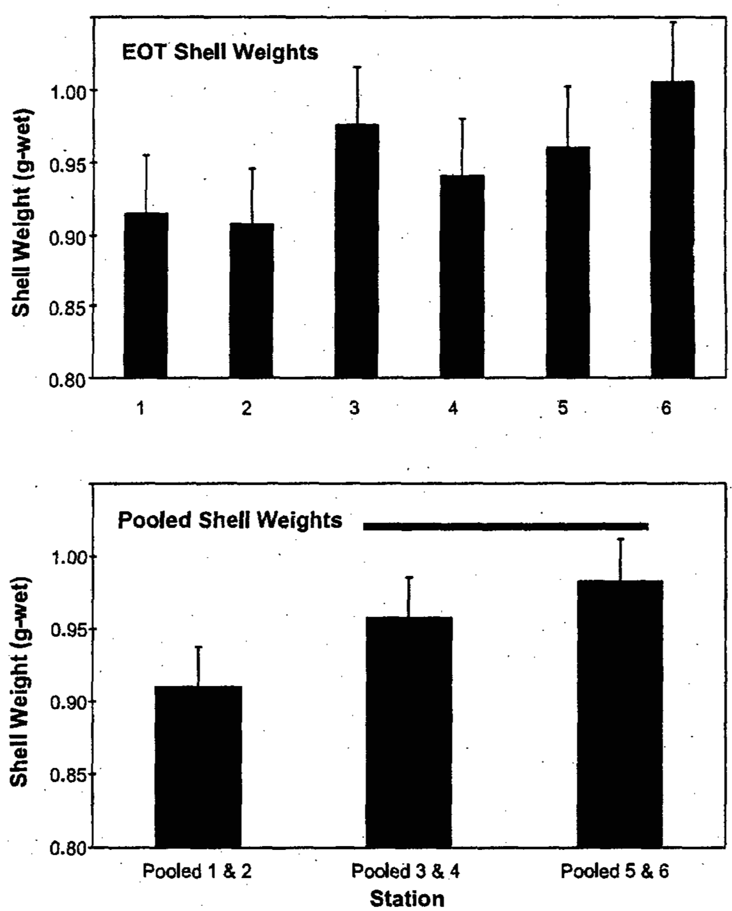


Figure 18. End-of-test (EOT) shell weight (g-wet) by station and pooled station. Statistically similar stations are grouped with a horizontal bar.

The shell weight data were also analyzed on a paired station basis using parametric statistics. EOT shell weights at Pooled Stations 1 and 2 were significantly lower than those at Pooled Stations 3 and 4 and at Pooled Stations 5 and 6. Respective mean EOT shell weights for these three pooled stations were 0.91, 0.96, and 0.98 g (Table 3).

Summary of Statistical Analyses: End-of-Test Shell Weights (SW)

Station Comparisons

Station:	1	2	3	4	5	6
SW (g-wet)	0.92	0.91	0.98	0.94	0.96	1.01
0.92	1					*
0.91		2				**
0.98			3			
0.94				4		
0.96					5	
1.01						6

Pooled Station Comparisons

Station:	1-2	3-4	5-6
SW (g-wet)	0.91	0.96	0.98
0.91	1-2	*	**
0.96		3-4	
0.98			5-6

* = p < 0.05
** = p < 0.01
*** = p < 0.001

5.7 *End-of-Test Condition Index*

Condition indices (Table 3, Appendix I) were calculated to determine if the combined relationship between tissue and shell metrics provide further insight into exposure and effects with depth and distance away from the mill. Condition index decreased slightly within a short distanced from the mill, and then gradually increased with distance in a regular stepwise fashion (Figure 19). Results of statistical analyses indicated that condition indices for mussels at Stations 1, 2, 3, and 4 were significantly lower than at Stations 5 and 6.

The pooled condition index shows the same statistical grouping as the wet tissue and percent lipid analyses (see Sections 5.5 and 5.9, respectively). This suggested that condition index provided a potentially more integrative index than the other mussel metrics and justified the use of this metric.

Summary of Statistical Analyses: End-of-Test Condition Index (CI)

Station Comparisons

Station:	1	2	3	4	5	6
CI	0.157	0.150	0.151	0.155	0.173	0.177
0.157	1				***	***
0.150		2			***	***
0.151			3		***	***
0.155				4	***	***
0.173					5	
0.177						6

Pooled Station Comparisons

Station:	1-2	3-4	5-6
CI	0.154	0.153	0.175
0.154	1-2		***
0.153		3-4	***
0.175			5-6

* = p < 0.05
** = p < 0.01
*** = p < 0.001

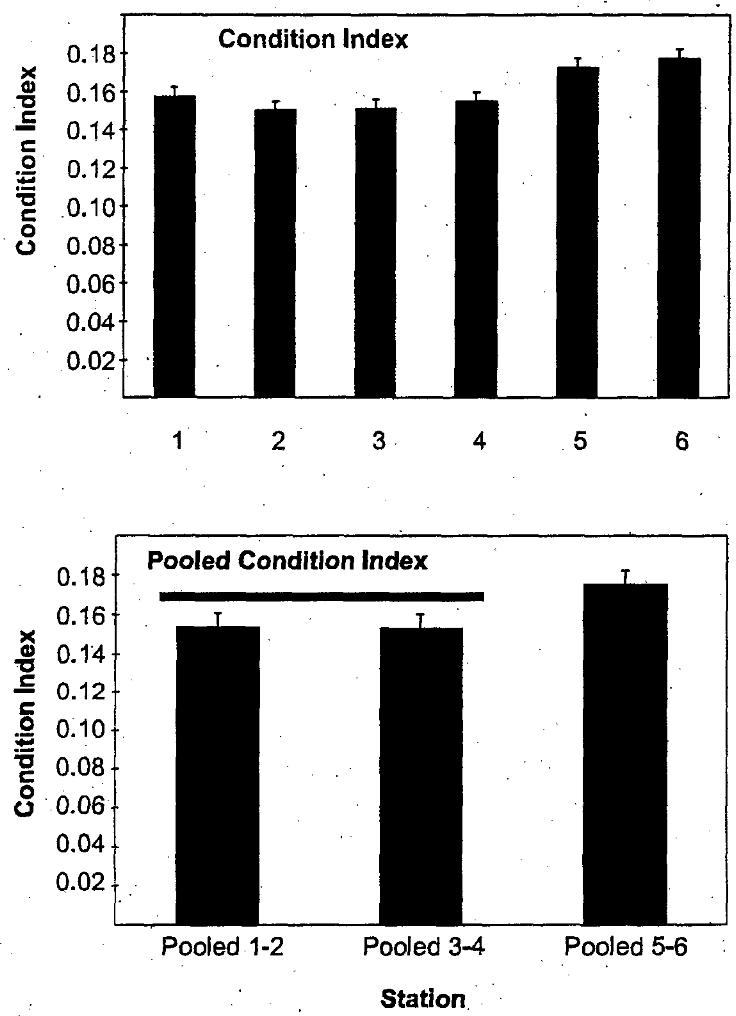


Figure 19. Condition index by station and pooled station. Statistically similar stations are grouped with a horizontal bar.

5.8 *Percent Lipids*

At the start of the test, estimated percent lipid per individual was 1.20 (Appendix J). Percent lipids measured in soft tissues at the end of the test ranged from 0.94 to 1.82; means by station ranged from 0.97 to 1.54% (Figure 20; Table 3). The lowest mean percent lipids were found for mussels deployed at Station 1; the highest were at Station 5. The end-of-test percent lipid data were suitable for a parametric analysis without transformation. Percent lipids for mussels deployed at Station 1 were significantly lower than at Station 5.

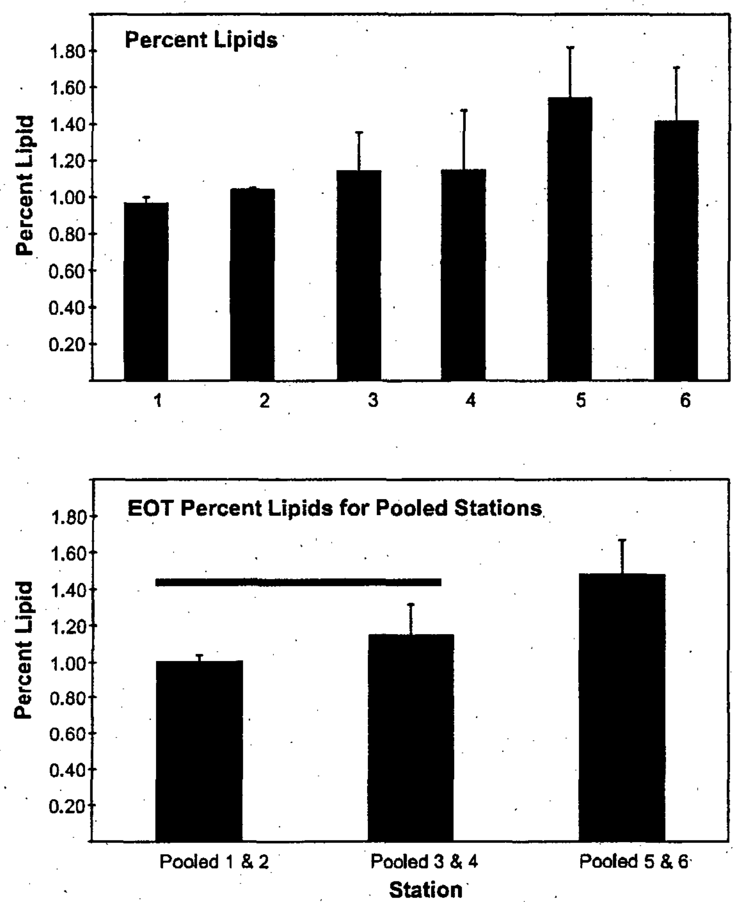


Figure 20. Percent lipids by station and pooled station. Statistically similar stations are grouped with a horizontal bar.

The percent lipid data were also analyzed on a paired station basis using parametric statistics. End-of-test percent lipids for mussels deployed at Pooled Stations 1 and 2 were significantly less than at Pooled Stations 3 and 4 and Pooled Stations 5 and 6. Respective mean end-of-test percent lipids for these three paired stations were 1.00, 1.14, and 1.48.

Summary of Statistical Analyses: End-of-Test Percent Lipids

Station Comparisons

Station:	1	2	3	4	5	6
% Lipids	0.97	1.04	1.14	1.15	1.54	1.41
0.97	1				*	
1.04		2				
1.14			3			
1.15				4		
1.54					5	
1.41						6

Pooled Station Comparisons

Station:	1-2	3-4	5-6
% Lipids	1.00	1.14	1.48
1.00	1-2		**
1.14		3-4	*
1.48			5-6

* = $p < 0.05$
** = $p < 0.01$
*** = $p < 0.001$

5.9 *Percent Water*

At the start of the test, estimated percent water per individual was 81.3 (Appendix J). Percent water measured in soft tissues at the end of the test ranged from 73.8 to 80.6; means by station ranged from 77.0 to 79.5 (Figure 21; Table 3). The lowest mean percent water was found for mussels deployed at Station 5; the highest at Station 2. The end-of-test percent water data were suitable for a parametric analysis without transformation. There was no statistically significant difference in end-of-test percent water among stations.

The percent water data were also analyzed on a paired station basis using parametric statistics. There was no statistically significant difference in end-of-test percent water among pooled stations. Respective mean end-of-test percent water for the pooled stations were 79.5, 78.4, and 77.5.

Summary of Statistical Analyses: End-of-Test Percent Water

Station Comparisons

Station:	1	2	3	4	5	6
% Water	79.4	79.5	79.2	77.6	77.0	78.1

NO DIFFERENCES AMONG STATIONS

Pooled Station Comparisons

Station:	1-2	3-4	5-6
% Water	79.5	78.4	77.5

NO DIFFERENCES AMONG STATIONS

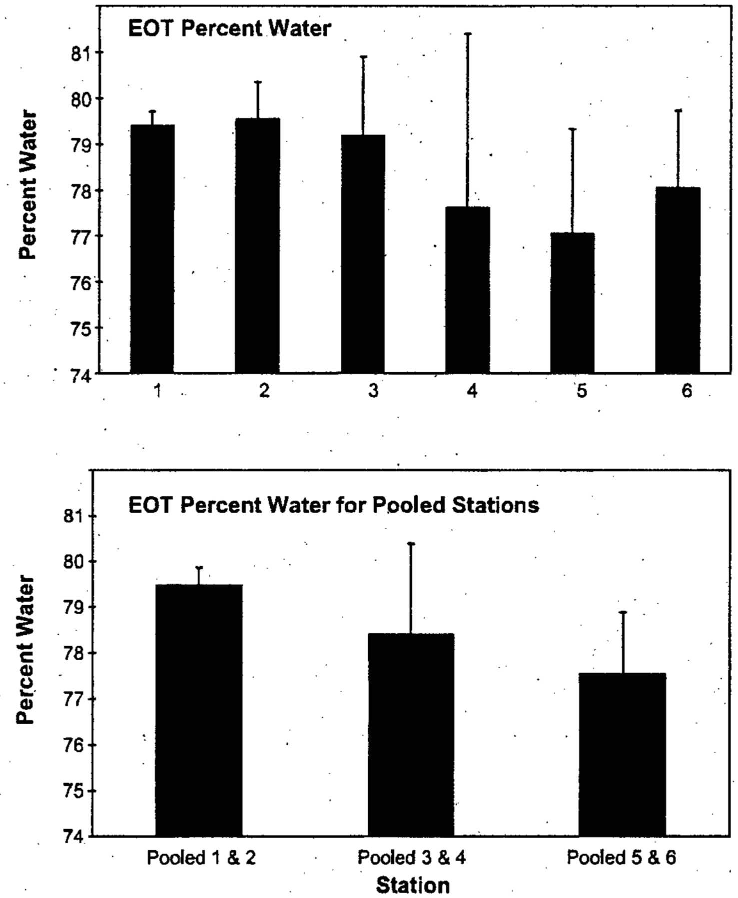


Figure 21. End-of-test (EOT) percent water by station and pooled station.

5.10 Tissue Chemistry

The mussel tissues were analyzed for five plant sterols (i.e., cholesterol, campesterol, stigmasterol, B-sitosterol, and D6-cholesterol surrogate). The only plant sterol that showed elevated concentrations, content, and a statistically significant relationship with distance from the diffuser was campesterol (Figures 22 through 26). For each of the other plant sterols, the end-of-test concentrations were significantly lower than measured in the mussels before deployment, and there were no consistent trends in end-of-test concentrations with distance from the diffuser. The dry weight concentrations of each of these chemicals measured in mussel tissues at each station are summarized in Table 4. The dry weight contents are summarized in Table 5. Raw wet-weight tissue chemistry and converted dry-weight data are provided in Appendix J.

Table 4. Mean concentration (ug/g-dry wt) of plant sterols in mussel tissues by station

Station	% Moisture	% Lipid	Campesterol	Cholesterol	Stigmasterol	B-sitosterol	D6-Cholesterol Surrogate
T_0	81.3	1.20	28.4	135.8	14.9	55.5	0.5
Station 1	79.4	0.97	44.4	83.3	5.6	31.1	0.3
Station 2	79.5	1.04	44.2	79.8	5.7	32.4	0.4
Station 3	79.2	1.14	25.6	83.8	5.7	27.2	0.3
Station 4	77.6	1.15	19.2	55.8	5.2	23.9	0.3
Station 5	77.0	1.54	19.9	87.7	6.7	35.7	0.3
Station 6	78.0	1.41	16.7	78.3	5.8	32.1	0.4
Detection limit (ng/g)	na	na	15	10	5	5	

Table 5. Mean content (ug/animal dry weight) of plant sterols in mussel tissues by station

Station	Dry Tissue (g)	Campesterol	Cholesterol	Stigmasterol	B-sitosterol	D6-Cholesterol Surrogate
T_0	0.045	1.3	6.1	0.7	2.5	0.02
Station 1	0.14	6.4	12.1	0.8	4.5	0.05
Station 2	0.14	5.9	10.8	0.8	4.4	0.05
Station 3	0.15	4.0	13.5	0.9	4.3	0.04
Station 4	0.15	2.7	7.9	0.7	3.4	0.05
Station 5	0.17	3.3	14.3	1.1	5.9	0.06
Station 6	0.18	2.9	13.2	1.0	5.4	0.07

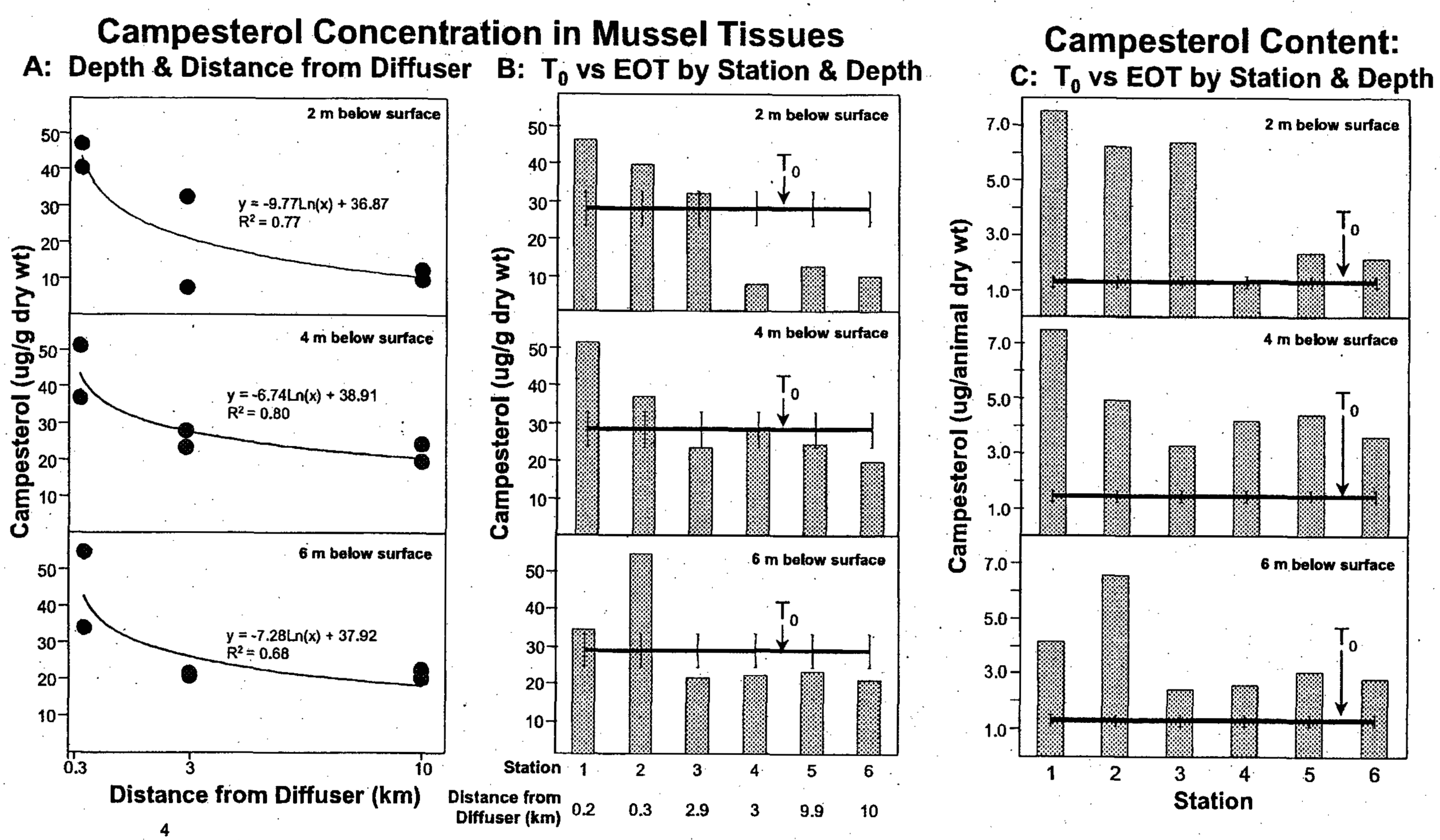


Figure 22. Campesterol concentration (ug/g dry) in mussel tissues. A: Depth and distance from diffuser showing decreasing concentration with distance from diffuser. B: Time zero (T_0) versus end-of-test (EOT) by station and depth (±2SE) showing significant accumulation at stations closest to the diffuser. C: Campesterol content (ug/animal): T_0 versus EOT by station and depth (±2SE).

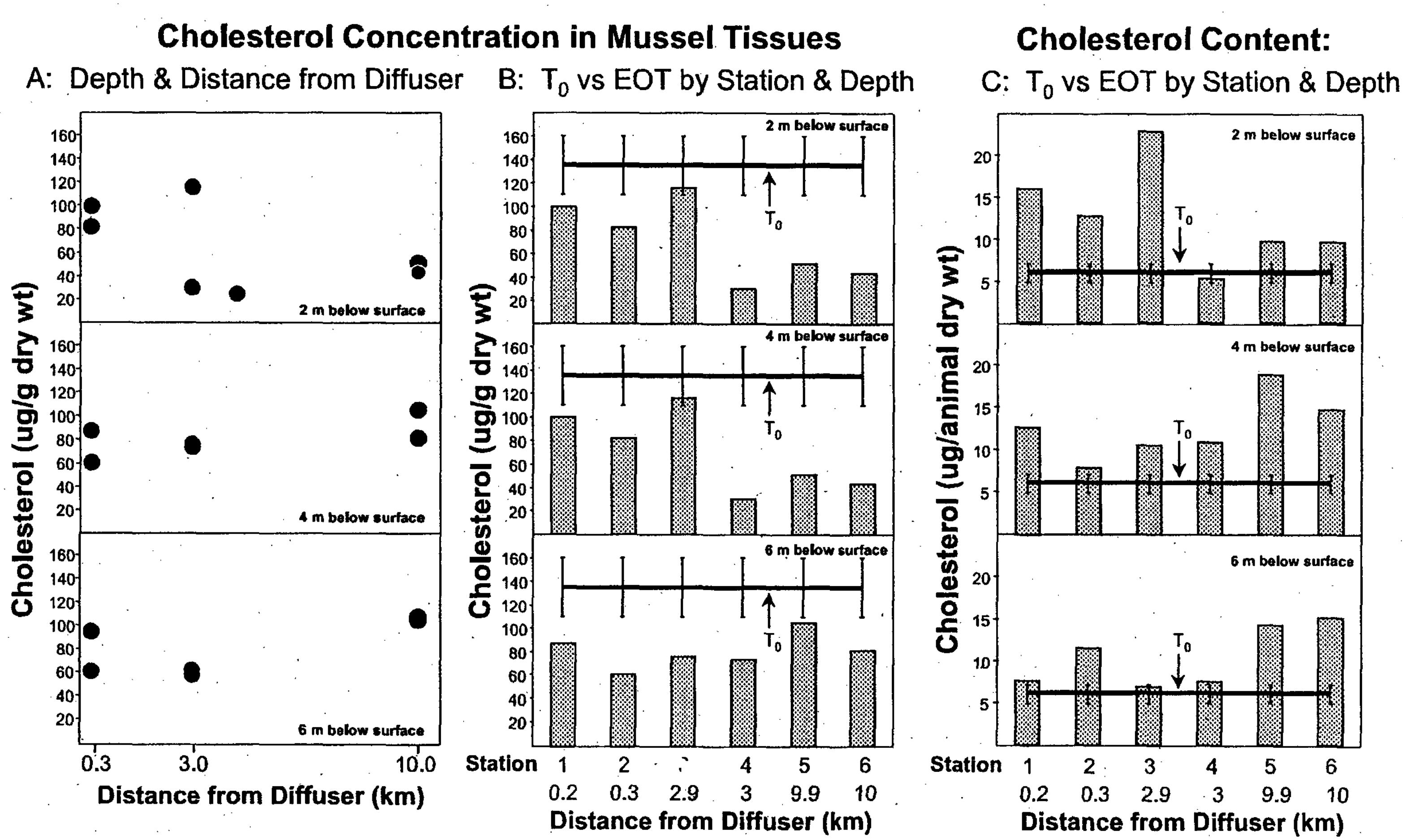


Figure 23. Cholesterol concentration (ug/g dry) in mussel tissues. A: Depth and distance from diffuser. B: Time zero (T_0) versus end-of-test (EOT) by station and depth (±2SE). C: Cholesterol content (ug/animal): T_0 versus EOT by station and depth (±2SE).

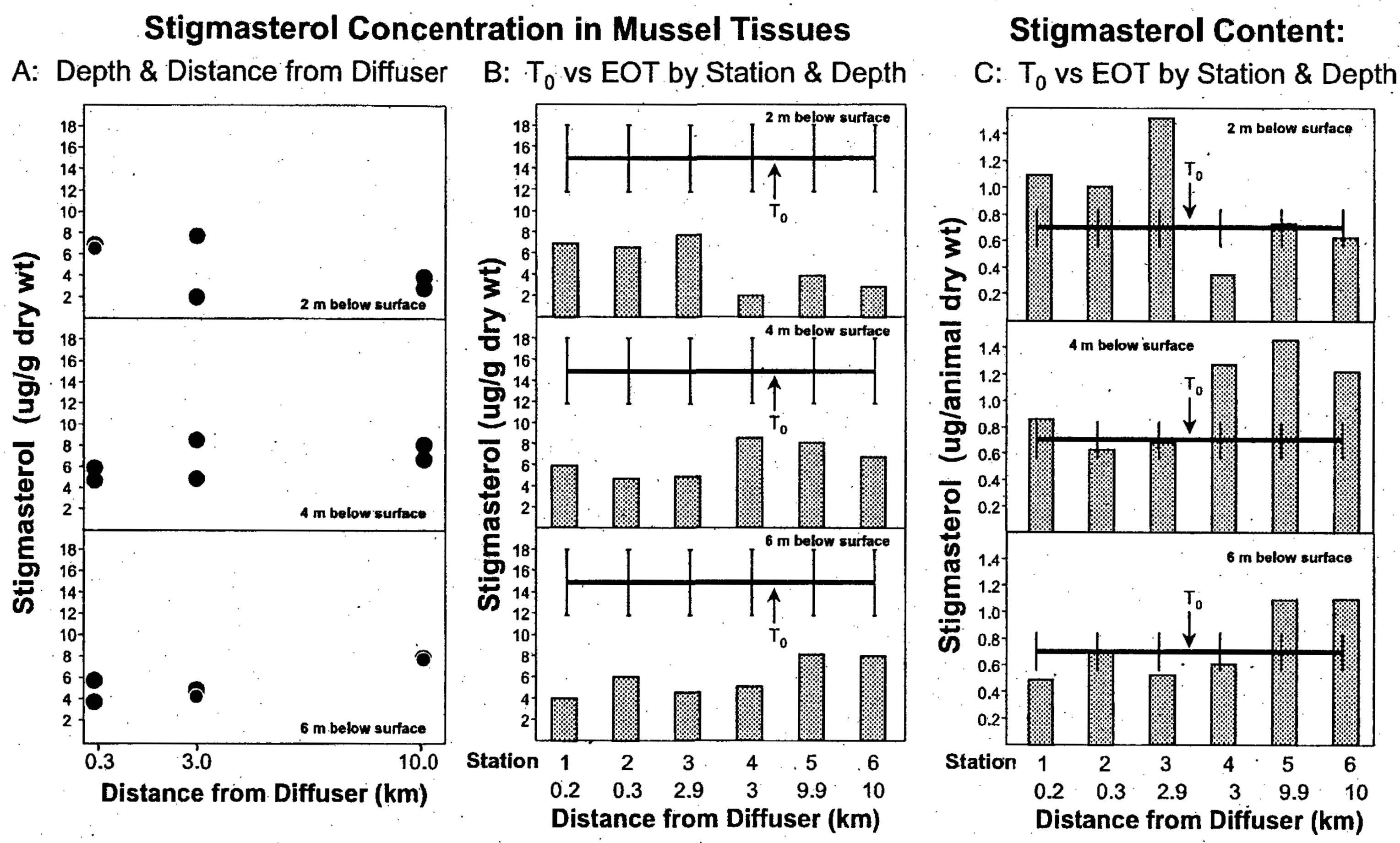


Figure 24. Stigmasterol concentration (ug/g-dry) in mussel tissues. A: Depth and distance from diffuser . B: Time zero (T_0) versus end-of-test (EOT) by station and depth (±2SE). C: Stigmasterol content (ug/animal): T_0 versus EOT by station and depth (±2SE).

B-Sitosterol Concentration in Mussel Tissues

B-Sitosterol Content:

A: Depth & Distance from Diffuser

B: T_0 vs EOT by Station & Depth

C: T_0 vs EOT by Station & Depth

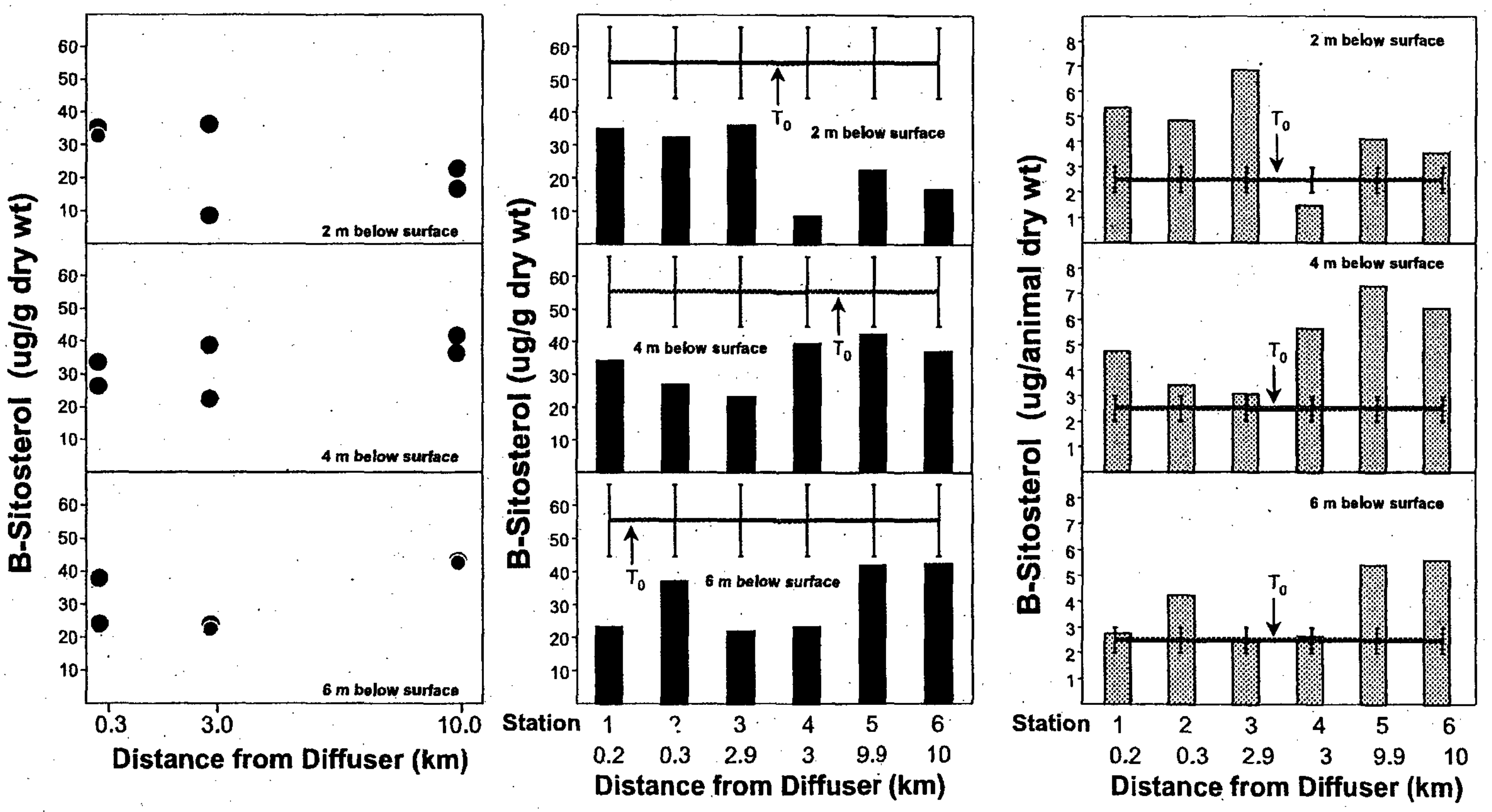


Figure 25. B-Sitosterol concentration (ug/g dry) in mussel tissues. A: Depth and distance from diffuser . B: Time zero (T_0) versus end-of-test (EOT) by station and depth (±2SE). C: B-Sitosterol content (ug/animal): T_0 versus EOT by station and depth (±2SE).

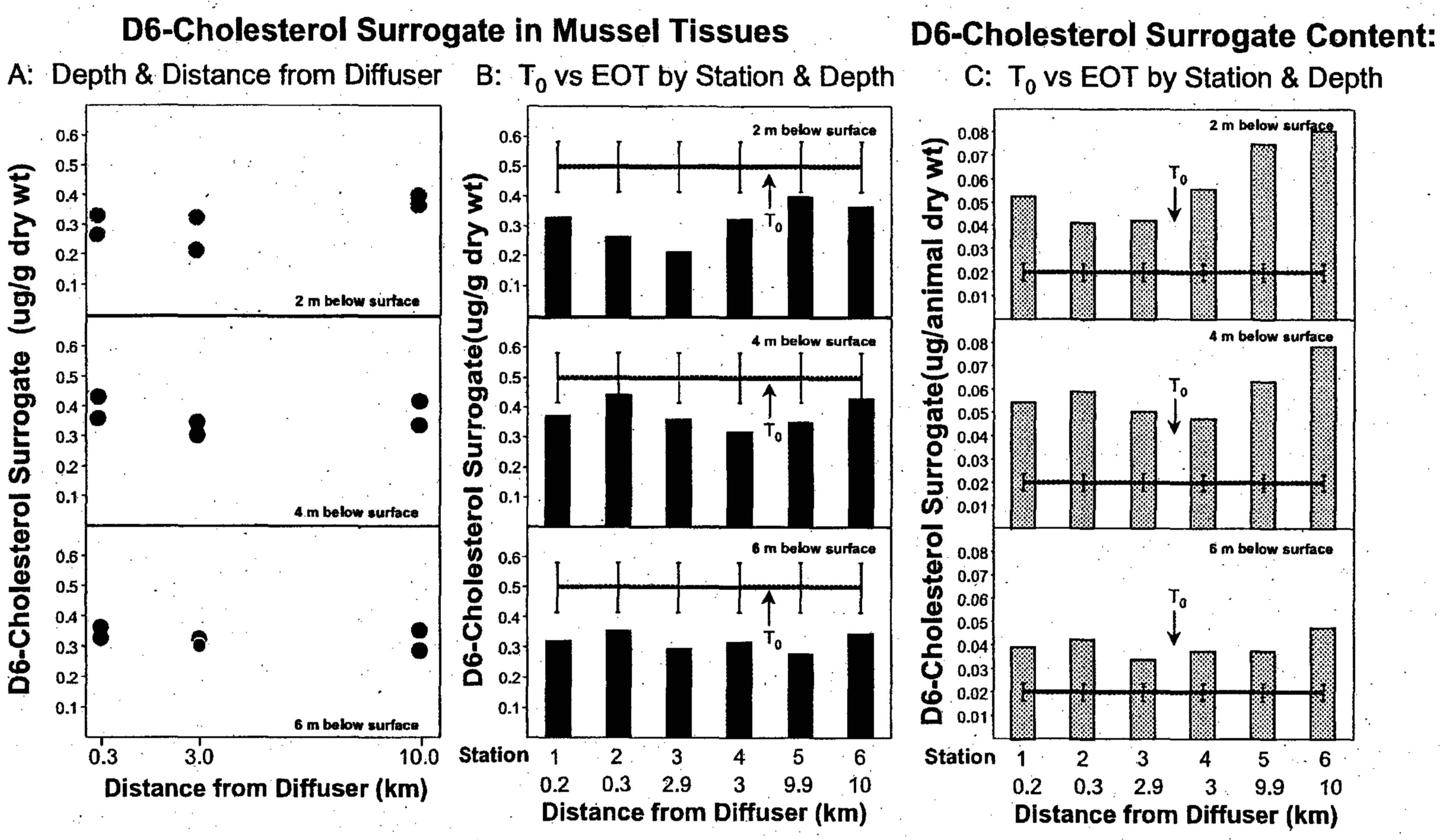


Figure 26. D6-Cholesterol Surrogate concentration (ug/g dry) in mussel tissues. A: Depth and distance from diffuser . B: Time zero (T_0) versus end-of-test (EOT) by station and depth (±2SE). C: D6-Cholesterol Surrogate content (ug/animal): T_0 versus EOT by station and depth (±2SE).

5.11 Supplemental Measurements

5.11.1 Water Temperature Monitoring by In-Situ Meters

Minimum, maximum, and mean water temperatures for each station at the 4-meter depth are summarized in Table 6. Although the minimum, maximum, and average data appear very consistent across stations, the water temperature profiles (Figure 27) show greater extremes, particularly during August, at stations closest to the diffuser. Peaks are less pronounced towards the mouth of Neroutsos Inlet, near Stations 5 and 6.

Table 6. Summary of water temperature conditions by station (4 meters)

Station	Minimum (°C)	Maximum (°C)	Average (°C)
1	9.8	18.5	13.1
2	9.7	18.4	13.1
3	9.8	17.5	13.1
4	9.7	17.4	12.9
5	10.0	17.4	12.9
6	10.2	17.1	13.1

The minimum, maximum, and average water temperatures by depth for Station 3, the only station where temperature monitors were deployed at each depth, show that water temperature was warmest at the 2-meter depth (Table 7). The daily average water temperatures for Stations 1 through 6 and by depth for Station 3 are shown in Table 8. Ranges in weekly water temperature are shown in Table 9.

Table 7. Summary of water temperature (°C) by depth (2, 4, 6 meters) at Station 3

Depth	Minimum	Maximum	Average
2 meters	10.2	19.1	13.8
4 meters	9.8	17.5	13.1
6 meters	9.7	16.5	12.5

Table 8. Summary of Daily Average Water Temperature (°C) Stations 1-6; by Depth at Station 3

Date	Sta 1	Sta 2	Sta 3	Sta 4	Sta 5	Sta 6	Sta 3, 2m	Sta 3, 6m
8/7/97	14.37	14.11	12.84	12.51	11.70	11.94	13.64	11.55
8/8/97	13.67	13.72	13.46	13.45	13.04	13.02	14.87	11.82
8/9/97	11.33	11.46	11.28	11.07	11.63	11.69	13.22	10.31
8/10/97	11.23	11.25	11.30	11.07	11.30	11.52	13.93	10.10
8/11/97	12.44	12.49	12.15	11.90	11.63	11.82	15.63	10.38
8/12/97	15.18	15.27	14.08	13.69	11.87	12.17	15.99	11.21
8/13/97	17.11	16.98	15.91	15.64	12.87	12.98	16.72	14.13
8/14/97	16.69	16.81	16.14	15.94	13.68	13.67	16.89	13.94
8/15/97	13.22	13.28	13.04	12.74	13.14	13.27	15.83	11.08
8/16/97	11.64	11.84	11.97	11.78	11.86	11.90	15.66	10.32
8/17/97	12.76	12.96	12.58	12.50	11.80	12.00	16.19	10.51
8/18/97	15.68	15.66	14.53	14.00	11.71	11.84	16.55	11.64
8/19/97	13.19	13.44	13.21	12.95	12.15	12.15	16.70	11.00
8/20/97	10.43	10.52	11.16	10.99	12.11	12.01	13.76	10.02
8/21/97	10.12	10.12	10.46	10.38	10.47	10.54	11.85	9.89
8/22/97	10.39	10.45	10.46	10.42	10.88	10.81	12.33	9.97
8/23/97	10.07	10.04	10.16	10.01	11.53	11.60	10.76	9.95
8/24/97	10.21	10.22	10.37	10.30	11.21	11.41	10.79	10.03
8/25/97	10.70	10.66	10.67	10.57	11.60	11.85	10.92	10.53
8/26/97	11.33	11.22	10.96	10.98	11.81	12.02	11.24	10.97
8/27/97	11.83	11.71	11.46	11.36	12.04	12.24	11.81	11.29
8/28/97	12.18	12.12	12.04	11.86	12.32	12.53	12.35	11.82
8/29/97	12.32	12.27	12.35	12.22	12.49	12.57	12.82	11.98
8/30/97	12.45	12.45	12.48	12.39	12.47	12.68	13.02	12.20
8/31/97	12.67	12.62	12.66	12.53	12.54	12.69	13.89	12.25
9/1/97	12.58	12.53	12.59	12.47	12.52	12.63	13.10	12.25
9/2/97	12.68	12.64	12.65	12.55	13.02	13.18	13.17	12.27
9/3/97	12.67	12.60	12.73	12.63	13.43	13.49	13.22	12.44
9/4/97	13.10	13.09	13.03	12.93	13.50	13.71	13.54	12.71
9/5/97	12.89	12.87	13.18	13.05	13.73	13.74	13.44	12.82
9/6/97	12.93	12.85	13.43	13.32	13.37	13.55	13.63	13.03
9/7/97	13.63	13.62	13.66	13.58	13.71	13.92	14.02	13.47
9/8/97	13.53	13.52	14.02	13.99	14.01	14.05	14.30	13.78
9/9/97	13.67	13.71	13.94	13.87	14.09	14.32	14.60	13.69
9/10/97	13.54	13.55	13.59	13.45	14.01	14.18	14.88	13.13
9/11/97	13.13	13.12	13.47	13.42	13.96	14.11	14.19	13.08
9/12/97	12.87	12.82	13.21	13.13	14.05	14.16	13.59	12.89
9/13/97	12.95	12.90	13.19	13.14	13.52	13.68	13.63	12.99
9/14/97	12.98	12.93	13.23	13.18	13.53	13.70	13.69	12.93
9/15/97	12.87	12.88	13.15	13.15	13.60	13.77	13.57	12.99
9/16/97	13.00	12.91	13.21	13.11	13.35	13.45	13.48	13.04
9/17/97	13.12	13.08	13.28	13.21	13.50	13.68	13.69	13.13
9/18/97	13.02	12.96	13.17	13.08	13.43	13.51	13.47	13.12
9/19/97	13.04	12.99	13.11	13.09	13.39	13.47	13.59	12.86
9/20/97	12.99	12.92	13.03	12.95	13.34	13.49	13.55	12.85
9/21/97	12.92	12.85	13.00	12.86	13.42	13.45	13.40	12.85
9/22/97	12.80	12.82	12.98	12.87	13.58	13.73	13.44	12.80
9/23/97	13.39	13.29	13.37	13.27	13.19	13.33	13.85	13.11

Date	Sta 1	Sta 2	Sta 3	Sta 4	Sta 5	Sta 6	Sta 3, 2m	Sta 3, 6m
9/24/97	13.36	13.39	13.79	13.70	13.87	13.93	14.19	13.21
9/25/97	13.10	13.13	13.26	13.14	13.98	14.14	13.48	13.12
9/26/97	13.41	13.25	13.40	13.31	13.77	14.02	13.65	13.24
9/27/97	13.85	13.73	13.83	13.75	13.85	14.09	14.03	13.80
9/28/97	14.10	14.02	14.04	14.02	14.01	14.16	14.30	14.02
9/29/97	14.18	14.07	14.22	14.11	13.96	14.19	14.32	14.03
9/30/97	14.04	14.02	14.17	14.03	14.02	14.30	14.20	14.04
10/1/97	14.19	14.07	14.19	14.04	13.70	13.92	14.16	14.13
10/2/97	14.02	14.03	14.05	13.97	13.63	13.71	13.96	13.90
10/3/97	14.30	14.29	13.85	13.73	13.42	13.60	13.99	13.53
10/4/97	14.31	14.29	13.94	13.84	13.42	13.51	13.81	13.69
10/5/97	14.19	14.17	14.04	13.98	13.42	13.51	14.11	13.73
10/6/97	14.18	14.02	14.01	13.98	13.45	13.71	14.02	13.78
10/7/97	14.15	14.07	13.81	13.68	13.28	13.44	13.90	13.48
10/8/97	13.93	13.95	13.74	13.66	13.12	13.14	13.87	13.62
10/9/97	14.00	14.00	13.51	13.48	12.92	13.07	13.70	13.57
10/10/97	14.03	14.02	13.50	13.38	12.83	13.05	13.60	13.54
10/11/97	13.95	14.02	13.50	13.37	12.83	13.02	13.47	13.48
10/12/97	13.80	13.90	13.43	13.39	12.80	13.03	13.37	13.37
10/13/97	13.78	13.72	13.45	13.37	12.88	13.06	13.58	13.40
mean	**13.12**	**13.11**	**13.05**	**12.93**	**12.95**	**13.09**	**13.83**	**12.50**

Table 9. Summary of Weekly Temperature Ranges (°C) Stations 1-6 (4m)

	Sta 1	Sta 2	Sta 3	Sta 4	Sta 5	Sta 6
Week 1	8.00	5.63	7.03	5.28	4.39	4.41
Week 2	8.63	7.63	7.66	6.92	5.63	5.65
Week 3	2.48	8.14	2.32	7.49	6.22	5.94
Week 4	1.40	2.87	1.24	7.45	7.49	6.89
Week 5	1.86	2.01	1.39	2.00	1.74	1.74
Week 6	1.39	1.18	1.39	1.76	1.78	1.48
Week 7	1.39	1.49	1.08	1.19	1.19	1.49
Week 8	0.93	2.69	0.93	1.49	1.49	1.20
Week 9	0.77	0.30	0.62	0.59	0.89	0.89
Average	**2.98**	**3.55**	**2.63**	**3.80**	**3.42**	**3.30**

Differences in Daily Average Water Temperature

Water temperature at all stations displayed similar patterns with daily and seasonal cycles (Figure 24). The daily average water temperatures showed similar patterns (Figure 28). The ANOVA showed that there were not statistically significant differences (p = 0.6156) in daily average water temperature across stations:

ANOVA Results

	DF	Sum of Squares	Mean Square
Treatments	2	0.9797	0.4898
Residuals	201	202.46	1.007
Total	203	203.44	

F = 0.4863 = (MStreatment/MSresidual)

Daily average water temperature at 2-, 4-, and 6-m at Station 3 displayed similar patterns over time (Figure 29). Daily average water temperatures were significantly different between the 2- and 4-m depths and between the 2- and 6-m depths. There was no statistically significant difference between the 4- and 6-m depths.

Nonparametric ANOVA Results (Kruskal-Wallis)

Comparison	Mean Rank Difference	Result
2m vs 4m	37.368	*** P<0.001
2m vs 6m	60.088	*** P<0.001
4m vs 6m	22.721	NSD P>0.05

Differences in Temperature Ranges

There were no significant differences (p = 0.9584) between the average weekly temperature ranges at all stations.

ANOVA Results

	DF	Sum of Squares	Mean Square
Treatments	5	7.852	1.570
Residuals	48	365.81	7.621
Total	53	373.66	

F = 0.2061 = (MStreatment/MSresidual)

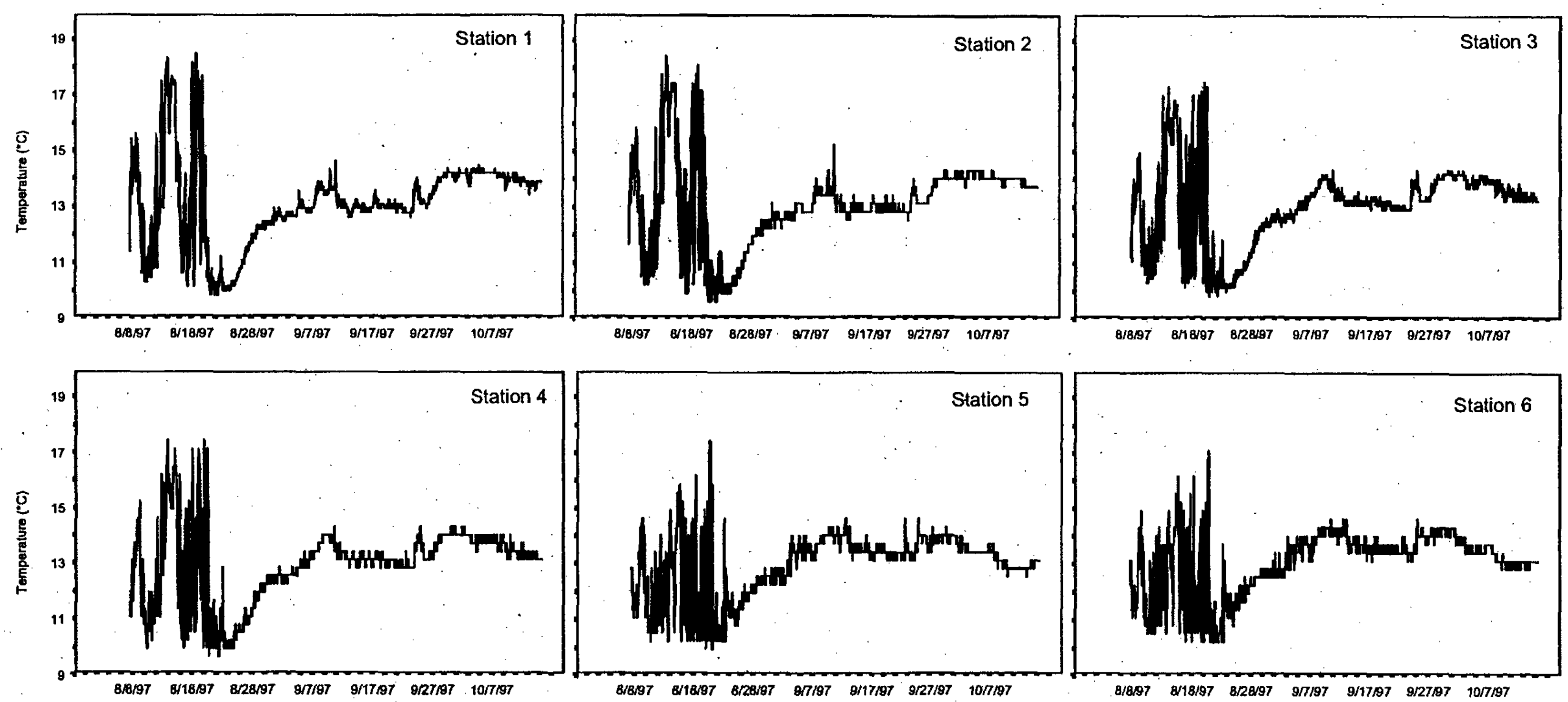


Figure 27. Temporal variation in 4-meter temperature profiles by station (all data). Note: temperature recorders were attached to the 4-m cages at all sites.

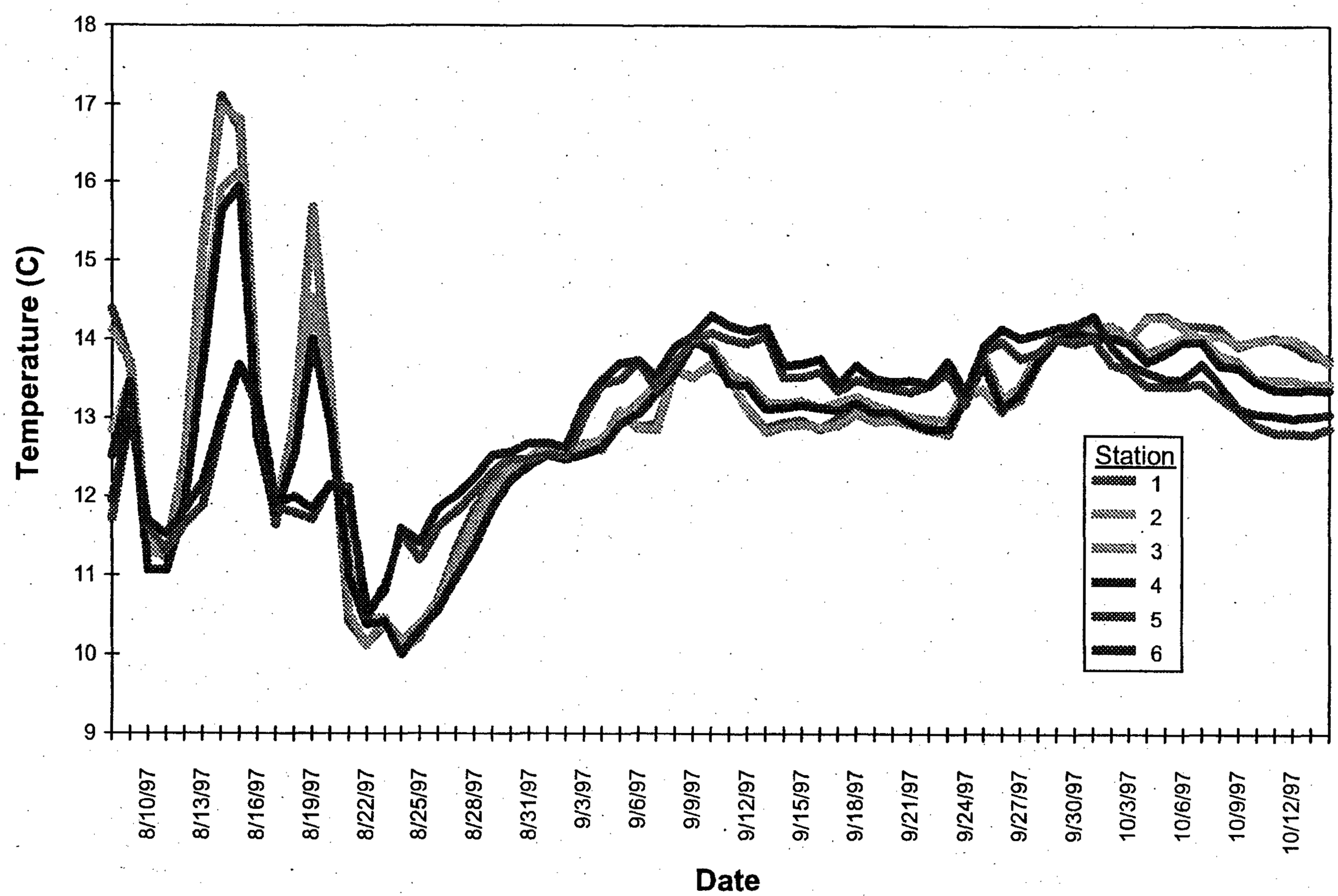


Figure 28. Temporal variation in daily average water temperatures at the 4-meter depth by station. Note: temperature recorders were attached to the 4-m cages at all sites.

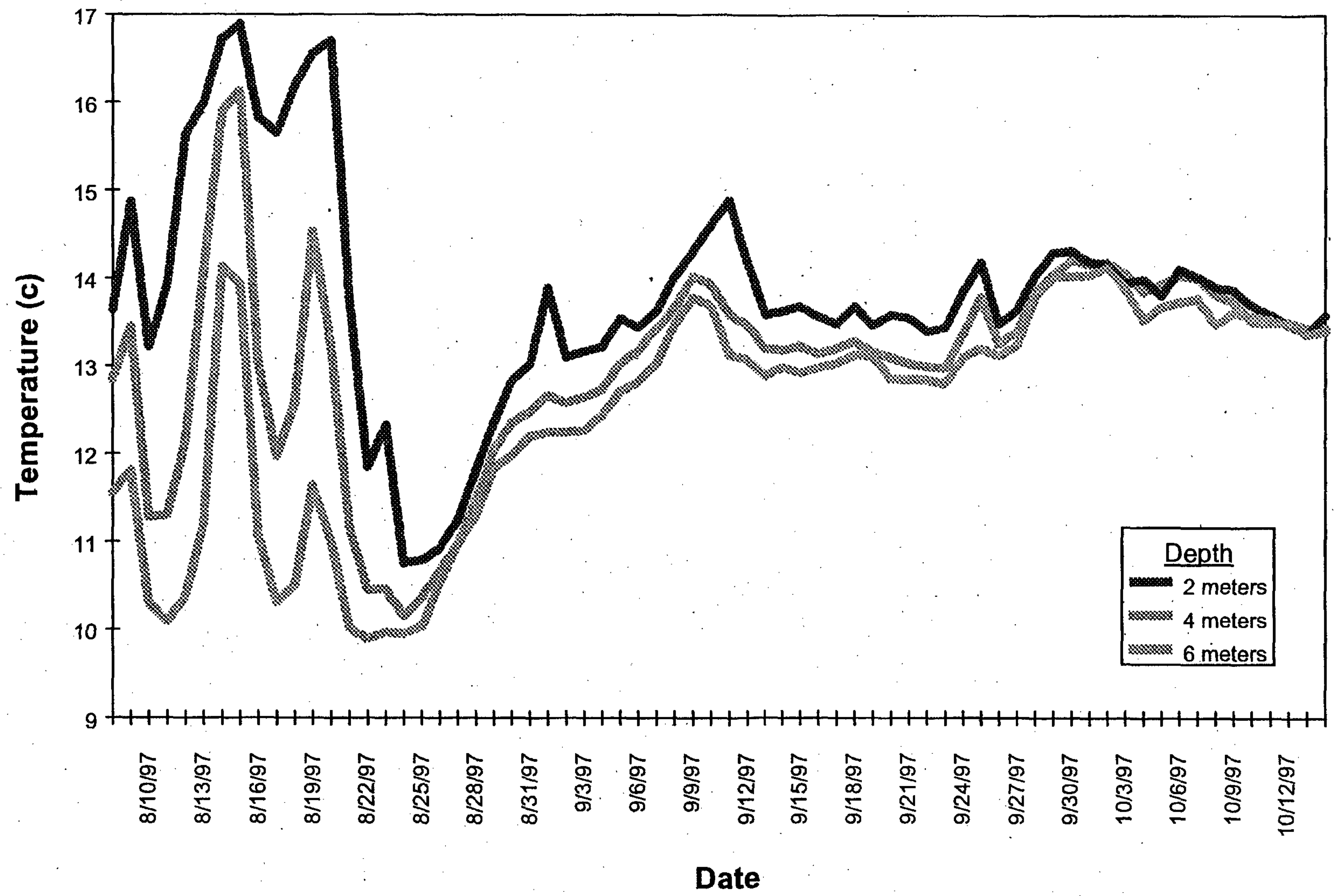


Figure 29. Temporal variation in daily average water temperatures at Station3 by depth (2, 4, and 6-meters). Note: temperature recorders were attached to all three cages at Station 3.

5.11.2 Water Quality Measurements Provided by the Mill and Environment Canada

As in both the EEM fish and benthos surveys, natural factors can affect the mussel effects endpoints. The gradient of increasing mussel growth with distance from the mill was compared to patterns of natural and mill-related factors along the same gradient including temperature, salinity, food availability (chlorophyll-a), DO, and SSL. The combined effects of depth and distance made these comparisons more difficult. Relationships among mussel growth measures, water quality variables, depth and distance were explored with a variety of statistical analyses to obtain a clearer understanding of the mill-related versus natural effects on mussel growth. The limited number of data points restricted statistical analyses for some water quality parameters (e.g., chlorophyll-a, nutrients).

Table 10 summarizes the water quality data collected by the mill (i.e., temperature, SSL, DO, colour, and salinity) and Environment Canada (i.e., chlorophyll-a, TOC, TSS) during the mussel study. Table 11 provides statistical results from ANOVAs comparing various water quality parameters among stations. SSL results showed the most highly significant differences in all station by station comparisons, both pooled and by depth (Table 11). The next most significant parameter was DO. Table 12 is a correlation matrix for selected metrics. The most significant correlation among any of the water quality or growth parameters and distance from the diffuser was SSL ($r = -0.934$). The only other higher correlation was between depth and temperature ($r = -0.972$). Using the mill water quality data across depths, mean SSL decreased with distance from the mill and DO increased (Figure 30). The relationships were statistically significant and explained by an exponential fit ($r^2 = 0.996$ and 0.975, respectively). The inverse relationship between SSL and DO (Figure 31) was also statistically significant and explained by an exponential fit ($r^2 = 0.99$). Among the mussel growth metrics used in this study for pooled Stations (1-2, 3-4 and 5-6), mussel weight growth (mg/wk) and SSL provided the most meaningful relationship ($r^2 = 0.99$). In addition, the relationship between EOT tissue weight (g-wet) and SSL was highly significant ($r^2 = 0.93$) as shown in Figure 32. The same two mussel metrics were significantly related to DO (Figure 33) and again weight growth was better related ($r^2 = 0.96$) than EOT tissue wet weight ($r^2 = 0.89$).

The highest SSL concentrations were found at depths of 4 and 6 meters near the mill. The concentration decreased with distance and higher SSL concentrations were found at the 2 meter depth (Figure 34). By contrast, the relationship between DO, depth, and distance is quite different. The highest DO concentrations were found at the 2 meter depth at the furthest distance from the mill (10 km). The relationship between DO and depth and distance remained proportional with proximity to the mill (Figure 35). Similar patterns were found for weight growth (mg/wk), distance, and depth (Figure 36) and percent lipids, distance, and depth (Figure 37). There was no significant correlation between temperature and distance from the mill, but there was a significant correlation between temperature and depth (Table 12). There was little change in temperature at any given depth with distance away from the mill, but temperature decreased with depth (Figure 38).

Table 10. Mean water quality data by depth and station

Temperature, SSL, DO, Colour, salinity data provided by the Mill		Water Quality Monitoring Station		
Parameter	Depth	WQ8	WQ14	WQ20
Temperature (°C)	2 meters	13.9	14.0	13.8
	4 meters	13.0	13.1	13.2
	6 meters	12.5	12.6	12.8
Spent Sulphite Liquor (ppm)	2 meters	61.9	50.8	26.1
	4 meters	82.1	46.2	20.0
	6 meters	80.4	41.7	14.2
Dissolved Oxygen (ppm)	2 meters	7.4	7.9	8.8
	4 meters	6.5	7.1	8.0
	6 meters	6.2	6.9	7.5
Colour	2 meters	41.1	36.2	26.5
	4 meters	43.1	31.9	21.9
	6 meters	40.5	26.4	15.8
Salinity (ppt)	2 meters	25.1	26.1	25.7
	4 meters	27.0	27.4	26.9
	6 meters	27.4	27.8	27.3
Chlorophyll-a, TOC, TSS data provided by Environment Canada		Mussel Station		
		1-2[1]	3-4[2]	5-6[3]
BOT Chlorophyll-a (ug/L)	2 meters	2.03	3.86	2.04
	4 meters	2.68	3.89	2.29
	6 meters	1.51	4.11	2.10
Mid-Test Chlorophyll-a (ug/L)	2 meters	0.32	2.81	0.85
	4 meters	0.27	1.37	0.74
	6 meters	0.10	0.67	0.28
EOT Chlorophyll-a (ug/L)	2 meters	0.31	0.32	0.43
	4 meters	0.25	0.22	0.43
	6 meters	0.17	0.20	0.39
		Mussel Station		
		1-2	3-4	5-6
BOT TOC (mg/L)	2 meters	7.9	10.0	4.0
	4 meters	8.6	10.0	4.0
	6 meters	10.3	8.6	3.9
Mid-Test TOC (mg/L)	2 meters	12.1	7.9	5.9
	4 meters	11.7	7.0	3.7
	6 meters	10.5	5.9	2.8
EOT TOC (mg/L)	2 meters	2.65	2.3	2.8
	4 meters	2.2	2.1	2.6
	6 meters	2.3	2.0	2.7
BOT TSS (mg/L)	2 meters	20	14	28
	4 meters	15	20	31
	6 meters	20	27	26
Mid-Test TSS (mg/L)	2 meters	28	35	22
	4 meters	30	39	33
	6 meters	29	24	27
EOT TSS (mg/L)	2 meters	12	9	32
	4 meters	7	6	57
	6 meters	12	6	57

1 - For 1-2, means calculated from data collected by Environment Canada at Mussel Sites 1 & 2
2 - For 3-4, means calculated from data collected by Environment Canada at Mussel Sites 3 & 4
3 - For 5-6, means calculated from data collected by Environment Canada at Mussel Sites 5 & 6

Table 11. Statistical comparisons for Water Quality Data

Temperature, Salinity, DO, SSL data provided by the Mill; Chlorophyll-a data provided by Environment Canada

Depth	Comparison	Temperature	Salinity	DO	SSL	Chl-a
4-meters	1-2 vs 3-4	NS	NS	NS	***	NS
	1-2 vs 5-6	NS	NS	**	***	NS
	3-4 vs 5-6	NS	NS	NS	**	NS
2, 4, 6 m Pooled	1-2 vs 3-4	NS	NS	*	***	*
	1-2 vs 5-6	NS	NS	***	***	NS
	3-4 vs 5-6	NS	NS	*	***	*
Station 1-2	2 vs 4 m	NS	NS	NS	NS	NS
	2 vs 6 m	NS	*	*	NS	NS
	4 vs 6 m	NS	NS	NS	NS	NS
Station 3-4	2 vs 4 m	NS	NS	NS	NS	NS
	2 vs 6 m	*	*	NS	NS	NS
	4 vs 6 m	NS	NS	NS	NS	NS
Station 5-6	2 vs 4 m	NS	NS	NS	NS	NS
	2 vs 6 m	*	NS	NS	**	NS
	4 vs 6 m	NS	NS	NS	NS	NS

Key: P < 0.05 (* = significant)
0.01 (** = very significant)
0.001 (*** = extremely significant)

A correlation analysis was run to further explore distance versus depth for selected metrics: depth, distance, temperature, DO, SSL, weight growth, EOT tissue dry and wet weight, percent lipids, percent water, condition index, and shell weight (Table 12). This matrix showed a strong inverse correlation of SSL and distance (r = 0.93). DO showed significant relationships with distance (r = 0.75), SSL (r = -0.73) and the growth metrics (see bolded values under DO in Table 12). Mill effluent can impact the DO concentrations in the inlet (increased oxygen demand) and therefore affect mussel growth. DO concentrations alone (6.2 - 8.8 mg/L mean range) were not low enough to completely explain the reduced mussel growth. Mussels filter relatively large volumes of water and only use a small portion of the DO for respiration (Widdows and Donkin 1992). Given the volume of water filtered per unit time (~25-50 gallons/day), the amount of oxygen present should have been sufficient to sustain mussel growth rates.

Temperature also showed significant positive correlations with growth metrics (see under TEMP in Table 12), a strong inverse relationship with depth (r = -0.97) and no relationship with distance. Temperature could in part explain reduced growth with depth but not increased growth with distance. Changes with depth were similar among stations (Table 11, Figure 38). Similarly, there were no significant differences between distance and salinity, only differences between 2 and 6 m at some stations (Table 11). There were no significant differences in chlorophyll-a among stations at any depth (Table 11).

Table 12. Correlation analysis on selected metrics

Marked Correlations are significant at P < 0.0500

	DEPTH	*DISTANCE*	*TEMP*	*DO*	*SSL*	*WAWW GROWTH*	*EOTISS WW*	*% LIPIDS*	*% WATER*	*CI*	*Shell Wts*	*EOTISS DW*
DEPTH	1											
DISTANCE	0	1										
TEMP	***-0.972***	0.094	1									
DO	-0.629	***0.751***	***0.704***	1								
SSL	-0.015	***-0.934***	-0.118	***-0.730***	1							
GROWTH	***-0.838***	0.439	***0.830***	***0.828***	-0.376	1						
EOTISS WW	***-0.825***	0.425	***0.782***	***0.804***	-0.326	***0.929***	1					
% LIPIDS	-0.472	***0.783***	0.529	***0.907***	-0.640	***0.749***	***0.706***	1				
% WATER	0.426	-0.534	-0.570	***-0.72***	0.486	-0.595	-0.401	***-0.806***	1			
CI	***-0.674***	0.635	***0.709***	***0.903***	-0.484	***0.823***	***0.844***	***0.934***	***-0.723***	1		
Shell Wts	***-0.885***	0.312	***0.872***	***0.757***	-0.279	***0.982***	***0.923***	0.629	-0.518	***0.746***	1	
EOTISS DW	***-0.817***	0.519	***0.826***	***0.899***	-0.417	***0.953***	***0.950***	***0.856***	-0.664	***0.937***	***0.918***	1

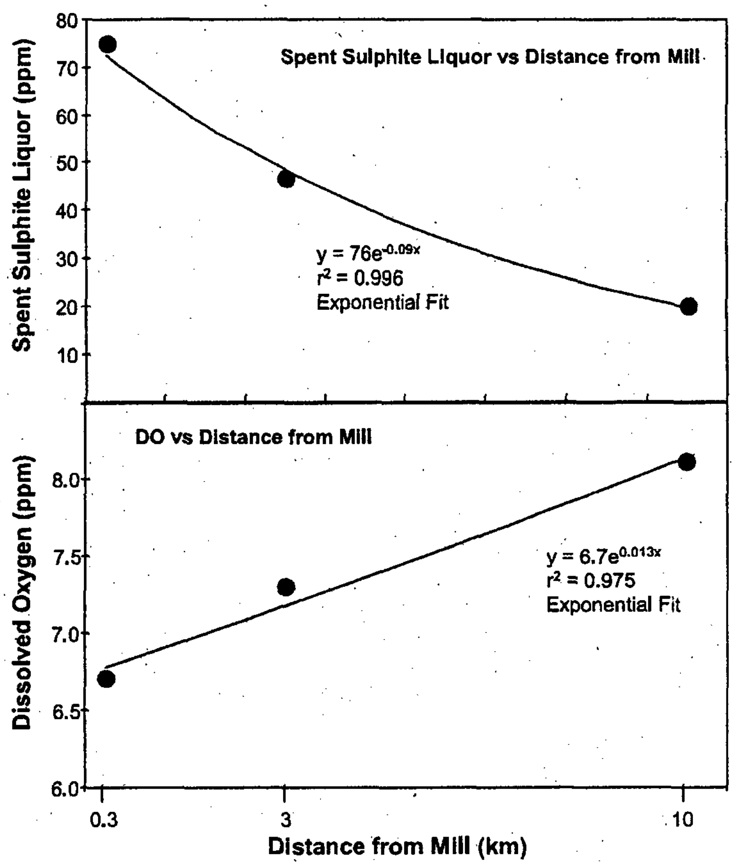


Figure 30. Spent sulphite liquor (SSL) and dissolved oxygen (DO) versus distance from the mill.

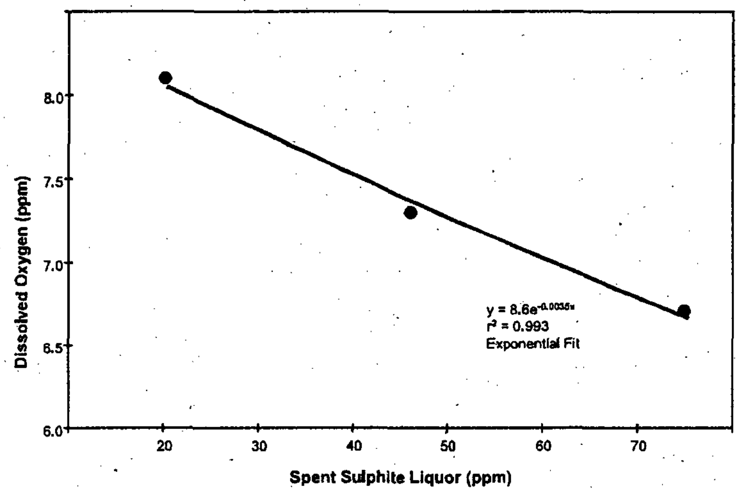


Figure 31. Relationship between spent sulphite liquor (SSL) and dissolved oxygen (DO).

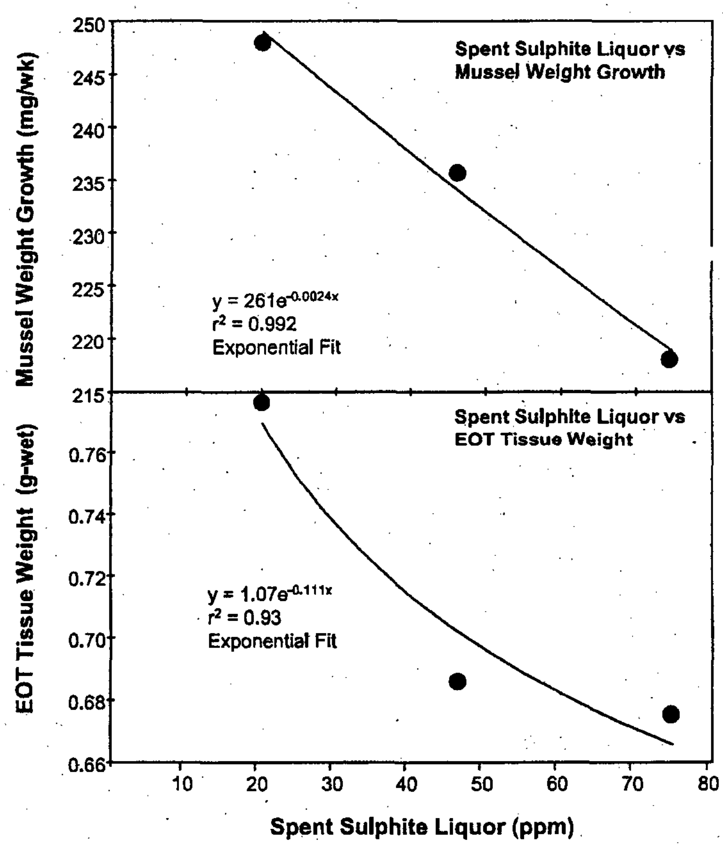


Figure 32. Spent sulphite liquor (SSL) versus mussel weight growth rates and end-of-test (EOT) tissue weights.

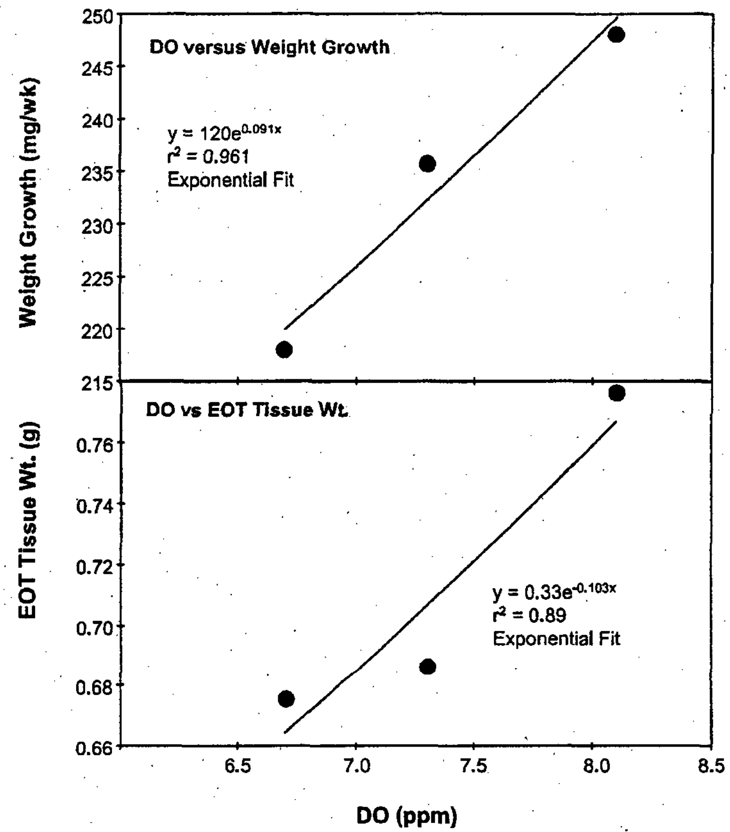


Figure 33. Dissolved oxygen (DO) versus mussel weight growth rates and end-of-test (EOT) tissue weights.

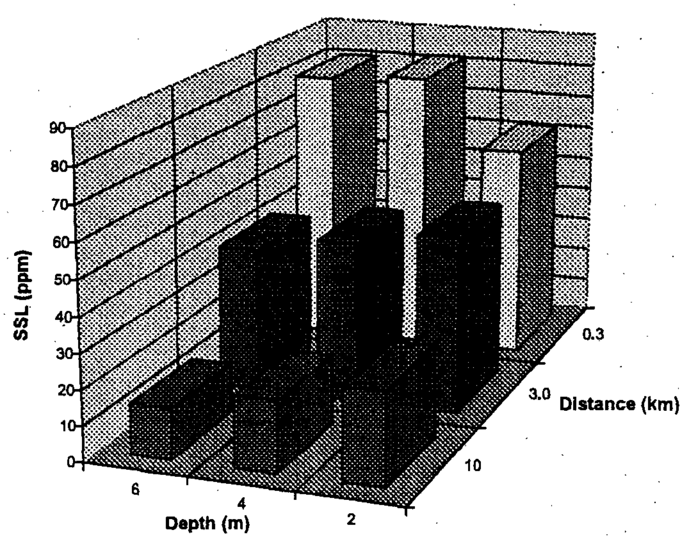


Figure 34. Spent sulphite liquor with distance from the mill and deployment depth.

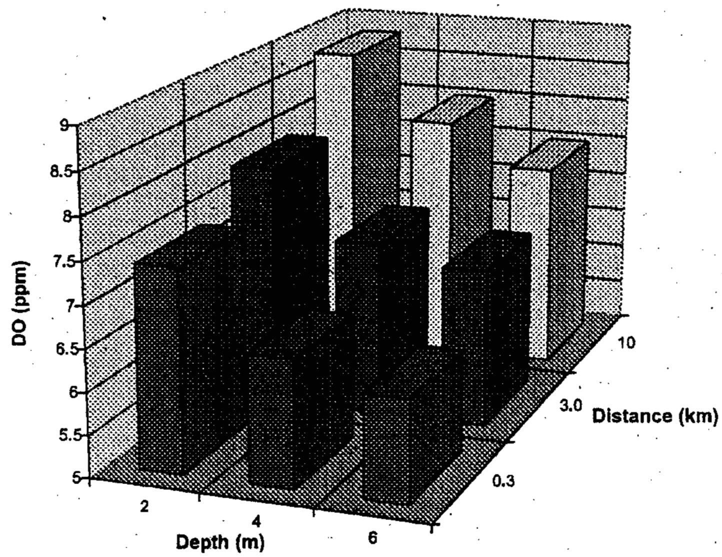


Figure 35. Dissolved oxygen with distance from the mill and deployment depth.

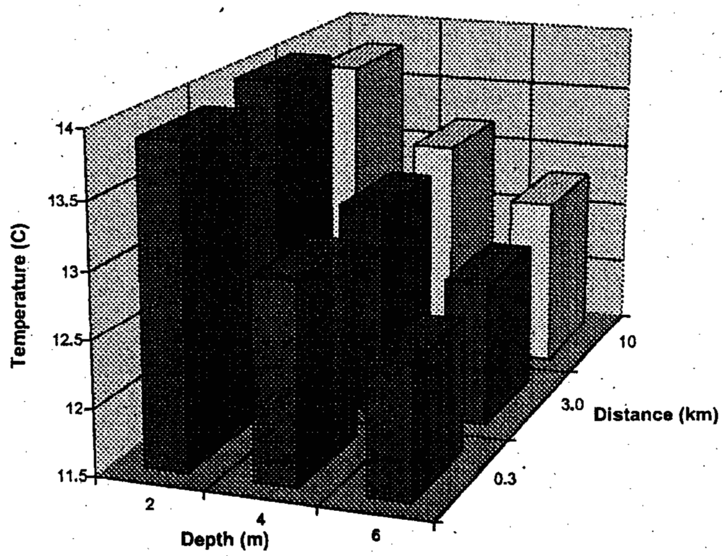


Figure 36. Temperature with distance from the mill and deployment depth.

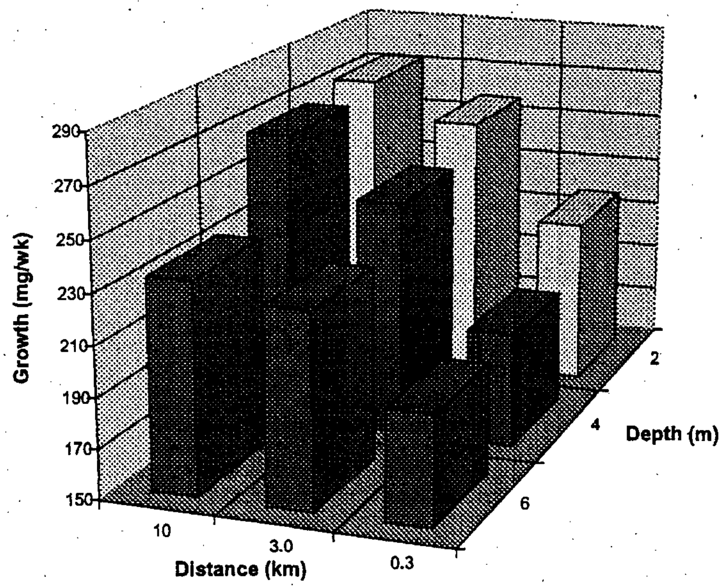


Figure 37. WAWW growth (mg/wk) with distance from the mill and deployment depth.

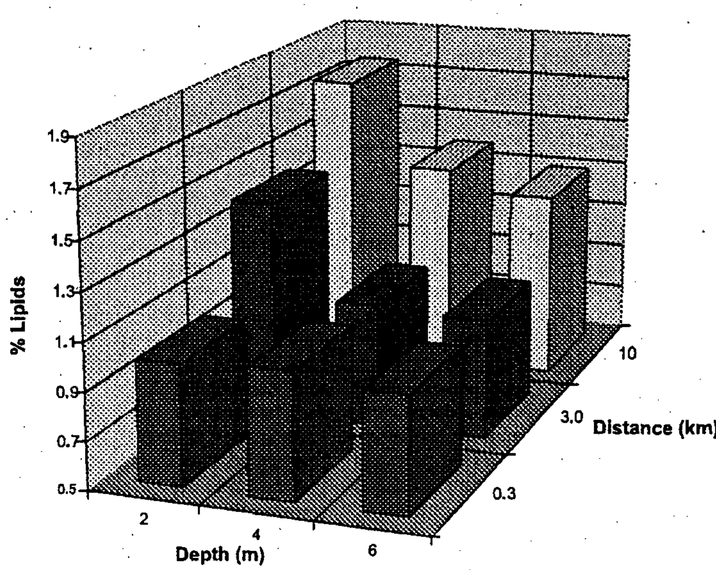


Figure 38. Percent lipids with distance from the mill and deployment depth.

6.0 DISCUSSION - APPLICATION TO EEM

The primary purpose of the caged mussel pilot study was to evaluate the feasibility and scientific value of using the caged bivalve methodology for EEM. Therefore, the focus of the discussion is on the generic results as applicable to EEM and not the evaluation of environmental effects of the Port Alice mill *per se*.

6.1 Characterizing Exposure

In the context of the exposure-dose-response (EDR) triad model used for the caged mussel pilot study (Figure 2), exposure was characterized in part with the water chemistry (spent sulphite liquor or SSL) measured by mill staff at mill water quality stations (Figure 5) twice weekly during the pilot study (Appendix L). Mean SSL calculated at four depths from surface to 10 m confirmed the presence of the effluent plume at the three cage depths (2, 4 and 6 m) and showed a significant gradient of decreasing exposure to SSL with increasing distance from the mill (Figure 24). The SSL data also showed the buoyant effluent plume approached the surface with increasing distance from the mill. Nearest the effluent diffuser (mill WQ Station 8 near Mussel Stations 1&2), the surface concentrations of SSL were less than half those concentrations found at 2,4, and 6 m. With increasing distance, the middle station (mill WQ Station 14 near Mussel Stations 3&4) surface sample approached the samples taken at depth while at the station furthest from the diffuser (mill WQ Station 20, near Mussel Stations 5&6) the surface SSL concentrations exceeded those taken at other depths.

Due to the mill water quality monitoring program, more extensive water chemistry data were available to characterize exposure for the caged mussel pilot study. While the mill water chemistry data clearly demonstrated exposure to mill effluent along a decreasing gradient, the EDR triad model suggests that water chemistry alone cannot completely characterize exposure because it may not represent biologically available chemicals. Therefore, tissue chemistry should be used to confirm that internal exposure has occurred. Tissue chemistry provides an integration of actual exposure to chemicals of concern because bivalves concentrate and integrate available chemicals over space and time. Ultimately, environmental assessments are concerned with chemical exposure at internal receptors of concern. Until these receptors have been identified, tissue chemistry is used as a reasonable surrogate of that exposure (McCarty and Mackay 1993). Mussels can be used to quantify chemicals in water even when chemical concentrations in water are below the limits of detection. Mussels were initially used to measure environmental concentrations of radionuclides because the concentration of radionuclides in water was below the limits of detection (Phillips and Rainbow 1993). In a more recent example, chemical analysis of water samples using high resolution, state-of-the-art techniques confirmed that contaminated sediments were the source of DDT and PCBs in the water column (Zeng et al. 1999). Interestingly, the same conclusion was reached almost 25 years previously by measuring the tissues of caged mussels deployed at various depths in the same location (Young et al. 1976). Caged mussels offer a more practical method of integrated water sampling, particularly when available methods can not achieve required detection limits.

For the pilot study, the most suitable mill effluent tracers to measure in the mussel tissue were not known. Ali et al. (1997) discussed problems finding effluent tracers in EEM Cycle 1, particularly given mill process and treatment improvements. They cited resin acids as the most promising tracer for softwood furnish. Tissue tracers selected for the pilot study included various chemicals found in pulp and paper mill effluents (resin acids, retene, plant sterols, and fichtelite). Of those selected, only resin acids were previously measured in the Port Alice mill effluent (Hatfield Consultants Ltd. 1997). Most plant sterols in mussel tissues did not show a decreasing gradient with distance from the mill (Figures 23 through 26). Campesterol, one of the plant sterols measured as part of this study, was an exception (Figure 22). Further evaluation of relevant effluent tracers in tissue is needed to more effectively apply the bioaccumulation component of the caged mussel approach to pulp and paper mill monitoring.

6.2 Characterizing Effects

Mussel survival was high (>90%, Table 2) and growth was substantial (~500% increase in WAWW, Table 3) over the 68 day exposure period. All mussel growth effects endpoints (i.e., weight growth rate, length growth rate, and EOT WAWW, length, shell weight, tissue dry and wet weight and condition index) increased with distance from the effluent diffuser and suggest improving mussel condition. Similarly, EOT percent lipids increased and EOT percent water decreased along the same gradient, and also suggest improving mussel condition. Most effects endpoints showed statistical differences among stations using a one-way ANOVA and Student-Newman-Keuls multiple range test (alpha = 0.05) even when the absolute difference was only 10%. Although the results did not show cause and effect, the preponderance of evidence from mussel growth metrics and biochemical measurements all suggested improving animal condition with distance from the diffuser.

Statistical comparisons of shell-related versus tissue-related mussel metrics showed different spatial patterns. Shell-related metrics (EOT WAWW, weight growth rate, EOT length, length growth rate and EOT shell weight) indicated that pooled Station 3-4 was similar to pooled Station 5-6 and that both were statistically different from pooled Station 1-2. This suggested that effects on growth, as measured by these metrics, were confined to Stations 1-2 and a distance of approximately 300 m from the effluent diffuser. Although the WAWW comparisons were significant at alpha levels between 0.01 and 0.001, the length-related measurements were only significant at the 0.05 level. This was consistent with most previous work using this method that showed weight measurements were more discriminating than length measurements (Salazar and Salazar 1995a).

The changes in tissue wet weights suggested a different relationship with distance from the mill. Reduced tissue wet weights seemed to be associated with pooled Stations 1-2 and 3-4 or a distance up to 3 km from the mill. Both were significantly lower than pooled Station 5-6.

Previous work shows that tissue and shell growth decouple and can proceed at different rates because they are affected by different natural factors (Hilbish 1986). It is also suggested that tissue growth and shell growth are affected by different chemicals (Salazar and Salazar 1998). This work suggests, for example, that TBT may have more of an effect on shell growth whereas certain organics like PAHs may have more of an effect on tissue growth. If this is true, an organic chemicals associated with the mill effluent may have more of an effect on tissue growth than shell growth, and therefore tissue growth could be affected at lower concentrations and further distances away from the effluent diffuser.

Wet tissue weights have not always been the most discriminating endpoint, but have often provided a different perspective on the data as in this pilot study. The discriminating power of the replication associated with EOT wet tissue weights was at the 0.001 level of significance. Percent lipids and condition index (tissue dry wt./ shell wt.) showed the same statistical grouping as the tissue wet weight. Condition index was more discriminating than in previous studies and similar to wet tissue weight (i.e., 0.001 level of significance). Although a limited number of replicates for percent lipids (one composite sample per cage), statistically significant differences were detected at both the 0.05 and 0.01 levels of confidence.

Surprisingly, dry tissue weights were the only growth metric that demonstrated statistically significant differences between each group of pooled stations. These data could be interpreted to suggest that the most significant effects were found within 300 m of the diffuser, lesser effects at 3 km from the diffuser, and no effects 10 km from the diffuser. Although individual dry tissue weights may have less error than wet tissue weights they require considerably more time and expense, particularly for ash free dry weights. Also, most chemical analyses can not be conducted on dry tissue weights, and it may not be possible to collect both dry tissue weight data and tissue chemistry data. It was not surprising to find that percent water was the least discriminating index of mussel condition and did not show statistically differences among any stations. This metric is generally used only to confirm results from other metrics.

There was little difference in the discriminating power of EOT WAWW versus weight growth rates (individual weight changes) to detect differences among stations in this study. However, in over 80 percent of 40 caged bivalve studies using this ASTM approved method (Salazar and Salazar 2001), individual growth rate measurements were more discriminating than EOT growth measurements.

Table 13. **Minimum size ranges in four most recent tests and mean percent change in weight**

		KPC - 1	KPC - 2	Port Valdez	Port Alice
Length	Range	7.1	5.01	4.99	6.42
	Mean	32.70	32.75	33.56	17.03
	S.D.	1.70	1.10	1.35	1.47
Weight	Range	4.88	4.94	4.73	0.75
	Mean	3.83	3.77	3.74	0.50
	S.D.	0.70	0.56	0.66	0.14
Weight	% increase	1%	1%	7%	500%
		2400 mussels 300/site			1620 mussels 270/site

Although the size range at the beginning of the test of the caged mussel pilot study was quite similar to the other studies conducted at high latitudes and low temperatures with the same methods, the absolute sizes were very different. The mean mussel length for the Port Alice pilot study was approximately 50 percent of the length in the other three studies and the weight was smaller by approximately 650 percent. Compared to the other studies, computing change in WAWW (subtracting initial test weights from EOT weights) was almost like subtracting zero from each WAWW since the average weight at the beginning of the test was only 0.50 g. Furthermore, weight increases of approximately 500 percent in the smaller, faster-growing animals used in the Port Alice were much larger than in the other studies. Port Valdez was the most extreme example since the animals were held at 70 m and weight increases were minimal, only 7.4 percent. Weight increases during the other two Alaskan studies (KPC -1 and KPC-2) were only about 1 percent. In KPC-1, using two different control stations and comparing EOT WAWW with five sites in the vicinity of the effluent diffuser, only one station was different. Using change in WAWW (weight growth) for the comparisons, every station was different from the controls. With only a 1 percent average increase in WAWW over the 60-day exposure period, the absolute difference in WAWW across stations was only 2 percent. Using change in WAWW, however, the range across stations was about 500 percent and increased the chances of detecting differences among stations.

Although not included in the pilot study, methods have been developed to monitor reproductive endpoints in both natural populations and caged bivalves. For example, in Australia, reproductive endpoints of gonad morphology and glochidial development in indigenous freshwater mussels were developed for in-situ assessments (Humphrey et al. 1990). In Howe Sound, BC, histopathological abnormalities and gonad development of a marine infaunal bivalve was used to evaluate potential reproductive effects associated with a marine mine-tailings discharge (Bright and Ellis 1989, Bright 1991a,b). Given that bivalves are gonochoristic (dioecious i.e., separate males and females), there is potential to measure similar reproductive measures in bivalves to those required for the EEM fish survey (e.g., fecundity, gonadosomatic index). Other possible endpoints could include sex steroid concentrations, vitellogenesis (masculinization or feminization), or changes in sex ratios. Recently, Gagne et al. (in press) have documented estrogenic effects in freshwater caged mussels deployed downstream of a municipal effluent by using a vitellin biomarker. This approach appears more practical than measuring morphological differences in bivalve reproductive tissues and may be more useful for EEM applications.

6.3 Natural versus Mill-related Factors in Evaluating Effects

As in both the EEM fish and benthos surveys, natural factors can influence mussel effects endpoints. Furthermore, while the in-situ field exposures using caged bivalves provide a more environmentally realistic exposure system than laboratory testing, there is less environmental control and this often makes it difficult to distinguish between natural versus mill-related effects on mussel condition. While statistically significant relationships were found with mussel condition and mill-related factors such as SSL and DO, mussel condition was also affected by depth, such as temperature. Similarly, although a statistically significant relationship was found between campesterol and mussel growth, there is insufficient evidence to demonstrate a causal relationship. However, by using a suite of biomarkers such as the vitellin index and others, it may be possible to increase the likelihood of establishing those relationships. Gagne et al. (in press) have recently suggested that coprostanol associated with mill effluents may be causing estrogenic effects. The limited number of data points also restricted the discriminating power of statistical analyses for some water quality parameters such as chlorophyll-a. A more comprehensive water quality monitoring program coupled with reproductive endpoints and biomarkers can increase the potential power of the caged mussel methodology. It is encouraging that so many differences in mussel condition where found when sites were separated by as little as two meters vertical distance. Similar results associated with depth were found in two similar studies using these ASTM-approved protocols (Applied Biomonitoring 1999, Salazar and Salazar 1995a, 1996, 1998).

6.4 Statistical Model

The choice of the appropriate statistical model was intensely debated for the caged mussel pilot study. The original statistical model was a split-plot design (Figure 12) which analyzed both location and depth effects (Appendix N). In EEM studies, differences among locations are the primary effects of interest. Depth was evaluated in the pilot study to demonstrate the need to consider depth effects and the location of the effluent plume in the sampling design. The split-plot design was more complex than those likely to be used for EEM and therefore the ANOVA model was more complex. This design sacrificed power for tests of location effects to improve power for tests of depth effects. While depth effects were observed (reduced growth with depth), these differences were similar among stations (Appendix N). The analysis was simplified by combining cage depths and comparing station differences using a one-way ANOVA. In future EEM studies, it might be more cost effective to replicate at stations rather than depths to provide more statistical power in examining effects associated with distance.

The systematic approach to bag-filling (Figure 9) was a control measure to distribute the mussels from different size classes equally among the cages. Initial size can affect both mussel growth rates and bioaccumulation of contaminants, so it has a confounding effect on the endpoints of interest. Care was taken to limit the initial size range of the test animals to ensure that they were at similar growth stages (i.e., 14-21 mm). When filling the mesh bags, mussels were systematically distributed across all cages one size class at a time (e.g., 14, 15, 16, 17 mm etc.). These steps effectively controlled for confounding differences in initial size by ensuring that animals of all sizes were exposed at all locations and depths. Although the cages were randomly assigned to stations and depths, some statisticians may claim that the systematic approach to bag-filling violated the basic assumptions of the statistical model. In practice, it is extremely difficult to randomly select 2000 mussels from a barrel because the smallest animals tend to sink to the bottom. The tendency to select the largest animals first and the smaller animals at the end skews their distribution among the cages. Therefore, beginning the test with a non-random sample would probably occur much more than by chance (5% of the time). Since the systematic distribution system has been used, there has never been a statistically significant difference in either weights or lengths at the beginning of the test. A strictly random approach does not allow for these confounding factors and would be extremely difficult to implement in practice. In a recent caged mussel pilot study at a Canadian pulp mill on the east coast where mussels were selected randomly, the size of mussels was significantly different among cages at the beginning of the test (Roy Parker, personal communication). This reduced the discriminating power of statistical analyses on end-of-test data.

Based on previous 40 bivalve transplant studies using this methodology, it is believed that a 10-25 percent absolute difference in growth rates can be routinely associated with statistical significance and could be considered environmentally significant. Numerous power analyses conducted for many data sets showed that about 100 individuals were necessary to achieve the power to detect statistically significant differences in growth when the growth rates differed by 25 percent (Salazar and Salazar 1995a). For example, the Sudbury River study with *Elliptio complanata* used three replicates of 35 animals each (about 100 animals) and detected statistically significant differences among sites (Beckvar et al. 2000, Salazar et al. 1996). The pilot study planned to use 100 mussels per cage but reduced the number to 90 because there were fewer mussels of the target size range. Nevertheless, the discriminating power was similar to what was predicted.

6.5 Commercial Availability

Commercial availability of the caged bivalve method increased through technology transfer during the pilot study. Representatives from government, industry, and consultants participated in every phase of the work from planning to mussel sorting and deployment, to retrieval and processing at the end of the test and data analysis. As a result of workshops on caged bivalves as a fish survey alternative (see Section 2.1) and involvement in the pilot study, other transplant studies were conducted using an early draft of the ASTM-accepted standard guidelines

(Salazar and Salazar 2001). For example, BC Ministry of Environment conducted caged mussel studies at two coastal pulp mills in 1997 and repeated the study at one mill in 1998 (Liz Freyman, BC Ministry of Environment, personal communication). They used *Mytilus trossulus* and exposed them for 42 to 52 days. Another study was conducted by BC Research Inc. for the BC Ministry of Environment to evaluate methylmercury contamination associated with a freshwater log salvage operation using the freshwater mussel *Elliptio complanata* (McDevitt et al. 1998). Paprican conducted a study at a freshwater site in Montreal, Quebec to test potential application to pulp and paper mill effluents. They used a 68-day exposure period and *Elliptio complanata* as the test species (Pierre Martel, Montreal EEM Research Meeting Presentation, December 1997).

After three years of intense peer review within ASTM, the *"Standard Guide for Conducting in-situ Field Bioassays with Marine, Estuarine and Freshwater Bivalves"* was finally approved on 12 November 2000. It will appear in the 2001 Annual Book of ASTM Standards.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The caged bivalve method, as a fish survey alternative, satisfies the weight of evidence approach used for EEM because it provides different information than the benthic surveys or the laboratory bioassays. Caged bivalves combine the experimental control of laboratory bioassays with the environmental realism of traditional field monitoring by measuring in situ exposure (bioaccumulation) and effects (growth and survival) in the same organism at the same time. The following conclusions and recommendations from the Port Alice Caged Mussel Pilot Study and related caged bivalve studies provide a basis to evaluate the approach for EEM:

- All 18 cages transplanted were retrieved (6 stations x 3 depths); predation, vandalism or other damage did not occur.

- Mussel survival was high (> 90%) and growth was substantial (~500% increase) over the 68-day exposure period.

- Test organisms (*Mytilus edulis*) came from the same broodstock (population and age) and were obtained from a local supplier. Selecting a minimal size range of test animals (length: 14-21 mm) and systematically distributing all sizes in each cage ensured no statistical differences among stations and depths at the start of the test. Cages were randomly assigned to stations. Growth differences among stations and depths at the end of the test were assumed to have occurred during the test period.

- Electronic measuring and recording devices made the data available for immediate analysis (e.g., confirming no statistical differences in length ana weight at the start of test before deploying cages).

- Although test animals were smaller than planned, 90 mussels per cage provided sufficient tissues for chemical analysis of resin acids, fichtelite, retene, and plant sterols using a new analytical technique developed by the Institute of Ocean Sciences (IOS) to accommodate the smaller sample volume.

- Several growth metrics (length growth, weight growth, EOT length, EOT WAWW, EOT shell weight, EOT tissue wet weight, and EOT condition index) and a biochemical endpoint (percent lipids) showed significant differences among sites ($p<0.05$). The method detected a statistically significant differences in mussel growth among sites when the absolute difference was as little as 10 percent. Significant growth differences were also observed with depth.

- Changes in mussel growth with depth and distance from the mill were compared to patterns of mill-related and natural factors using various analytical techniques. A significant relationship between the growth metrics weight growth and EOT tissue wet weight and the mill-related parameters SSL and DO was explained by exponential fit. Spent sulphite liquor measurements were the best available estimates of water column exposure to the mill effluent. Dissolved oxygen was a natural factor affected by the presence of mill effluent which increases oxygen demand. SSL significantly decreased and DO increased with distance down inlet from the mill diffuser and showed a strong inverse correlation to each other. Although temperature may have affected mussel growth with depth, it did not explain differences in mussel growth with distance. Food availability as measured by chlorophyll-a did not appear to be a significant factor affecting mussel growth with distance in the pilot study although the few data points made this relationship less certain.

- Standardized caged bivalve protocols were tested using workers inexperienced with the method. Some procedures were modified to improve guidance on application and technology was transferred to a number of participating consultants.

- Commercial availability of the caged bivalve method increased through technology transfer during the pilot study. Representatives from government, industry and consultants participated in every phase of the work from planning to mussel sorting and deployment to retrieval and processing at the end of the test and data analysis. Other studies were initiated using this approach. Recent approval and adoption of these methods by ASTM should increase the demand for its use and interest by consultants in learning the methodology.

- Depth was evaluated in the pilot study to demonstrate the need to consider depth effects and the location of the effluent plume in the sampling design. For EEM studies, it might be more effective to replicate at stations rather than depths to provide more statistical power in examining effects associated with distance and limit confounding depth effects from natural parameters.

- Based on the Port Alice Pilot Study and the previous 40 bivalve transplant studies using this methodology, it is believed that a 10-25 percent absolute difference in growth rates can be routinely associated with statistical significance and considered environmentally significant. Similarly, it is recommended that differences less than 10 percent be considered environmentally insignificant for purposes of EEM regardless of whether or not statistical significance has been demonstrated. It is further recommended that differences greater than 25 percent be considered environmentally significant whether or not there is statistical significance.

8.0 ACKNOWLEDGMENTS

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Caged Mussel Pilot Study
Port Alice Mill, Vancouver Island
EEM Program

APPENDICES

Appendix A

Initial Mussel Lengths

Initial Mussel Length (mm)

mean	17.05	17.03	17.03	17.08	17.05	16.97
min	14.77	14.62	14.63	14.56	14.64	14.65
max	20.98	20.96	20.93	20.79	20.65	20.92
stdev	1.49	1.42	1.51	1.44	1.48	1.49
count	270	270	270	270	270	270
2SE	0.181	0.173	0.184	0.175	0.180	0.181
Cage Numbers:	2, 10, 13	6, 17, 19	5, 7, 21	11, 15, 16	1, 9, 18,	4, 8, 14
	Station 1	**Station 2**	**Station 3**	**Station 4**	**Station 5**	**Station 6**
2meter 1	15.38	15.95	15.41	15.81	15.44	15.24
2	15.88	15.61	15.79	14.94	15.23	14.93
3	15.5	15.6	16.94	15.68	15.41	15.98
4	14.94	16.05	15.7	14.92	15.47	16.02
5	15.02	15.38	16.01	16.28	16.03	16.82
6	16.15	14.86	15.71	15.72	15.71	15.05
7	15.33	15.44	14.92	15.46	16.07	16.07
8	15.09	15.2	15.34	15.2	15.21	15.28
9	15.28	15.13	15.32	14.7	15.53	16.17
10	16.53	15.39	15.32	16.2	16.38	15.85
11	15.94	15.52	15.05	15.7	15.14	15.39
12	15.85	14.97	15.44	15.06	15.77	15.56
13	15.94	16	15.31	15.81	14.72	15.02
14	15.26	15.4	15.46	14.86	15.94	15.34
15	15.75	15.33	15.25	16.31	16.14	15.78
16	15.39	15.38	15.22	15.21	15.73	15.57
17	15.49	15.71	15.65	16.69	16.3	14.99
18	15.61	15.19	14.98	15.34	14.99	14.68
19	15.1	15.43	15.79	14.85	15.07	15.2
20	16.08	15.18	14.63	15.64	15.39	15.79
21	15.86	15.54	14.99	15.41	15.27	14.88
22	15.9	15.73	15.96	15.37	15.22	15.57
23	15.3	14.75	15.28	15.11	15.26	15.94
24	16.15	16.04	15.38	15.83	15.05	15.23
25	15.66	15.61	15.33	14.85	15.74	16.18
26	15.37	15.34	15.41	15.84	14.69	15.04
27	15.55	17.16	14.9	16.13	15.97	15.78
28	15.62	15.06	15.69	15.93	15.23	15.09
29	15.45	16.39	15.54	16.45	15.62	15.57
30	16.19	15.66	16.54	16.63	16.65	16.07
31	17.06	16.23	16.43	16.31	16.82	16.33
32	16.13	16.39	16.21	16.19	17.71	16.68
33	16.03	16.34	16.46	16.93	16.08	15.96
34	16.29	16.89	17.02	16.21	15.75	15.47
35	15.94	16.63	17.01	16.67	16.75	16.92
36	15.89	16.89	16.16	16.75	16.48	16.33
37	16.14	16.61	17.37	14.64	16.79	15.78
38	16.84	16.91	16.32	16.77	16.69	17.1
39	17.01	16.3	16.91	17.04	15.74	16.54
40	16.65	16.5	16.22	16.7	16.72	16.73
41	16.66	16.63	16.43	16.44	16.56	16.71
42	16.59	16.1	16.6	16.3	16.75	15.83
43	16.8	16.91	16.14	14.76	17.12	16.09
44	16.31	16.51	16.41	17.19	16.94	16.97
45	16.35	16.47	16.88	16.07	17.02	16.69
46	16.6	16.1	15.74	16.35	15.76	16.31
47	16.87	17.18	16.26	16.6	16.87	16.28
48	16.29	16.56	16.22	16.51	16.77	14.83
49	16.49	16.99	17.16	15.82	16.64	16.6
50	16.1	15.53	16.55	15.16	15.92	16.63
51	16.55	16.46	17.06	16.63	16.15	15.69
52	15.85	14.7	16.17	18.1	16.06	15.7
53	17.52	17.38	18	17.82	16.9	17.81
54	16.89	18.09	18.65	17.88	17.02	17.35
55	18.95	18.79	17.43	18.06	17.2	16.91
56	16.9	16.75	16.95	17.49	17.64	17.27
57	18.11	17.56	18.37	16.97	17.41	16.71

Initial Mussel Length (mm)

		Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
	58	16.87	16.87	17.22	17.58	18.15	16.78
	59	17.4	17.28	17.69	17.56	17.58	17.67
	60	18.42	17.88	17.75	18.93	16.79	17.58
	61	17.36	17.89	18.96	17.51	20.02	17.17
	62	17.31	17.48	17.02	17.17	17.47	19.81
	63	17.6	17.88	16.4	17.72	18.83	18.01
	64	17.14	18.27	17.61	16.79	17.77	17.28
	65	17.05	17.43	17.75	17.28	17.39	17.76
	66	17.68	16.85	17.04	17.49	18.94	18.9
	67	17.56	17.31	18.31	17.68	17.65	17.55
	68	17.48	17.61	17.56	17.5	17.66	17.28
	69	16.65	17.72	17.62	17.51	17.52	17.7
	70	18.89	18.33	18.77	18.23	19.23	17.06
	71	18.84	18.75	18.26	17.76	18.77	18.73
	72	18.03	18.02	18.44	19.45	18.1	19.04
	73	17.5	18.4	18.25	18.47	19.33	17.92
	74	18.91	18.74	18.64	18.74	18.36	18.48
	75	17.67	18.88	18.61	19.58	18.82	18.22
	76	18.33	18.87	18.26	17.76	18.59	19.89
	77	17.42	18.59	17.52	18.39	20.39	17.47
	78	18.47	20.57	20.25	19.16	17.82	18.03
	79	17.8	20.35	17.28	18.24	18.62	18.28
	80	16.91	18.34	18.27	18.45	18.84	18.49
	81	18.33	19.72	19.86	19.3	18.8	18.13
	82	19.52	19.3	20.05	19.65	19.59	19.35
	83	19.22	19.25	19.65	19.83	20.14	19.03
	84	19.63	20.24	19.78	20.06	19.93	19.68
	85	19.48	19.5	19.42	19.46	19.61	18.82
	86	18.79	19.47	19.29	18.29	20	19.6
	87	18.8	19.16	19.16	19.55	19.3	19.2
	88	19.69	19.17	18.93	19.73	18.95	19.51
	89	20.96	20.96	20.58	20.27	19.06	20.92
	90	19.99	19.94	20.58	20.55	20.35	19.59
4meter	1	15.78	15.06	16.32	14.61	15.49	15.23
	2	15.69	14.94	16.22	15.5	16.02	15.92
	3	15.87	15.63	15.92	15.59	15.14	15.06
	4	15.91	15.26	15.68	15.81	16.21	15.49
	5	15.17	15.01	14.81	15.19	16.12	14.97
	6	14.96	15.17	15.93	16.64	16.5	16.18
	7	14.93	16.2	15.42	14.92	15.44	15.37
	8	15.37	15.92	15.79	15.66	15.06	14.65
	9	15.92	14.62	15.61	16.08	15.03	15.78
	10	15.64	16.01	15.59	15.72	15.55	15.94
	11	15.78	15.51	15.94	15.67	15.9	14.97
	12	14.94	16	15.3	16.13	15.34	16.18
	13	15.14	15.9	15.51	15.2	15.21	15.48
	14	14.83	15.52	14.92	15.91	15.15	15.27
	15	15.48	16.12	15.16	15.15	15.1	14.96
	16	15.92	15.21	15.13	15.96	15.85	15.12
	17	16.03	15.04	15	15.81	16	16.21
	18	15.78	15.23	15.09	15.41	15.78	15.43
	19	15.26	15.24	16.13	15.82	16.23	15.31
	20	15.43	15.62	16.23	16.23	15.31	15.33
	21	14.83	15.33	15.6	15.58	15.11	14.72
	22	15.79	15.39	15.05	15.09	14.64	15.11
	23	15.7	14.94	14.69	14.95	14.8	15.56
	24	14.87	15.52	15.11	16.25	15.71	15.37
	25	15.17	16.1	16.11	17.28	15.71	15.38
	26	15.38	15.68	16.16	15.58	15.37	15.21
	27	15.47	18.21	14.83	16.39	15.58	14.9
	28	15.75	16.08	16.04	16.45	14.9	15.33
	29	16.8	16.31	14.92	16.89	15.15	15.58
	30	16.93	16	16.52	17.05	16.61	16.45
	31	16.11	16.31	16.75	16.34	16.35	16.25

Initial Mussel Length (mm)

		Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
	32	17.06	16.04	16.04	16.38	16.29	15.77
	33	15.96	16.69	16.69	17.18	16.35	16.48
	34	16.61	16.62	16.41	15.36	16.17	16.52
	35	16.28	16.29	15.81	16.72	16.01	16.18
	36	16.75	16.77	14.87	16.69	16.16	16.47
	37	16.7	16.71	15.05	16.05	16.56	17.07
	38	16.18	16.83	17.11	16.2	17	16.49
	39	17.15	16.87	16.3	16.72	16.27	16.22
	40	16.24	16.6	17.87	16.17	17.08	16.39
	41	17.41	16.68	16.92	16.71	16.49	16.49
	42	16.12	16.67	16.75	16.98	16.06	16.82
	43	16.95	16.64	15.92	16.64	16.82	15.91
	44	16.48	17.11	16.05	16.76	16.69	16.11
	45	16.02	16.73	16.72	16.35	16.44	16.15
	46	16.23	16.74	16.71	16.84	16.86	16.36
	47	15.87	16.62	16.7	16.89	16.13	16.79
	48	15.71	16.1	17.5	16.11	16.93	16.13
	49	16.01	16.52	16.64	14.67	16.27	16.79
	50	15.65	15.82	15.94	15.96	17.11	16.33
	51	16.55	17.89	16.71	20.02	16.84	16.16
	52	17.83	17.44	15.21	17.57	17.67	20.16
	53	17.85	18.06	17.34	17.06	17.24	17.34
	54	18.52	18.44	17.71	17.28	17.35	17.15
	55	18.01	17.99	17.3	17.72	17.62	19.83
	56	17.05	18.19	18.61	17.04	16.99	16.77
	57	17.67	17.22	17.39	18.04	16.96	17.27
	58	17.86	17.38	17.27	17.08	17.26	18.36
	59	18.37	17.41	19.84	20.38	19.07	17.48
	60	17.29	17.22	18.03	17.35	18.19	17.14
	61	17.46	17.45	17.54	19.09	18.73	17.22
	62	17.12	18.18	16.68	19.07	16.75	17.01
	63	16.96	17.74	17.14	18	17.23	17.33
	64	16.94	17.64	17.82	17.44	17.03	17.45
	65	17.34	17.4	17.42	16.6	17.8	17.3
	66	19.31	17.21	17.25	17.21	17.52	17.39
	67	17.54	17.08	17.92	17.82	17.43	17.32
	68	16.91	17.99	18.01	17.31	17.12	19.69
	69	19.67	18.56	17.83	18.26	17.44	17.82
	70	18.46	18.43	18.35	18.33	18.28	18.31
	71	20.98	18.15	18	19.02	18.7	18.73
	72	18.7	19.97	19.27	18.71	20.35	18.76
	73	18.94	18.12	18.18	18.85	18.46	18.33
	74	18.43	18.56	18.76	18.3	18.41	18.29
	75	18.45	18.62	17.26	18.11	18.91	18.88
	76	20.3	18.71	19.09	18.44	19.66	18.26
	77	19	19.11	19.16	18.73	19.82	18.35
	78	18.99	18.22	19.31	19.27	18.41	18.85
	79	18.19	18.26	18.49	18.48	18.48	17.65
	80	18.6	18.51	18.91	18.2	18.68	18.17
	81	19.21	18.18	19.29	18.32	19.43	19.31
	82	19.37	19.27	19.22	17.92	19.87	19.51
	83	19.92	19.78	19.47	19.48	19.68	19.78
	84	19.46	18.69	19.6	19.52	19.4	19.02
	85	19.36	18.92	19.41	19.86	18.71	20
	86	19.02	19.1	19.43	18.57	19.74	19.28
	87	19.45	19.68	19.4	19.61	19.04	18.97
	88	19.5	19.29	19.64	19.11	19.2	19.4
	89	20.87	19.78	20.64	19.42	20.65	20.51
	90	20.58	19.35	20.86	19.35	19.67	20.55
	6meter 1	15.32	15.84	17.09	15.84	15.48	15.22
	2	15.12	15.07	15.42	15.63	16.05	15.9
	3	14.77	15.37	14.85	15.32	16.21	15.48
	4	16.13	15.11	15.8	15.78	16.06	15.49
	5	15.44	15.19	15.5	16.45	15.39	14.82

Initial Mussel Length (mm)

		Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
	6	16.56	15.68	15.71	15.61	16.51	16.37
	7	15.85	15.53	15.33	16.28	15.03	14.91
	8	15.87	15.21	15.54	15.85	15.54	15.52
	9	15.54	16.22	16	15.86	15.74	14.93
	10	15.25	15.85	15.1	15.77	15.27	15.52
	11	15.44	15.33	15.68	15.96	15.83	14.77
	12	15.75	15.17	15.02	14.56	14.84	15.93
	13	15.71	16.07	15.99	17.43	15.58	15.5
	14	15.73	16.05	15.87	15.55	14.71	15.72
	15	15.43	15.66	15.25	16.14	15.19	15.13
	16	15.45	14.93	15.64	15.73	15.4	15.15
	17	15.52	15.72	15.12	15.85	16.02	15.1
	18	15.41	16.16	15.07	15.2	15.14	15.84
	19	15.56	15.27	15.67	14.95	16.14	15.41
	20	15.41	15.55	15.31	16	15.11	14.91
	21	15.73	15.58	16	15.61	15.69	14.77
	22	15.68	15.71	15.74	15.94	15.27	15.38
	23	15.16	15.92	14.69	14.92	15.33	15.65
	24	15.31	16.06	15.4	14.96	15.06	15.91
	25	15.24	15.25	16.01	16.08	15.45	15.8
	26	15.98	15.58	16.09	15.28	14.98	15.82
	27	17.15	16.17	16.57	16.8	16.38	17.18
	28	15.87	17.2	15.77	16.46	16.48	16.87
	29	16.31	16.21	16.12	16.66	16.36	16.59
	30	16.48	16.34	16.69	16.95	16.98	16.14
	31	17	16.75	16.35	17.17	16.17	16.51
	32	16.12	16.54	17.07	16.33	16.97	17.07
	33	16.81	17.07	16.04	16.15	16.43	16.81
	34	15.9	16.62	16.06	16.98	16.52	16
	35	17.26	16.3	16.12	17.11	15.69	15.87
	36	17.1	16.78	16.98	16.36	16.31	16.28
	37	16.69	16.16	16.37	16.58	16.9	16.64
	38	16.57	16.41	15.73	16.14	16.31	16.74
	39	18.09	16.95	17.9	17.01	16.59	16.72
	40	15.78	17.32	16.73	16.39	17.17	16.29
	41	16.8	16.62	16.54	16.67	16.69	16.99
	42	16.6	16.29	16.19	16.51	17.13	16.68
	43	16.81	16.71	15.38	16.68	16.45	16.73
	44	16.06	16.49	16.55	17.69	15.68	17.04
	45	16.9	15.76	16.73	16.61	16.27	16.89
	46	16.4	16.75	16.23	16.11	16.56	16.62
	47	16.82	16.35	16.57	16.83	16.45	16.7
	48	16.47	16.91	16.85	16.72	17.09	16.78
	49	15.96	16.86	16.99	16.55	16.33	16.58
	50	17.06	14.78	16.82	15.69	17.1	16.5
	51	17.13	17.49	18.88	18	17.82	17.68
	52	18.03	18.5	18.09	18.55	17.17	17.27
	53	17.3	17.22	17.22	17.28	17.66	17.1
	54	17.7	17.64	17.56	17.4	18.53	17.68
	55	17.9	18.11	17.63	17.57	18.01	19.11
	56	17.15	17.59	19.3	18.69	17.43	17.31
	57	17.68	19.82	20.93	17.55	17.51	18.14
	58	19.3	17.53	17.89	17.5	18.33	17.57
	59	16.83	17.26	18.01	17.84	17.1	17.39
	60	17.49	18.93	16.84	17.8	17.44	17.88
	61	17.76	18.17	17.59	17.27	19.09	17.52
	62	18.72	16.83	17.41	17.62	17.8	17.79
	63	19.08	17.65	19.93	17.01	17.53	17.9
	64	17.48	17.48	17.78	17.48	17.32	17.24
	65	17.92	17.84	17.95	17.35	17.67	18.76
	66	17.82	17.48	17.49	17.32	17.4	17.8
	67	18.97	17.2	17.28	17.61	17.91	18.78
	68	19.17	17.61	17.94	17.68	18.69	17.66
	69	18.39	18.77	18.28	18.9	18.42	19.82

Initial Mussel Length (mm)

		Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
	70	17.8	18.29	18.35	19.07	18.46	19.21
	71	19.16	18.79	18.38	18.36	20.51	18.87
	72	20.29	18.41	18.41	18.19	18.56	20.83
	73	18.79	18.51	18.58	18.08	18.06	18.82
	74	18.54	18.18	18.52	18.53	18.86	20.34
	75	18.63	17.71	19.25	20.79	19.06	18.52
	76	20.72	17.99	18.21	18.64	18	18.48
	77	18.36	18.1	18.18	18.66	19.08	18.15
	78	18.09	17.81	18.58	20.13	18.26	17.99
	79	18.63	17.03	18.27	18.52	18.84	18.75
	80	18.49	18.37	18.46	18.39	18.1	17.02
	81	18.51	18	18.41	17.93	18.47	18.17
	82	18.21	19.82	19.28	18.6	17.93	18.13
	83	19.41	19.52	19.68	19.84	19.92	19.36
	84	19.75	19.04	19.58	19.58	19.11	19.43
	85	19.9	19.47	19.77	19.1	19.18	19.01
	86	19.36	18.92	19.62	19.62	18.59	18.12
	87	19.53	19.82	19.21	20.02	19.08	19.55
	88	19.32	19.22	19.08	19.09	19.32	19.32
	89	19.83	19.74	19.59	19.28	19.3	19.51
	90	19.72	19.07	19.25	19.97	19.73	18.09

Appendix B

End-of-Test Mussel Lengths

End-of-Test Mussel Shell Length (mm)

mean	29.15	28.66	29.56	29.63	29.85	29.84
min	16.00	16.37	14.96	17.79	15.90	17.07
max	39.58	38.05	38.76	39.56	39.57	39.03
stdev	4.77	4.72	4.60	4.48	4.82	4.63
count	249	256	258	254	257	255
2SE	0.605	0.589	0.573	0.562	0.602	0.579
Cage#:	2, 10, 13	6, 17, 19	5, 7, 21	11, 15, 16	1, 9, 18,	4, 8, 14
	Station 1	**Station 2**	**Station 3**	**Station 4**	**Station 5**	**Station 6**
2meter 1	M	23.29	M	28.94	23.45	22.10
2	32.92	33.11	31.17	30.89	D	29.42
3	25.09	21.23	29.85	19.84	30.92	33.14
4	16.07	25.59	25.96	25.24	29.02	30.03
5	28.14	32.48	30.06	30.62	34.76	34.36
6	M	30.37	34.99	M	28.65	22.82
7	22.26	18.57	25.61	30.46	30.12	33.28
8	M	29.23	33.83	33.39	28.67	19.89
9	20.20	30.41	34.23	18.80	30.84	34.81
10	32.51	24.55	M	26.50	30.87	30.55
11	29.14	22.11	33.58	28.76	M	28.89
12	31.16	31.54	30.16	24.88	33.60	29.61
13	19.28	30.12	31.84	26.63	31.02	33.27
14	M	29.55	31.30	24.54	21.40	26.62
15	33.43	30.52	33.95	35.12	28.54	23.64
16	20.74	30.99	32.39	M	M	M
17	28.67	27.64	19.48	35.25	24.33	21.32
18	21.82	30.79	33.16	32.88	20.46	33.59
19	29.57	28.87	27.52	30.73	29.69	23.89
20	D	17.88	22.93	M	30.56	17.07
21	35.47	28.43	27.39	32.14	31.03	33.09
22	M	22.56	29.88	29.07	21.69	26.01
23	29.28	25.26	28.58	M	M	34.60
24	36.50	34.13	29.07	31.59	34.45	18.16
25	26.07	28.02	22.84	32.06	32.21	20.87
26	33.42	33.12	32.93	34.58	32.50	36.62
27	33.46	35.76	14.96	33.79	34.88	25.32
28	29.39	21.26	32.82	29.49	26.77	29.28
29	36.32	30.86	33.17	29.06	33.39	M
30	33.25	29.63	24.38	34.11	34.97	24.10
31	19.78	35.29	29.89	33.88	35.82	29.25
32	30.60	27.64	33.52	32.44	26.02	26.77
33	25.88	31.36	34.13	31.39	33.47	33.31
34	28.75	32.05	25.90	30.16	20.34	27.44
35	22.62	33.09	29.93	31.99	M	26.52
36	28.51	27.48	28.03	32.97	25.32	M
37	M	20.83	32.69	32.35	32.39	32.13
38	33.86	24.45	33.10	22.65	30.51	M
39	33.81	29.66	27.61	34.58	34.31	23.71
40	25.04	33.32	D	28.90	35.86	28.25
41	32.93	M	32.79	29.77	33.05	32.18
42	20.00	21.97	36.13	31.42	20.57	33.32
43	35.16	M	31.68	32.13	18.77	M
44	34.42	25.64	33.47	33.32	24.53	28.74
45	30.77	M	36.07	33.87	27.53	19.55
46	19.57	M	20.27	26.83	35.43	21.68
47	26.42	26.72	24.73	27.65	31.14	34.65
48	35.01	22.03	34.40	24.75	36.22	33.68
49	32.82	20.22	34.86	33.36	26.72	30.32
50	30.09	35.41	35.07	D	27.58	19.90
51	23.72	33.22	M	36.09	31.70	29.39
52	26.65	27.49	28.72	23.13	26.73	29.82
53	32.84	23.90	36.28	25.45	34.43	33.01
54	32.98	35.67	33.80	34.72	21.30	34.75
55	36.52	31.73	27.19	29.48	27.14	30.79
56	35.38	M	24.18	34.67	27.64	34.11
57	34.68	37.40	37.03	35.09	34.10	30.01
58	21.72	30.72	35.66	34.06	29.37	34.29
59	25.43	32.38	35.78	29.57	38.61	32.49

End-of-Test Mussel Shell Length (mm)

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
60	35.33	34.72	30.12	24.00	39.57	35.43
61	32.27	22.38	25.40	31.35	35.49	32.59
62	25.73	24.99	28.61	31.58	24.80	32.74
63	34.99	33.38	D	27.43	34.40	25.78
64	31.51	25.48	35.16	18.50	24.90	28.89
65	31.93	34.85	34.48	33.10	30.44	29.06
66	31.16	32.13	32.52	29.73	32.85	31.32
67	30.04	32.44	30.25	23.17	25.54	29.60
68	33.29	29.20	34.13	32.20	36.97	32.34
69	31.18	22.79	26.35	30.63	24.21	35.76
70	24.11	28.82	27.37	34.32	37.53	36.68
71	24.94	31.19	26.98	31.20	22.38	33.40
72	33.08	19.84	26.65	32.33	34.77	29.62
73	29.67	27.77	34.33	23.85	30.79	26.45
74	39.58	30.93	35.17	33.46	38.14	36.16
75	28.65	30.19	32.20	23.10	38.22	36.61
76	36.00	28.44	36.88	23.62	27.34	36.26
77	32.79	30.02	27.64	27.18	28.29	34.08
78	30.54	38.05	38.76	35.34	28.19	39.03
79	M	24.30	26.22	27.43	38.96	32.88
80	29.30	33.97	26.57	24.16	28.34	36.17
81	21.77	37.94	34.83	36.20	36.51	26.10
82	35.18	34.73	35.36	38.65	31.45	38.49
83	35.69	35.00	27.15	33.61	31.27	32.95
84	33.21	35.62	37.42	37.37	30.75	33.12
85	32.89	24.54	32.54	25.30	36.20	23.04
86	25.08	34.24	36.26	37.14	30.98	35.88
87	22.18	24.47	35.34	31.95	29.94	35.26
88	28.30	36.68	32.19	34.73	32.99	35.99
89	27.62	23.93	35.95	28.21	31.14	27.98
90	30.63	30.51	24.47	39.45	36.49	35.56
4meter 1	25.93	16.37	25.84	29.24	M	28.09
2	32.34	18.39	31.78	30.78	29.80	21.87
3	29.96	28.87	30.82	20.16	26.43	M
4	31.00	24.92	D	M	32.56	D
5	30.46	21.52	31.27	M	22.29	M
6	30.09	22.42	33.50	33.01	26.71	31.96
7	M	30.11	31.63	21.68	24.77	30.90
8	32.58	29.57	24.16	M	32.50	33.78
9	28.76	18.13	M	32.93	27.80	28.51
10	20.73	21.61	30.13	31.31	16.68	31.77
11	22.03	30.48	28.77	26.04	18.91	28.73
12	23.54	17.83	28.01	27.35	M	34.40
13	M	25.37	31.80	32.69	32.27	31.43
14	31.74	31.37	32.09	M	35.23	28.25
15	M	24.09	28.57	29.55	31.20	C
16	31.48	30.54	32.01	32.54	29.93	23.88
17	27.83	19.77	23.01	29.97	30.98	M
18	25.86	28.26	33.32	30.14	35.22	31.92
19	34.17	28.12	32.30	23.79	25.05	31.01
20	18.69	23.96	28.88	31.42	33.48	27.08
21	31.94	32.57	28.86	30.30	33.43	36.20
22	35.93	D	27.20	20.41	31.50	31.94
23	16.00	30.19	35.05	27.36	33.83	30.05
24	32.97	27.31	31.01	30.43	M	18.51
25	32.98	29.45	33.67	33.48	32.78	33.02
26	23.13	24.37	16.87	26.42	28.96	31.16
27	27.47	30.36	M	27.39	19.95	27.01
28	M	31.31	24.55	35.12	15.90	32.91
29	29.24	25.14	31.97	34.38	26.43	30.26
30	30.55	19.56	26.76	28.04	30.55	23.87
31	30.72	23.13	26.90	35.96	31.99	29.69
32	33.04	22.15	18.26	32.52	32.54	22.44
33	19.38	18.10	29.32	30.67	24.69	28.54
34	27.24	30.46	26.83	21.07	18.52	28.31
35	18.99	29.78	21.85	30.83	32.61	23.32

End-of-Test Mussel Shell Length (mm)

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
36	23.41	D	M	23.17	27.96	26.25
37	28.11	31.32	18.16	32.05	32.56	29.22
38	22.61	30.16	36.25	29.52	31.35	31.68
39	31.10	31.42	29.07	33.66	M	31.79
40	27.88	33.06	23.88	29.59	35.69	34.80
41	28.58	29.82	33.78	31.35	32.31	34.81
42	33.83	32.48	30.59	31.62	32.96	33.87
43	33.61	31.83	32.88	32.70	34.30	32.20
44	33.72	26.72	M	28.83	33.31	18.38
45	M	30.55	30.76	20.05	33.38	28.86
46	28.00	28.27	29.07	24.53	25.67	33.34
47	26.02	32.61	27.11	33.66	22.93	33.24
48	17.20	22.47	22.20	18.56	28.53	20.58
49	M	D	21.67	19.02	32.92	35.47
50	25.16	28.62	26.76	32.12	32.13	25.65
51	26.69	22.80	34.25	33.02	32.02	24.35
52	35.74	29.76	33.34	28.40	30.43	27.64
53	33.39	33.28	30.16	33.85	18.87	24.69
54	30.60	33.30	31.66	34.02	29.39	32.84
55	32.56	34.38	22.95	30.36	34.85	35.71
56	27.32	29.43	34.44	28.52	35.47	32.19
57	32.73	24.67	33.51	33.17	31.47	29.99
58	33.16	34.18	34.98	33.18	35.04	33.44
59	37.25	32.28	34.37	30.65	36.18	32.58
60	32.32	32.64	31.30	31.42	36.63	34.05
61	31.92	27.72	35.00	33.86	32.39	23.73
62	36.13	30.38	26.77	24.72	19.79	29.61
63	36.31	27.38	32.35	25.33	33.53	30.19
64	34.04	31.58	34.00	31.56	23.92	M
65	28.33	28.64	D	32.33	35.77	32.28
66	30.85	31.32	32.50	32.11	33.99	36.06
67	29.48	28.15	37.01	23.75	24.19	34.61
68	34.99	22.90	26.56	34.16	28.33	36.44
69	31.58	31.31	35.46	27.75	34.83	35.94
70	35.56	34.11	30.22	23.00	27.15	26.47
71	33.81	32.53	30.70	24.81	34.35	32.66
72	32.51	35.22	32.18	28.12	36.66	25.22
73	33.04	33.52	32.83	33.74	29.40	36.68
74	36.18	32.50	31.96	32.47	26.26	26.69
75	34.82	32.50	27.44	36.41	31.51	31.83
76	34.07	25.99	33.15	27.86	34.08	M
77	26.09	38.05	36.33	34.94	35.34	24.50
78	D	31.84	26.96	28.38	25.29	34.00
79	D	35.29	32.22	35.96	37.34	31.92
80	34.70	34.39	33.52	32.52	32.19	34.00
81	29.92	33.29	24.11	29.02	34.80	35.23
82	D	32.09	29.43	33.03	33.98	34.05
83	31.43	25.43	27.03	30.19	39.09	28.02
84	34.97	31.64	33.99	34.01	31.51	33.11
85	36.30	28.41	33.40	39.56	20.93	35.82
86	24.31	31.19	29.24	37.94	33.13	35.70
87	36.17	26.32	31.83	26.40	23.85	26.72
88	31.88	33.29	27.25	32.93	24.00	37.87
89	29.18	27.03	28.20	29.08	35.29	35.49
90	33.03	30.10	27.07	35.45	35.49	31.43
6meter 1	28.31	27.62	27.23	24.41	22.29	21.50
2	19.01	31.71	24.96	28.52	24.98	27.17
3	28.50	33.11	31.72	33.00	30.19	31.10
4	30.02	17.45	27.19	28.13	32.65	30.07
5	29.51	25.58	31.15	M	31.06	24.90
6	22.71	20.98	20.05	19.91	29.50	30.14
7	28.87	26.98	32.00	20.02	27.64	27.85
8	20.88	19.83	20.96	30.03	20.24	27.59
9	26.78	28.71	28.80	28.17	30.28	29.42
10	33.56	18.77	16.78	27.87	28.96	33.70
11	31.80	30.55	21.69	D	30.36	23.54

End-of-Test Mussel Shell Length (mm)

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
12	D	29.59	28.98	29.91	28.14	31.61
13	19.60	28.14	17.81	30.60	27.89	25.22
14	27.64	30.25	22.76	27.44	D	24.41
15	29.99	25.20	29.81	25.52	27.18	31.48
16	31.96	30.11	20.66	29.99	D	23.45
17	31.53	23.91	M	30.63	19.37	29.08
18	18.67	25.24	26.61	M	26.34	28.75
19	25.86	M	29.70	23.14	32.86	26.20
20	28.57	31.95	29.01	M	30.12	18.37
21	25.91	31.22	33.38	24.24	30.57	20.44
22	28.07	30.84	28.56	31.51	M	22.11
23	25.76	21.47	29.25	25.79	26.85	17.80
24	27.24	29.78	17.28	D	30.63	29.96
25	18.68	31.00	33.39	33.08	28.89	25.06
26	30.37	17.62	19.27	25.94	31.31	28.41
27	27.25	M	34.02	29.59	33.72	28.66
28	30.27	33.16	27.53	25.02	28.57	31.01
29	31.16	26.89	24.33	29.12	M	31.31
30	21.25	27.98	29.05	28.16	31.33	33.35
31	22.99	27.74	27.76	18.10	32.70	30.96
32	29.15	30.28	20.22	25.71	29.64	29.56
33	19.28	31.32	26.40	32.33	28.24	23.14
34	31.84	29.50	32.45	33.43	27.03	24.41
35	29.43	26.74	31.17	29.16	26.80	32.22
36	M	28.99	29.12	25.98	32.28	33.16
37	25.65	D	29.72	28.94	23.55	32.75
38	27.68	31.58	20.63	30.21	25.53	26.91
39	30.67	21.14	24.41	29.17	24.58	29.59
40	31.10	25.36	23.13	M	24.71	23.91
41	22.16	33.11	29.33	30.21	29.26	30.55
42	30.79	25.11	30.10	29.72	33.38	31.00
43	21.84	26.06	29.27	18.00	29.63	28.58
44	30.20	26.29	29.32	30.33	20.61	23.90
45	26.75	27.11	17.62	17.79	28.38	30.27
46	31.70	30.49	32.62	30.19	18.53	28.37
47	32.14	20.12	28.71	30.47	26.62	28.32
48	24.78	33.50	25.89	32.04	22.29	31.99
49	M	30.06	31.21	28.20	32.96	34.02
50	34.07	M	25.87	M	21.70	32.50
51	29.19	20.30	25.43	30.43	33.58	33.43
52	22.36	30.53	27.16	33.76	31.25	M
53	30.71	28.00	30.58	25.63	31.50	32.45
54	28.91	20.65	27.24	23.71	27.72	20.11
55	25.86	31.32	26.15	32.95	32.11	M
56	22.88	30.05	34.36	27.33	22.37	28.61
57	24.69	22.01	27.79	30.69	26.63	26.84
58	D	32.73	29.36	30.46	31.18	32.89
59	28.03	28.04	24.44	30.12	31.89	31.57
60	26.52	32.28	34.66	32.56	31.51	28.21
61	28.53	25.51	34.46	31.94	28.02	27.78
62	33.22	31.73	31.91	20.57	33.56	24.89
63	33.64	30.39	33.26	32.71	21.68	27.68
64	31.35	18.78	30.48	24.05	31.91	M
65	31.73	D	27.78	21.41	33.53	31.18
66	28.10	29.97	30.51	25.93	34.38	29.78
67	32.99	32.60	33.89	22.93	32.49	30.21
68	32.17	28.43	32.25	30.85	26.24	32.45
69	23.37	35.80	31.84	24.52	25.29	25.36
70	32.74	33.52	23.42	35.05	32.23	30.78
71	32.02	33.74	36.21	23.84	34.72	31.84
72	33.23	32.05	24.36	33.30	34.86	36.04
73	30.64	32.47	34.81	19.42	24.47	28.06
74	22.38	31.97	31.57	31.92	23.26	36.47
75	31.69	25.69	30.22	29.18	33.86	19.96
76	30.79	29.33	32.53	33.45	24.78	34.98
77	24.15	30.39	30.34	29.96	24.87	31.76

End-of-Test Mussel Shell Length (mm)

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
78	29.87	32.28	30.74	33.95	28.91	34.34
79	26.46	29.49	30.04	29.54	26.14	34.79
80	25.84	23.06	28.71	28.93	34.29	23.21
81	30.70	27.50	30.83	32.15	28.76	33.12
82	32.26	34.12	24.63	32.03	34.31	33.50
83	29.31	36.37	33.72	28.49	35.67	31.64
84	27.40	23.51	23.85	29.04	33.34	30.92
85	31.82	32.36	34.60	32.24	34.97	26.28
86	32.89	24.67	24.74	35.05	31.08	29.89
87	25.17	34.56	28.50	34.93	35.55	35.39
88	22.07	D	31.03	28.49	29.55	32.00
89	33.63	34.54	33.52	36.73	31.06	33.07
90	29.28	29.49	27.32	33.31	32.37	32.77
	D = dead					
	M = missing					
	C = crushed; not able to make weight or length measurements,					
		but tissue still intact				

Appendix C

Length Growth Rates

Length Growth Rates (mm/wk)

mean	1.24	1.20	1.29	1.28	1.31	1.32
min	0.03	0.13	0.01	0.10	0.10	0.13
max	2.15	2.05	2.10	2.03	2.35	2.22
stdev	0.47	0.46	0.46	0.45	0.48	0.44
count	249	256	258	254	257	255
2SE	0.060	0.057	0.058	0.056	0.060	0.056
Cage#:	2, 10, 13	6, 17, 19	5, 7, 21	11, 15, 16	1, 9, 18,	4, 8, 14
	Station 1	**Station 2**	**Station 3**	**Station 4**	**Station 5**	**Station 6**
2meter 1	M	0.76	M	1.35	0.83	0.71
2	1.76	1.80	1.59	1.64	D	1.49
3	0.99	0.58	1.33	0.43	1.60	1.77
4	0.12	0.98	1.06	1.06	1.40	1.44
5	1.35	1.76	1.45	1.48	1.93	1.81
6	M	1.60	1.99	M	1.33	0.80
7	0.71	0.32	1.10	1.55	1.45	1.77
8	M	1.45	1.91	1.88	1.39	0.48
9	0.51	1.58	1.95	0.42	1.58	1.92
10	1.65	0.94	M	1.06	1.49	1.52
11	1.36	0.68	1.91	1.35	M	1.39
12	1.58	1.71	1.52	1.01	1.84	1.45
13	0.34	1.46	1.70	1.12	1.68	1.88
14	M	1.46	1.63	1.00	0.56	1.16
15	1.82	1.57	1.93	1.94	1.28	0.81
16	0.55	1.61	1.77	M	M	M
17	1.36	1.23	0.39	1.91	0.83	0.65
18	0.64	1.61	1.87	1.81	0.56	1.95
19	1.49	1.39	1.21	1.64	1.51	0.90
20	D	0.28	0.86	M	1.56	0.13
21	2.02	1.33	1.28	1.72	1.62	1.88
22	M	0.70	1.44	1.41	0.67	1.08
23	1.44	1.08	1.37	M	M	1.92
24	2.10	1.86	1.41	1.62	2.00	0.30
25	1.07	1.28	0.77	1.77	1.70	0.48
26	1.86	1.83	1.81	1.93	1.84	2.22
27	1.85	1.92	0.01	1.82	1.95	0.98
28	1.42	0.64	1.77	1.40	1.19	1.46
29	2.15	1.49	1.82	1.30	1.83	M
30	1.76	1.44	0.81	1.80	1.89	0.83
31	0.28	1.96	1.39	1.81	1.96	1.33
32	1.49	1.16	1.78	1.68	0.86	1.04
33	1.02	1.55	1.82	1.49	1.79	1.79
34	1.28	1.56	0.92	1.44	0.47	1.23
35	0.69	1.70	1.33	1.58	M	0.99
36	1.30	1.09	1.22	1.67	0.91	M
37	M	0.44	1.58	1.83	1.61	1.69
38	1.75	0.78	1.73	0.61	1.42	M
39	1.73	1.38	1.10	1.81	1.91	0.74
40	0.86	1.73	D	1.26	1.97	1.19
41	1.68	M	1.69	1.37	1.70	1.59
42	0.35	0.61	2.01	1.56	0.39	1.80
43	1.89	M	1.60	1.79	0.17	M
44	1.87	0.94	1.76	1.66	0.78	1.21
45	1.49	M	1.98	1.84	1.08	0.29
46	0.31	M	0.47	1.08	2.03	0.55
47	0.98	0.98	0.87	1.14	1.47	1.89
48	1.93	0.56	1.87	0.85	2.01	1.94
49	1.68	0.33	1.82	1.81	1.04	1.41
50	1.44	2.05	1.91	D	1.20	0.34
51	0.74	1.73	M	2.01	1.60	1.41
52	1.11	1.32	1.29	0.52	1.10	1.46
53	1.58	0.67	1.88	0.79	1.81	1.57
54	1.66	1.81	1.56	1.74	0.44	1.79
55	1.81	1.33	1.01	1.18	1.02	1.43
56	1.91	M	0.75	1.77	1.03	1.74
57	1.71	2.05	1.92	1.87	1.72	1.37
58	0.50	1.43	1.90	1.70	1.16	1.81
59	0.83	1.56	1.86	1.24	2.17	1.53

Length Growth Rates (mm/wk)

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
60	1.74	1.74	1.28	0.52	2.35	1.84
61	1.54	0.46	0.66	1.43	1.59	1.59
62	0.87	0.77	1.19	1.49	0.76	1.33
63	1.79	1.60	D	1.00	1.61	0.80
64	1.48	0.74	1.81	0.18	0.74	1.20
65	1.53	1.80	1.72	1.63	1.35	1.16
66	1.39	1.58	1.60	1.26	1.43	1.28
67	1.29	1.56	1.23	0.57	0.81	1.24
68	1.63	1.19	1.71	1.52	1.99	1.55
69	1.50	0.52	0.90	1.35	0.69	1.86
70	0.54	1.08	0.89	1.66	1.89	2.02
71	0.63	1.28	0.90	1.39	0.37	1.51
72	1.55	0.19	0.85	1.33	1.72	1.09
73	1.25	0.97	1.66	0.55	1.18	0.88
74	2.13	1.26	1.70	1.52	2.04	1.82
75	1.13	1.17	1.40	0.36	2.00	1.90
76	1.82	0.99	1.92	0.60	0.90	1.69
77	1.58	1.18	1.04	0.91	0.81	1.71
78	1.24	1.80	1.91	1.67	1.07	2.16
79	M	0.41	0.92	0.95	2.10	1.51
80	1.28	1.61	0.86	0.59	0.98	1.82
81	0.35	1.88	1.54	1.74	1.83	0.82
82	1.61	1.59	1.58	1.96	1.22	1.97
83	1.70	1.62	0.77	1.42	1.15	1.44
84	1.40	1.59	1.82	1.78	1.11	1.39
85	1.38	0.52	1.35	0.60	1.71	0.44
86	0.65	1.52	1.75	1.94	1.13	1.68
87	0.35	0.55	1.67	1.28	1.10	1.66
88	0.89	1.81	1.37	1.55	1.45	1.70
89	0.69	0.31	1.58	0.82	1.25	0.73
90	1.10	1.09	0.40	1.95	1.66	1.65
4meter 1	1.05	0.14	0.98	1.51	M	1.33
2	1.72	0.36	1.60	1.58	1.42	0.61
3	1.45	1.36	1.54	0.47	1.16	M
4	1.56	1.00	D	M	1.69	D
5	1.58	0.67	1.70	M	0.64	M
6	1.56	0.75	1.81	1.69	1.05	1.63
7	M	1.43	1.67	0.70	0.96	1.60
8	1.77	1.41	0.86	M	1.80	1.97
9	1.32	0.36	M	1.74	1.32	1.31
10	0.52	0.58	1.50	1.61	0.12	1.63
11	0.64	1.54	1.32	1.07	0.31	1.42
12	0.89	0.19	1.31	1.16	M	1.88
13	M	0.98	1.68	1.80	1.76	1.64
14	1.74	1.63	1.77	M	2.07	1.34
15	M	0.82	1.38	1.48	1.66	C
16	1.60	1.58	1.74	1.71	1.45	0.90
17	1.22	0.49	0.83	1.46	1.54	M
18	1.04	1.34	1.88	1.52	2.00	1.70
19	1.95	1.33	1.67	0.82	0.91	1.62
20	0.34	0.86	1.30	1.57	1.87	1.21
21	1.76	1.78	1.37	1.52	1.89	2.21
22	2.08	D	1.25	0.55	1.74	1.74
23	0.03	1.57	2.10	1.28	1.96	1.49
24	1.87	1.22	1.64	1.46	M	0.32
25	1.84	1.38	1.81	1.67	1.76	1.82
26	0.80	0.90	0.07	1.12	1.40	1.64
27	1.24	1.25	M	1.13	0.45	1.25
28	M	1.57	0.88	1.92	0.10	1.81
29	1.28	0.91	1.76	1.80	1.16	1.51
30	1.40	0.37	1.06	1.13	1.44	0.76
31	1.51	0.70	1.05	2.02	1.61	1.39
32	1.65	0.63	0.23	1.66	1.68	0.69
33	0.35	0.15	1.30	1.39	0.86	1.24
34	1.10	1.43	1.07	0.59	0.24	1.22
35	0.28	1.39	0.62	1.45	1.71	0.74

Length Growth Rates (mm/wk)

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
36	0.69	D	M	0.67	1.22	1.01
37	1.18	1.51	0.32	1.65	1.65	1.25
38	0.66	1.37	1.97	1.37	1.48	1.57
39	1.44	1.50	1.32	1.75	M	1.61
40	1.20	1.70	0.62	1.38	1.92	1.90
41	1.15	1.35	1.74	1.51	1.63	1.89
42	1.83	1.63	1.43	1.51	1.74	1.76
43	1.72	1.57	1.75	1.66	1.80	1.68
44	1.78	0.99	M	1.24	1.71	0.23
45	M	1.42	1.45	0.38	1.75	1.31
46	1.21	1.19	1.27	0.79	0.91	1.75
47	1.05	1.65	1.07	1.73	0.70	1.70
48	0.15	0.66	0.48	0.25	1.20	0.46
49	M	D	0.52	0.45	1.72	1.93
50	0.98	1.32	1.12	1.67	1.55	0.96
51	1.05	0.51	1.81	1.34	1.56	0.84
52	1.85	1.27	1.87	1.12	1.32	0.77
53	1.60	1.57	1.32	1.73	0.17	0.76
54	1.25	1.53	1.44	1.73	1.24	1.62
55	1.50	1.69	0.58	1.30	1.78	1.64
56	1.06	1.16	1.63	1.18	1.91	1.59
57	1.55	0.77	1.66	1.56	1.50	1.31
58	1.58	1.73	1.83	1.66	1.83	1.55
59	1.95	1.53	1.50	1.06	1.76	1.56
60	1.55	1.59	1.37	1.45	1.90	1.74
61	1.49	1.06	1.80	1.52	1.41	0.67
62	1.96	1.26	1.04	0.58	0.31	1.30
63	1.99	0.99	1.57	0.76	1.68	1.33
64	1.76	1.44	1.67	1.46	0.71	M
65	1.13	1.16	D	1.62	1.85	1.54
66	1.19	1.45	1.57	1.54	1.70	1.92
67	1.23	1.14	1.97	0.61	0.70	1.78
68	1.86	0.51	0.88	1.74	1.16	1.73
69	1.23	1.31	1.82	0.98	1.79	1.87
70	1.76	1.62	1.22	0.48	0.91	0.84
71	1.32	1.48	1.31	0.60	1.61	1.44
72	1.42	1.57	1.33	0.97	1.68	0.67
73	1.45	1.59	1.51	1.54	1.13	1.89
74	1.83	1.44	1.36	1.46	0.81	0.87
75	1.69	1.43	1.05	1.89	1.30	1.34
76	1.42	0.75	1.45	0.97	1.49	M
77	0.73	1.95	1.77	1.67	1.60	0.63
78	D	1.40	0.79	0.94	0.71	1.56
79	D	1.76	1.42	1.80	1.94	1.47
80	1.66	1.64	1.51	1.48	1.39	1.63
81	1.10	1.56	0.50	1.10	1.58	1.64
82	D	1.32	1.05	1.56	1.45	1.50
83	1.19	0.58	0.78	1.10	2.00	0.85
84	1.60	1.34	1.48	1.49	1.25	1.45
85	1.75	0.98	1.44	2.03	0.23	1.63
86	0.55	1.25	1.01	2.00	1.38	1.69
87	1.72	0.68	1.28	0.70	0.50	0.80
88	1.28	1.44	0.78	1.42	0.49	1.90
89	0.86	0.75	0.78	1.00	1.51	1.54
90	1.28	1.11	0.64	1.66	1.63	1.12
6meter 1	1.34	1.21	1.05	0.88	0.70	0.65
2	0.40	1.72	0.98	1.33	0.92	1.16
3	1.42	1.83	1.74	1.82	1.44	1.61
4	1.43	0.24	1.17	1.27	1.71	1.50
5	1.45	1.07	1.61	M	1.62	1.04
6	0.63	0.55	0.45	0.44	1.34	1.42
7	1.34	1.18	1.72	0.39	1.30	1.33
8	0.52	0.48	0.56	1.46	0.48	1.24
9	1.16	1.29	1.32	1.27	1.50	1.49
10	1.89	0.30	0.17	1.25	1.41	1.87
11	1.69	1.57	0.62	D	1.50	0.90

Length Growth Rates (mm/wk)

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
12	D	1.49	1.44	1.58	1.37	1.62
13	0.40	1.24	0.19	1.36	1.27	1.00
14	1.23	1.46	0.71	1.23	D	0.90
15	1.50	0.98	1.50	0.97	1.24	1.69
16	1.70	1.56	0.52	1.47	D	0.86
17	1.65	0.84	M	1.52	0.35	1.44
18	0.34	0.94	1.19	M	1.15	1.33
19	1.06	M	1.45	0.84	1.72	1.11
20	1.36	1.69	1.41	M	1.55	0.36
21	1.05	1.61	1.79	0.89	1.53	0.58
22	1.28	1.56	1.32	1.61	M	0.69
23	1.09	0.57	1.50	1.12	1.19	0.22
24	1.23	1.41	0.19	D	1.61	1.45
25	0.35	1.62	1.79	1.75	1.39	0.95
26	1.48	0.21	0.33	1.10	1.68	1.30
27	1.04	M	1.80	1.32	1.79	1.18
28	1.48	1.65	1.21	0.88	1.25	1.46
29	1.53	1.10	0.85	1.28	M	1.52
30	0.49	1.20	1.27	1.16	1.48	1.77
31	0.62	1.13	1.18	0.10	1.70	1.49
32	1.34	1.42	0.32	0.97	1.31	1.29
33	0.25	1.47	1.07	1.67	1.22	0.65
34	1.64	1.33	1.69	1.70	1.08	0.87
35	1.25	1.08	1.55	1.24	1.15	1.69
36	M	1.26	1.25	0.99	1.65	1.74
37	0.92	D	1.38	1.27	0.69	1.66
38	1.15	1.56	0.51	1.45	0.95	1.05
39	1.30	0.43	0.67	1.25	0.82	1.33
40	1.58	0.83	0.66	M	0.78	0.79
41	0.55	1.70	1.32	1.40	1.30	1.40
42	1.46	0.91	1.43	1.36	1.68	1.48
43	0.52	0.96	1.43	0.14	1.36	1.22
44	1.46	1.01	1.32	1.30	0.51	0.71
45	1.02	1.17	0.09	0.12	1.25	1.38
46	1.58	1.42	1.69	1.45	0.20	1.21
47	1.58	0.39	1.25	1.41	1.05	1.20
48	0.86	1.71	0.93	1.58	0.54	1.57
49	M	1.36	1.47	1.20	1.71	1.80
50	1.75	M	0.93	M	0.47	1.65
51	1.24	0.29	0.68	1.28	1.62	1.62
52	0.45	1.24	0.94	1.57	1.45	M
53	1.38	1.11	1.38	0.86	1.43	1.58
54	1.16	0.31	1.00	0.65	0.95	0.25
55	0.82	1.36	0.88	1.59	1.45	M
56	0.59	1.28	1.55	0.89	0.51	1.16
57	0.72	0.23	0.71	1.35	0.94	0.90
58	D	1.57	1.18	1.34	1.32	1.58
59	1.15	1.11	0.66	1.27	1.52	1.46
60	0.93	1.38	1.84	1.52	1.45	1.06
61	1.11	0.76	1.74	1.51	0.92	1.06
62	1.49	1.54	1.49	0.30	1.62	0.73
63	1.50	1.31	1.37	1.62	0.43	1.01
64	1.43	0.13	1.31	0.68	1.50	M
65	1.42	D	1.01	0.42	1.64	1.28
66	1.06	1.29	1.34	0.89	1.75	1.24
67	1.45	1.59	1.71	0.55	1.50	1.18
68	1.34	1.12	1.48	1.36	0.78	1.52
69	0.51	1.76	1.40	0.58	0.71	0.57
70	1.54	1.57	0.52	1.65	1.42	1.19
71	1.33	1.54	1.84	0.56	1.46	1.34
72	1.33	1.41	0.61	1.56	1.68	1.57
73	1.22	1.44	1.67	0.14	0.66	0.95
74	0.40	1.42	1.35	1.38	0.45	1.66
75	1.35	0.82	1.13	0.86	1.53	0.15
76	1.04	1.17	1.48	1.53	0.70	1.70
77	0.60	1.27	1.25	1.16	0.60	1.40

Length Growth Rates (mm/wk)

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
78	1.21	1.49	1.25	1.42	1.10	1.69
79	0.81	1.28	1.21	1.14	0.75	1.65
80	0.76	0.48	1.06	1.09	1.67	0.64
81	1.26	0.98	1.28	1.47	1.06	1.54
82	1.45	1.47	0.55	1.38	1.69	1.58
83	1.02	1.74	1.45	0.89	1.62	1.27
84	0.79	0.46	0.44	0.98	1.47	1.18
85	1.23	1.33	1.53	1.35	1.63	0.75
86	1.39	0.59	0.53	1.59	1.29	1.21
87	0.58	1.52	0.96	1.54	1.70	1.63
88	0.28	D	1.23	0.97	1.05	1.31
89	1.42	1.53	1.44	1.80	1.21	1.40
90	0.99	1.07	0.83	1.38	1.30	1.51
	D = Dead					
	M = Missing					
	C = crushed; not able to make measurement					

Appendix D

Initial Whole-Animal Wet-Weights

Initial Whole Weight (g-wet)

	mean	0.50	0.49	0.50	0.50	0.50	0.49
	min	0.27	0.26	0.27	0.27	0.24	0.24
	max	0.99	0.91	0.99	0.95	0.99	0.96
	stdev	0.15	0.13	0.15	0.14	0.15	0.14
	count	270	270	270	270	270	270
	2se	0.018	0.016	0.018	0.018	0.018	0.017
Cage Numbers:		2, 10, 13	6, 17, 19	5, 7, 21	11, 15, 16	1, 9, 18,	4, 8, 14
		Station 1	**Station 2**	**Station 3**	**Station 4**	**Station 5**	**Station 6**
	2meter 1	0.32	0.42	0.34	0.43	0.4	0.4
	2	0.4	0.47	0.41	0.39	0.35	0.43
	3	0.4	0.42	0.49	0.43	0.36	0.38
	4	0.32	0.35	0.37	0.28	0.41	0.41
	5	0.36	0.31	0.43	0.41	0.46	0.48
	6	0.44	0.33	0.44	0.29	0.38	0.31
	7	0.33	0.42	0.37	0.35	0.46	0.44
	8	0.34	0.41	0.37	0.32	0.4	0.35
	9	0.4	0.35	0.33	0.39	0.4	0.36
	10	0.44	0.32	0.41	0.39	0.41	0.37
	11	0.43	0.33	0.34	0.39	0.33	0.39
	12	0.36	0.39	0.41	0.36	0.4	0.36
	13	0.35	0.4	0.34	0.32	0.34	0.34
	14	0.3	0.37	0.38	0.31	0.35	0.36
	15	0.35	0.33	0.45	0.5	0.4	0.39
	16	0.34	0.41	0.31	0.33	0.34	0.36
	17	0.35	0.34	0.4	0.42	0.45	0.31
	18	0.34	0.27	0.27	0.29	0.29	0.26
	19	0.27	0.31	0.36	0.36	0.3	0.34
	20	0.39	0.31	0.41	0.34	0.31	0.42
	21	0.37	0.33	0.36	0.43	0.4	0.31
	22	0.41	0.46	0.41	0.38	0.36	0.33
	23	0.31	0.33	0.35	0.37	0.32	0.45
	24	0.38	0.42	0.37	0.32	0.38	0.3
	25	0.37	0.44	0.34	0.32	0.31	0.47
	26	0.28	0.47	0.43	0.42	0.28	0.31
	27	0.33	0.41	0.33	0.33	0.38	0.36
	28	0.39	0.34	0.35	0.48	0.37	0.42
	29	0.35	0.42	0.35	0.47	0.31	0.36
	30	0.4	0.46	0.47	0.51	0.59	0.38
	31	0.47	0.37	0.5	0.43	0.52	0.41
	32	0.38	0.46	0.36	0.38	0.51	0.46
	33	0.47	0.43	0.49	0.56	0.44	0.36
	34	0.4	0.49	0.57	0.33	0.3	0.33
	35	0.33	0.43	0.46	0.44	0.48	0.41
	36	0.36	0.37	0.41	0.49	0.5	0.54
	37	0.42	0.46	0.5	0.28	0.41	0.4
	38	0.46	0.41	0.48	0.44	0.5	0.39
	39	0.49	0.45	0.48	0.47	0.45	0.45
	40	0.51	0.49	0.38	0.39	0.47	0.63
	41	0.44	0.39	0.44	0.43	0.39	0.51
	42	0.49	0.43	0.58	0.45	0.38	0.4
	43	0.4	0.41	0.36	0.29	0.46	0.38
	44	0.41	0.42	0.35	0.49	0.55	0.49
	45	0.48	0.49	0.48	0.42	0.53	0.51
	46	0.47	0.35	0.38	0.45	0.4	0.43
	47	0.44	0.45	0.36	0.45	0.5	0.43
	48	0.36	0.56	0.4	0.38	0.5	0.31
	49	0.48	0.4	0.52	0.46	0.41	0.59
	50	0.38	0.4	0.46	0.4	0.42	0.37
	51	0.48	0.38	0.41	0.39	0.4	0.38
	52	0.38	0.26	0.44	0.51	0.33	0.41
	53	0.82	0.54	0.61	0.5	0.45	0.56
	54	0.42	0.51	0.65	0.5	0.46	0.57
	55	0.73	0.68	0.46	0.63	0.48	0.49
	56	0.39	0.4	0.47	0.66	0.57	0.56
	57	0.57	0.49	0.52	0.44	0.6	0.45

Initial Whole Weight (g-wet)

		Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
	58	0.51	0.48	0.54	0.5	0.57	0.36
	59	0.52	0.45	0.74	0.52	0.55	0.66
	60	0.59	0.53	0.54	0.75	0.48	0.64
	61	0.78	0.47	0.71	0.57	0.74	0.45
	62	0.43	0.49	0.47	0.57	0.52	0.71
	63	0.52	0.47	0.35	0.54	0.67	0.57
	64	0.5	0.71	0.6	0.51	0.62	0.51
	65	0.38	0.59	0.7	0.51	0.56	0.49
	66	0.53	0.44	0.4	0.54	0.67	0.69
	67	0.53	0.42	0.56	0.5	0.61	0.61
	68	0.46	0.59	0.5	0.53	0.53	0.42
	69	0.67	0.46	0.58	0.42	0.62	0.61
	70	0.64	0.53	0.66	0.74	0.72	0.55
	71	0.63	0.56	0.56	0.67	0.63	0.61
	72	0.6	0.56	0.68	0.72	0.63	0.66
	73	0.33	0.62	0.59	0.52	0.57	0.59
	74	0.6	0.67	0.58	0.41	0.62	0.58
	75	0.53	0.74	0.63	0.73	0.66	0.49
	76	0.61	0.76	0.51	0.5	0.54	0.88
	77	0.46	0.57	0.42	0.83	0.9	0.46
	78	0.56	0.78	0.79	0.7	0.52	0.67
	79	0.55	0.76	0.49	0.55	0.66	0.96
	80	0.41	0.61	0.61	0.57	0.65	0.55
	81	0.47	0.91	0.78	0.69	0.71	0.46
	82	0.67	0.73	0.83	0.66	0.87	0.73
	83	0.72	0.61	0.76	0.95	0.99	0.73
	84	0.81	0.82	0.73	0.83	0.64	0.85
	85	0.71	0.68	0.61	0.73	0.66	0.58
	86	0.53	0.58	0.77	0.56	0.69	0.85
	87	0.59	0.75	0.87	0.75	0.65	0.61
	88	0.75	0.67	0.61	0.66	0.64	0.63
	89	0.99	0.76	0.8	0.72	0.62	0.83
	90	0.52	0.71	0.83	0.72	0.78	0.68
	4meter 1	0.41	0.35	0.4	0.31	0.34	0.31
	2	0.31	0.35	0.36	0.36	0.43	0.49
	3	0.42	0.4	0.44	0.39	0.38	0.28
	4	0.47	0.35	0.38	0.37	0.44	0.37
	5	0.33	0.39	0.28	0.32	0.47	0.35
	6	0.35	0.35	0.37	0.47	0.48	0.4
	7	0.32	0.43	0.46	0.32	0.47	0.31
	8	0.32	0.36	0.38	0.33	0.32	0.34
	9	0.4	0.32	0.33	0.38	0.35	0.4
	10	0.39	0.38	0.48	0.36	0.36	0.38
	11	0.35	0.31	0.3	0.44	0.24	0.24
	12	0.38	0.35	0.35	0.35	0.38	0.36
	13	0.31	0.36	0.43	0.29	0.36	0.44
	14	0.29	0.36	0.43	0.4	0.38	0.32
	15	0.34	0.38	0.32	0.31	0.36	0.32
	16	0.41	0.32	0.35	0.35	0.4	0.32
	17	0.38	0.3	0.32	0.45	0.31	0.35
	18	0.36	0.38	0.34	0.4	0.44	0.41
	19	0.33	0.4	0.39	0.34	0.57	0.34
	20	0.33	0.45	0.38	0.37	0.35	0.44
	21	0.38	0.35	0.41	0.46	0.35	0.27
	22	0.38	0.36	0.33	0.34	0.33	0.37
	23	0.38	0.39	0.29	0.34	0.4	0.39
	24	0.38	0.42	0.31	0.35	0.35	0.31
	25	0.32	0.46	0.33	0.53	0.43	0.37
	26	0.38	0.33	0.37	0.37	0.3	0.32
	27	0.42	0.61	0.3	0.5	0.39	0.33
	28	0.33	0.45	0.33	0.55	0.32	0.4
	29	0.48	0.49	0.33	0.42	0.32	0.41
	30	0.48	0.37	0.4	0.46	0.42	0.43
	31	0.42	0.34	0.55	0.45	0.47	0.37

Initial Whole Weight (g-wet)

		Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
	32	0.43	0.43	0.41	0.37	0.42	0.48
	33	0.37	0.41	0.39	0.52	0.48	0.43
	34	0.47	0.48	0.54	0.34	0.34	0.49
	35	0.45	0.43	0.43	0.48	0.55	0.42
	36	0.53	0.4	0.31	0.44	0.4	0.49
	37	0.47	0.4	0.3	0.37	0.44	0.63
	38	0.4	0.49	0.52	0.5	0.48	0.48
	39	0.46	0.45	0.44	0.38	0.38	0.48
	40	0.42	0.39	0.47	0.34	0.46	0.5
	41	0.63	0.53	0.47	0.46	0.45	0.49
	42	0.41	0.4	0.49	0.54	0.41	0.6
	43	0.49	0.48	0.41	0.5	0.48	0.52
	44	0.4	0.49	0.41	0.43	0.37	0.45
	45	0.4	0.43	0.49	0.45	0.4	0.4
	46	0.47	0.39	0.48	0.56	0.45	0.38
	47	0.35	0.42	0.46	0.61	0.41	0.46
	48	0.36	0.4	0.57	0.35	0.47	0.38
	49	0.43	0.49	0.38	0.4	0.49	0.44
	50	0.36	0.32	0.4	0.43	0.46	0.43
	51	0.36	0.57	0.37	0.89	0.37	0.61
	52	0.51	0.47	0.32	0.46	0.62	0.74
	53	0.56	0.65	0.51	0.51	0.42	0.5
	54	0.64	0.61	0.52	0.52	0.53	0.38
	55	0.52	0.52	0.53	0.58	0.58	0.73
	56	0.52	0.65	0.71	0.39	0.59	0.47
	57	0.64	0.42	0.51	0.57	0.44	0.59
	58	0.49	0.46	0.54	0.45	0.48	0.56
	59	0.7	0.44	0.71	0.8	0.65	0.5
	60	0.58	0.48	0.49	0.58	0.55	0.49
	61	0.55	0.47	0.53	0.67	0.53	0.55
	62	0.49	0.64	0.46	0.55	0.48	0.42
	63	0.42	0.53	0.47	0.56	0.42	0.49
	64	0.52	0.51	0.64	0.5	0.53	0.6
	65	0.56	0.49	0.54	0.45	0.53	0.45
	66	0.82	0.43	0.51	0.43	0.62	0.62
	67	0.43	0.49	0.47	0.59	0.55	0.4
	68	0.47	0.61	0.53	0.5	0.53	0.73
	69	0.64	0.59	0.51	0.64	0.62	0.48
	70	0.63	0.6	0.78	0.72	0.73	0.52
	71	0.94	0.63	0.56	0.71	0.86	0.59
	72	0.61	0.75	0.65	0.72	0.85	0.61
	73	0.6	0.69	0.59	0.77	0.59	0.54
	74	0.49	0.53	0.69	0.47	0.67	0.58
	75	0.93	0.63	0.44	0.69	0.74	0.63
	76	0.93	0.59	0.71	0.72	0.7	0.64
	77	0.71	0.61	0.93	0.62	0.8	0.48
	78	0.77	0.64	0.9	0.79	0.92	0.59
	79	0.56	0.66	0.63	0.62	0.6	0.56
	80	0.6	0.56	0.63	0.46	0.52	0.51
	81	0.7	0.57	0.69	0.59	0.81	0.59
	82	0.6	0.68	0.9	0.57	0.73	0.65
	83	0.82	0.74	0.73	0.71	0.66	0.61
	84	0.71	0.59	0.64	0.78	0.57	0.64
	85	0.56	0.58	0.78	0.81	0.54	0.95
	86	0.73	0.67	0.73	0.78	0.71	0.72
	87	0.77	0.68	0.65	0.75	0.74	0.63
	88	0.58	0.7	0.7	0.65	0.68	0.52
	89	0.77	0.65	0.77	0.78	0.96	0.82
	90	0.69	0.71	0.84	0.73	0.72	0.61
6meter	1	0.38	0.44	0.45	0.35	0.37	0.38
	2	0.37	0.29	0.33	0.35	0.44	0.4
	3	0.35	0.33	0.4	0.31	0.37	0.41
	4	0.35	0.33	0.41	0.34	0.33	0.34
	5	0.32	0.34	0.33	0.46	0.39	0.28

Initial Whole Weight (g-wet)

		Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
	6	0.49	0.36	0.4	0.35	0.38	0.39
	7	0.41	0.32	0.32	0.35	0.34	0.35
	8	0.42	0.35	0.39	0.44	0.3	0.44
	9	0.35	0.37	0.45	0.35	0.31	0.33
	10	0.38	0.33	0.3	0.37	0.33	0.3
	11	0.37	0.42	0.39	0.35	0.34	0.42
	12	0.37	0.29	0.28	0.27	0.32	0.37
	13	0.36	0.39	0.43	0.48	0.33	0.32
	14	0.45	0.43	0.37	0.37	0.31	0.34
	15	0.38	0.41	0.34	0.41	0.35	0.32
	16	0.32	0.35	0.4	0.42	0.39	0.3
	17	0.45	0.42	0.28	0.41	0.34	0.38
	18	0.42	0.38	0.35	0.35	0.31	0.37
	19	0.42	0.34	0.41	0.43	0.41	0.46
	20	0.43	0.31	0.4	0.37	0.33	0.37
	21	0.49	0.41	0.42	0.43	0.39	0.33
	22	0.35	0.36	0.37	0.38	0.33	0.38
	23	0.43	0.44	0.4	0.32	0.34	0.41
	24	0.31	0.46	0.34	0.27	0.34	0.35
	25	0.33	0.41	0.36	0.33	0.5	0.42
	26	0.37	0.3	0.34	0.35	0.32	0.37
	27	0.45	0.36	0.49	0.47	0.44	0.54
	28	0.45	0.49	0.46	0.47	0.41	0.54
	29	0.44	0.44	0.44	0.49	0.4	0.49
	30	0.38	0.44	0.38	0.46	0.37	0.41
	31	0.55	0.35	0.41	0.39	0.33	0.5
	32	0.39	0.53	0.49	0.5	0.52	0.45
	33	0.46	0.5	0.36	0.55	0.47	0.4
	34	0.45	0.46	0.37	0.48	0.32	0.42
	35	0.51	0.34	0.46	0.47	0.41	0.44
	36	0.46	0.42	0.43	0.45	0.46	0.4
	37	0.42	0.43	0.44	0.51	0.53	0.55
	38	0.51	0.48	0.55	0.4	0.54	0.52
	39	0.56	0.5	0.5	0.44	0.44	0.48
	40	0.34	0.46	0.42	0.37	0.55	0.45
	41	0.4	0.67	0.47	0.46	0.48	0.54
	42	0.44	0.5	0.49	0.45	0.45	0.51
	43	0.58	0.48	0.31	0.43	0.5	0.47
	44	0.36	0.48	0.42	0.5	0.36	0.5
	45	0.46	0.39	0.34	0.52	0.42	0.48
	46	0.43	0.53	0.49	0.39	0.44	0.56
	47	0.45	0.41	0.46	0.46	0.41	0.52
	48	0.51	0.53	0.51	0.46	0.57	0.55
	49	0.41	0.47	0.59	0.48	0.41	0.46
	50	0.48	0.31	0.43	0.36	0.51	0.48
	51	0.54	0.45	0.64	0.74	0.6	0.65
	52	0.62	0.49	0.65	0.54	0.48	0.42
	53	0.41	0.41	0.5	0.42	0.62	0.45
	54	0.51	0.46	0.55	0.54	0.65	0.52
	55	0.49	0.61	0.48	0.54	0.64	0.58
	56	0.46	0.52	0.58	0.73	0.41	0.43
	57	0.57	0.77	0.99	0.55	0.54	0.6
	58	0.66	0.63	0.58	0.5	0.62	0.48
	59	0.56	0.52	0.42	0.58	0.51	0.41
	60	0.48	0.65	0.41	0.55	0.46	0.54
	61	0.45	0.61	0.48	0.45	0.6	0.37
	62	0.7	0.49	0.53	0.49	0.63	0.56
	63	0.58	0.55	0.83	0.52	0.48	0.52
	64	0.58	0.46	0.45	0.44	0.48	0.53
	65	0.54	0.53	0.61	0.51	0.46	0.79
	66	0.54	0.53	0.47	0.48	0.41	0.54
	67	0.74	0.49	0.61	0.58	0.6	0.64
	68	0.73	0.55	0.63	0.51	0.76	0.6
	69	0.62	0.57	0.95	0.66	0.6	0.83

Initial Whole Weight (g-wet)

		Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
	70	0.59	0.59	0.53	0.76	0.59	0.74
	71	0.72	0.66	0.61	0.62	0.75	0.62
	72	0.84	0.58	0.55	0.54	0.64	0.85
	73	0.67	0.7	0.75	0.65	0.65	0.6
	74	0.68	0.54	0.63	0.6	0.48	0.82
	75	0.61	0.55	0.62	0.93	0.76	0.62
	76	0.74	0.49	0.58	0.59	0.48	0.63
	77	0.77	0.53	0.5	0.61	0.8	0.55
	78	0.58	0.65	0.78	0.75	0.67	0.55
	79	0.66	0.42	0.58	0.68	0.63	0.66
	80	0.52	0.67	0.63	0.65	0.53	0.54
	81	0.63	0.49	0.66	0.54	0.76	0.52
	82	0.66	0.69	0.63	0.72	0.62	0.6
	83	0.72	0.6	0.95	0.64	0.77	0.79
	84	0.73	0.62	0.73	0.82	0.56	0.73
	85	0.84	0.82	0.66	0.57	0.59	0.63
	86	0.68	0.71	0.58	0.75	0.59	0.6
	87	0.69	0.53	0.66	0.9	0.76	0.77
	88	0.57	0.66	0.6	0.66	0.72	0.77
	89	0.79	0.77	0.65	0.77	0.73	0.94
	90	0.92	0.82	0.73	0.79	0.75	0.53

Appendix E

End-of-Test Whole Animal Wet-Weights

End-of-Test Whole Weight (g-wet)

mean	2.67	2.55	2.79	2.80	2.89	2.93
min	0.44	0.51	0.35	0.57	0.45	0.53
max	5.33	5.81	5.26	5.99	5.93	6.46
stdev	1.02	1.00	1.05	1.02	1.16	1.07
count	249	256	258	254	257	255
2SE	0.129	0.125	0.131	0.128	0.145	0.134
Cage#:	2, 10, 13	6, 17, 19	5, 7, 21	11, 15, 16	1, 9, 18,	4, 8, 14
	Station 1	**Station 2**	**Station 3**	**Station 4**	**Station 5**	**Station 6**
2meter. 1	M	1.88	M	2.77	1.37	1.30
2	3.43	3.69	3.35	3.09	D	2.87
3	1.60	0.93	2.85	0.84	3.34	4.04
4	0.51	1.94	2.34	1.57	2.49	2.88
5	2.84	3.04	3.13	3.48	3.97	3.75
6	M	2.65	3.98	M	2.72	1.21
7	1.20	0.82	1.96	3.08	2.86	3.84
8	M	2.45	3.38	3.23	2.81	0.87
9	0.87	2.59	3.46	0.73	3.20	3.77
10	3.24	1.71	M	1.87	2.94	3.04
11	2.67	1.02	3.57	3.07	M	2.85
12	2.88	3.34	2.99	1.70	3.72	3.28
13	1.03	2.58	3.52	1.84	3.52	3.80
14	M	2.12	2.70	1.81	0.98	2.54
15	3.22	2.54	4.17	3.94	2.84	1.57
16	0.98	3.26	3.55	M	M	M
17	2.70	2.21	1.00	4.02	1.50	1.47
18	1.09	2.59	3.79	3.25	0.76	3.43
19	2.02	2.22	1.80	2.96	2.40	1.45
20	D	0.62	1.49	M	2.53	0.53
21	4.00	2.78	1.78	3.37	3.09	3.05
22	M	1.71	2.90	2.95	1.09	2.42
23	2.42	2.11	2.46	M	M	3.16
24	4.13	4.10	2.80	3.07	4.18	0.75
25	2.08	2.55	1.20	3.17	2.71	0.95
26	3.30	3.53	3.69	3.63	3.42	4.28
27	3.15	3.90	0.35	3.57	3.92	2.36
28	2.66	1.14	2.99	3.16	2.03	2.34
29	4.27	2.64	3.21	2.89	3.78	M
30	3.05	2.52	2.04	4.07	4.35	1.48
31	0.79	3.69	3.03	3.68	5.06	3.06
32	3.00	2.41	3.42	3.66	1.92	2.22
33	2.40	3.05	4.00	3.01	3.49	3.76
34	2.71	3.40	2.24	2.20	0.91	1.71
35	1.19	3.48	2.77	3.09	M	3.23
36	2.37	2.57	1.97	3.50	2.18	M
37	M	1.12	4.05	3.11	3.42	3.19
38	3.87	1.89	3.79	1.22	2.79	M
39	3.33	2.80	2.67	3.93	3.84	1.88
40	1.73	3.40	D	2.52	5.08	3.10
41	3.98	M	3.71	3.02	3.52	3.99
42	1.03	1.43	4.58	3.19	0.82	3.17
43	3.67	M	2.76	3.30	0.70	M
44	3.94	1.40	3.00	3.64	1.43	3.11
45	3.01	M	4.68	3.43	2.63	0.78
46	0.80	M	0.88	2.42	4.09	1.66
47	1.86	1.86	1.43	2.15	3.13	4.19
48	3.77	1.14	3.91	1.66	4.91	3.78
49	3.59	0.81	4.15	3.82	2.05	3.34
50	2.41	4.12	4.36	D	2.43	0.87
51	1.81	3.21	M	4.09	3.22	2.85
52	1.97	2.50	2.94	1.19	2.12	2.72
53	3.77	1.61	5.17	1.85	4.09	3.81
54	3.38	4.42	4.06	4.07	1.03	4.36
55	4.19	3.81	2.02	3.15	1.82	2.92
56	3.69	M	2.06	4.66	2.96	3.95
57	4.20	4.29	4.65	3.79	4.64	3.06
58	1.25	3.41	4.07	3.72	2.84	3.16
59	2.14	3.12	4.84	2.98	4.87	3.96

End-of-Test Whole Weight (g-wet)

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
60	3.89	3.85	2.61	2.42	5.75	4.33
61	3.71	1.09	1.99	3.54	4.77	3.17
62	2.04	1.47	2.44	3.55	1.55	3.91
63	4.20	3.50	D	2.36	3.45	2.25
64	3.40	2.09	4.13	0.68	1.64	2.52
65	3.12	4.10	4.57	3.66	2.77	2.85
66	3.40	3.33	2.86	2.68	3.83	3.48
67	3.12	3.33	2.90	1.53	1.97	3.30
68	3.27	2.97	3.71	3.00	4.68	3.30
69	3.44	1.21	2.78	2.55	1.84	4.31
70	1.83	2.33	2.69	3.95	5.41	4.38
71	2.06	3.04	2.11	3.58	1.12	3.62
72	3.56	0.92	2.29	3.46	4.31	2.41
73	2.47	2.50	3.95	1.43	2.98	1.95
74	5.33	4.00	3.95	3.42	5.02	4.62
75	2.99	3.20	4.65	1.27	5.40	4.84
76	4.58	2.56	4.59	1.60	2.07	5.34
77	3.29	3.27	2.26	2.05	3.33	4.28
78	3.17	5.33	5.26	4.34	2.88	6.46
79	M	1.56	1.95	2.13	5.93	3.72
80	2.84	3.74	2.47	1.92	2.69	4.29
81	1.08	5.81	4.24	5.01	5.61	1.68
82	4.34	3.95	4.62	5.29	3.23	5.49
83	4.77	3.76	1.97	4.10	3.99	4.76
84	3.63	4.24	4.72	4.98	3.69	3.72
85	4.07	1.57	3.72	1.72	5.20	1.33
86	1.71	3.84	4.93	4.65	3.19	4.57
87	1.25	1.71	4.73	3.52	2.93	4.04
88	2.94	4.33	3.40	5.02	4.45	4.36
89	3.32	1.37	4.69	2.81	4.08	2.53
90	3.16	2.71	1.91	5.04	5.70	4.37
4meter 1	2.36	0.56	1.83	2.45	M	2.13
2	3.16	0.70	3.34	2.98	2.65	1.19
3	2.73	2.18	2.87	0.89	2.01	M
4	3.65	2.13	D	M	3.23	D
5	2.75	1.66	3.09	M	1.26	M
6	2.86	1.06	3.53	3.70	1.73	3.46
7	M	2.66	3.25	1.08	1.80	3.15
8	3.36	2.59	1.42	M	4.00	3.80
9	2.25	0.66	M	2.87	2.21	2.27
10	0.89	1.08	3.02	3.56	0.56	3.02
11	1.26	2.92	2.40	2.22	0.74	2.41
12	1.59	0.64	1.96	2.14	M	3.82
13	M	1.71	3.17	3.21	3.38	2.91
14	2.85	2.72	3.19	M	3.62	2.05
15	M	2.09	2.32	2.67	2.99	D
16	3.28	2.42	3.37	3.29	2.42	1.80
17	2.15	0.64	1.36	2.94	2.98	M
18	1.96	2.45	3.80	2.88	3.90	3.19
19	3.58	2.17	3.31	1.37	2.06	2.88
20	0.58	2.37	2.74	2.93	2.84	2.42
21	3.45	3.46	2.25	2.91	3.55	3.89
22	3.86	D	1.96	0.85	2.83	3.60
23	0.44	2.76	4.19	2.37	3.88	2.86
24	3.58	2.21	2.67	2.40	M	0.71
25	3.62	2.84	3.58	3.64	3.91	3.26
26	1.23	1.54	0.50	2.08	2.40	2.84
27	2.18	2.76	M	2.41	0.77	1.99
28	M	3.13	1.71	3.70	0.45	3.55
29	2.50	1.65	2.83	3.75	1.98	2.96
30	3.13	0.84	2.28	2.05	2.88	1.86
31	2.59	1.26	2.31	4.22	3.16	2.88
32	3.06	1.19	0.70	3.35	3.47	1.16
33	0.74	0.62	2.95	2.91	1.54	2.12
34	2.40	2.94	2.25	0.82	0.70	2.58
35	0.73	3.16	1.11	3.05	3.56	1.32

End-of-Test Whole Weight (g-wet)

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
36	1.39	D	M	1.45	2.31	2.20
37	2.27	2.59	0.57	2.97	3.35	2.91
38	1.20	2.30	3.93	2.73	2.78	3.47
39	2.53	3.14	2.80	3.58	M	3.42
40	2.52	3.75	1.47	2.75	3.94	4.66
41	2.95	3.04	3.71	3.08	3.39	3.40
42	3.58	3.18	3.25	3.33	3.18	4.21
43	3.66	2.91	3.26	3.36	3.94	3.68
44	3.11	1.86	M	2.68	3.05	0.73
45	M	2.69	2.62	1.12	2.94	2.59
46	2.65	1.81	2.70	1.57	1.79	3.39
47	1.97	3.22	1.87	4.03	1.21	3.43
48	0.51	1.14	1.41	0.65	2.32	0.91
49	M	D	1.07	0.81	3.62	4.01
50	1.62	2.37	1.80	3.46	3.33	1.84
51	2.02	1.24	3.53	4.05	2.99	2.27
52	3.95	2.71	3.36	1.99	3.32	2.39
53	3.74	4.27	2.87	3.94	0.60	1.57
54	3.14	3.70	3.45	3.95	3.25	3.50
55	3.52	3.92	1.41	2.77	4.16	4.06
56	1.86	2.87	3.95	2.38	4.98	2.99
57	3.94	1.92	3.63	3.31	3.01	3.58
58	3.46	3.60	3.99	3.40	3.65	3.65
59	4.45	3.38	4.32	3.23	4.92	3.43
60	3.43	3.36	3.15	3.63	4.30	3.44
61	1.23	2.33	3.89	3.85	3.02	1.71
62	3.98	3.03	1.60	1.88	0.88	2.59
63	3.84	2.28	3.08	1.56	3.07	2.97
64	3.48	3.19	4.00	2.84	1.53	M
65	2.57	2.46	D	3.18	4.04	3.69
66	3.48	2.52	3.28	3.24	4.06	4.66
67	2.61	2.29	4.44	1.71	2.04	3.66
68	3.95	1.17	1.87	3.52	2.56	4.73
69	3.23	2.66	4.18	2.43	3.79	4.96
70	4.18	3.63	3.27	1.45	2.53	2.09
71	4.13	3.45	2.82	2.33	4.16	3.43
72	3.41	4.51	3.12	3.02	4.63	1.77
73	3.30	4.02	3.46	4.35	3.17	4.88
74	4.41	3.25	3.64	3.17	1.98	2.67
75	3.44	3.72	2.37	4.73	3.21	3.82
76	4.10	1.90	3.90	2.62	3.85	M
77	2.62	4.28	5.19	4.25	4.46	1.39
78	D	3.73	2.24	2.92	1.59	4.06
79	D	3.92	3.35	4.35	4.81	3.00
80	3.71	3.36	3.59	3.38	3.13	3.86
81	3.22	3.68	1.47	2.56	4.47	4.38
82	D	3.33	2.93	3.34	4.42	4.10
83	4.04	2.02	2.50	3.70	5.45	2.37
84	4.48	3.14	4.36	4.07	3.35	3.62
85	4.36	2.34	4.25	5.99	0.98	4.98
86	1.64	2.89	3.18	5.47	3.76	4.10
87	4.59	1.91	3.22	2.40	2.06	2.07
88	2.69	3.56	1.94	3.74	1.95	5.28
89	3.38	2.29	2.68	2.83	4.37	4.60
90	4.11	3.23	2.79	3.98	4.06	3.65
6meter 1	2.30	2.23	2.08	1.37	1.26	1.19
2	0.74	2.63	1.60	2.21	1.92	2.03
3	2.35	3.09	3.07	3.06	2.61	3.26
4	2.67	0.56	2.10	2.58	2.98	2.71
5	2.05	2.00	2.71	M	2.83	1.54
6	1.30	0.94	0.86	0.79	2.44	2.42
7	2.40	1.93	2.97	0.84	1.91	2.15
8	0.85	0.80	1.01	2.77	0.80	2.56
9	1.94	2.27	2.19	2.28	2.50	2.27
10	3.70	0.66	0.49	2.25	2.12	3.41
11	3.01	2.56	1.16	D	2.68	1.71

End-of-Test Whole Weight (g-wet)

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
12	D	2.44	2.26	2.71	2.14	2.84
13	0.86	2.40	0.58	2.69	2.21	2.19
14	2.14	2.58	1.22	2.30	D	1.78
15	3.05	1.74	2.65	1.99	2.07	2.57
16	2.82	2.58	1.06	2.73	D	1.58
17	3.12	1.72	M	2.76	0.82	2.48
18	0.79	1.85	1.88	M	1.70	2.80
19	1.84	M	2.63	1.19	3.47	2.13
20	2.20	3.18	2.67	M	3.11	0.71
21	2.07	2.73	3.39	1.35	2.89	0.88
22	2.21	2.72	2.11	2.92	M	1.40
23	1.68	1.27	2.28	1.47	1.72	0.63
24	2.12	2.56	0.55	D	2.88	2.51
25	0.65	2.70	3.11	3.13	2.51	1.78
26	2.70	0.51	0.76	1.96	2.91	2.25
27	1.83	M	3.64	2.62	3.39	2.04
28	2.75	3.17	2.42	1.61	2.19	3.33
29	2.58	2.06	1.60	2.95	M	3.15
30	1.14	2.56	2.46	2.95	2.68	3.29
31	1.59	1.74	2.19	0.60	2.99	3.04
32	2.41	2.86	0.85	2.00	2.85	2.48
33	0.85	2.80	1.63	3.01	2.27	1.48
34	2.77	2.57	2.67	3.32	2.03	1.90
35	2.44	1.99	3.06	2.70	2.24	3.27
36	M	2.41	2.33	1.60	2.96	3.03
37	1.67	D	2.60	2.42	1.33	3.51
38	2.33	2.72	1.03	2.39	1.89	2.47
39	2.92	1.03	1.45	2.22	1.77	2.63
40	2.57	1.89	1.12	M	1.81	1.48
41	1.04	3.91	2.31	3.09	2.94	2.79
42	2.61	1.77	2.68	2.71	3.62	3.33
43	1.15	2.27	2.08	0.57	2.26	2.06
44	2.39	1.88	2.47	2.50	0.90	1.49
45	1.82	2.23	0.53	0.68	2.40	2.74
46	3.21	2.89	3.18	2.42	0.68	2.71
47	2.99	0.77	2.40	2.61	1.67	2.58
48	1.63	3.20	2.24	2.58	1.28	3.44
49	M	2.68	3.04	2.23	3.27	3.42
50	3.63	M	2.10	M	1.07	3.48
51	2.68	0.83	1.87	3.00	3.52	3.95
52	1.30	2.74	2.28	3.62	3.35	M
53	2.59	2.25	2.80	1.78	3.42	3.01
54	2.48	0.88	2.22	1.35	2.29	0.99
55	2.02	3.21	1.87	3.31	3.31	M
56	1.33	2.54	3.68	2.47	1.03	2.79
57	1.71	1.14	2.76	2.93	2.70	2.45
58	D	3.67	2.79	2.71	2.97	3.25
59	2.39	2.56	1.36	2.71	3.09	2.73
60	1.78	3.23	3.57	3.56	2.69	2.53
61	2.15	1.58	3.72	2.93	2.42	1.95
62	3.48	3.03	3.04	0.88	3.91	1.52
63	3.36	2.79	3.38	3.12	1.01	2.38
64	3.28	0.75	2.46	1.62	2.98	M
65	2.97	D	1.87	1.02	3.06	3.25
66	2.15	2.68	2.89	1.74	3.35	2.71
67	3.57	3.46	3.77	1.33	3.57	2.97
68	3.69	2.46	3.34	2.49	2.54	3.28
69	1.74	3.67	3.73	1.47	1.82	2.06
70	3.23	3.40	1.30	3.71	2.90	3.33
71	3.22	3.78	4.20	1.40	3.70	3.25
72	3.79	3.09	1.90	3.31	3.98	4.19
73	3.29	3.60	3.63	0.97	1.48	2.62
74	1.22	2.84	3.34	3.30	1.12	4.09
75	3.07	2.20	2.93	2.93	4.06	0.95
76	2.76	2.46	3.17	3.47	1.42	4.06
77	1.87	2.85	2.50	2.46	1.79	3.79

End-of-Test Whole Weight (g-wet)

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
78	2.91	3.47	3.38	3.84	2.28	4.27
79	1.96	2.34	2.73	3.25	1.65	3.93
80	1.76	1.44	2.75	2.68	3.44	1.47
81	2.68	2.00	3.03	3.12	3.00	3.24
82	3.50	3.88	1.50	3.45	3.83	3.74
83	2.95	4.24	4.57	2.15	4.12	3.46
84	2.51	1.34	1.67	3.17	3.21	3.11
85	3.90	3.60	3.66	3.11	3.80	2.00
86	3.39	1.62	1.41	4.18	3.19	3.07
87	2.07	3.48	2.11	4.32	4.54	4.18
88	1.08	D	2.80	2.68	2.44	3.72
89	3.70	4.25	3.61	4.41	3.37	4.49
90	2.79	3.35	2.68	3.77	3.75	3.40
	D = dead					
	M = missing					
	C = crushed; not able to make weight or length measurements,					
		but tissue still intact				

Appendix F

Whole-Animal Wet-Weight Growth Rates

Whole-Animal Wet-Weight Growth Rates (mg/wk)

mean	224	212	236	236	246	251
min	6	22	2	14	13	11
max	488	505	470	534	543	597
stdev	101	98	103	101	115	105
count	249	256	258	254	257	255
2SE	12.8	12.2	12.9	12.6	14.3	13.1
Cage#:	2, 10, 13	6, 17, 19	5, 7, 21	11, 15, 16	1, 9, 18,	4, 8, 14
	Station 1	**Station 2**	**Station 3**	**Station 4**	**Station 5**	**Station 6**
2meter 1	M	151	M	241	100	93
2	312	332	303	278	D	252
3	124	53	243	42	307	377
4	20	164	203	133	214	255
5	256	281	278	316	362	337
6	M	239	365	M	241	93
7	90	41	164	281	247	351
8	M	210	310	300	248	54
9	48	231	323	35	289	352
10	289	143	M	153	261	275
11	231	71	333	276	M	254
12	260	304	266	138	342	301
13	70	225	328	157	328	357
14	M	180	239	155	65	225
15	296	228	384	355	252	122
16	66	294	334	M	M	M
17	242	193	62	371	108	120
18	77	239	363	305	48	327
19	180	197	148	268	216	114
20	D	32	111	M	229	11
21	374	253	146	303	277	282
22	M	129	257	265	75	215
23	218	184	218	M	M	279
24	387	379	251	284	392	46
25	176	218	89	294	247	49
26	311	315	336	331	324	409
27	291	360	2	334	365	206
28	234	82	272	276	171	198
29	404	229	295	249	358	M
30	273	212	162	367	388	113
31	33	342	261	335	468	273
32	270	201	315	338	145	181
33	199	270	362	253	314	351
34	238	300	172	193	63	142
35	89	314	238	273	M	291
36	207	227	161	310	173	M
37	M	68	366	292	310	288
38	352	153	341	80	236	M
39	293	242	226	357	349	147
40	126	300	D	220	475	255
41	365	M	337	267	323	359
42	56	103	412	282	45	286
43	337	M	247	310	25	M
44	364	101	273	325	91	270
45	261	M	433	310	216	28
46	34	M	52	203	380	127
47	146	145	110	175	271	388
48	352	60	362	132	455	358
49	321	42	374	346	169	284
50	209	384	402	D	207	52
51	137	292	M	381	291	255
52	164	231	258	70	185	238
53	304	110	470	139	375	335
54	305	403	352	368	59	391
55	357	323	161	260	138	251
56	340	M	164	412	246	349
57	374	392	426	345	416	269
58	76	302	364	332	234	289

Whole-Animal Wet-Weight Growth Rates (mg/wk)

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
59	167	275	423	254	445	340
60	340	342	213	172	543	380
61	302	64	132	306	415	280
62	166	101	203	307	106	330
63	379	312	D	188	287	173
64	299	142	364	18	105	207
65	282	362	399	325	228	243
66	296	298	254	221	326	288
67	267	300	241	106	140	277
68	290	245	331	255	428	297
69	286	77	227	220	126	381
70	123	186	209	331	484	395
71	147	256	160	300	51	310
72	305	37	166	282	379	180
73	221	194	346	94	248	140
74	488	343	347	310	454	416
75	254	254	414	56	489	448
76	409	186	421	113	158	460
77	292	278	190	126	251	394
78	269	469	461	375	243	597
79	M	82	151	163	543	285
80	251	323	192	139	210	386
81	63	505	357	445	505	126
82	378	332	391	477	243	491
83	418	325	125	325	309	415
84	291	353	411	428	314	296
85	346	92	321	102	468	77
86	122	336	429	422	258	384
87	68	99	398	286	235	354
88	226	377	288	449	393	385
89	240	63	401	215	357	175
90	272	206	111	445	507	380
4meter 1	201	22	147	221	M	188
2	294	36	307	270	229	72
3	238	184	251	52	168	M
4	328	184	D	M	288	D
5	249	131	290	M	81	M
6	259	73	326	333	129	315
7	M	230	288	78	137	293
8	313	230	107	M	379	357
9	191	35	M	257	192	193
10	52	72	262	330	21	272
11	94	269	216	184	52	224
12	125	30	166	185	M	357
13	M	139	282	301	311	255
14	264	243	285	M	334	178
15	M	176	206	243	271	D
16	296	216	311	303	208	153
17	182	35	107	257	275	M
18	165	213	357	256	357	287
19	335	182	301	106	154	262
20	26	198	243	264	257	204
21	316	321	190	253	330	373
22	359	D	168	53	258	333
23	6	244	402	209	359	255
24	330	185	243	211	M	41
25	340	245	335	321	359	298
26	88	125	13	176	216	260
27	181	222	M	197	39	171
28	M	276	142	325	13	325
29	208	120	258	343	171	263
30	273	48	194	164	254	147
31	224	95	181	389	277	259
32	271	78	30	307	314	70
33	38	22	264	246	109	174

Whole-Animal Wet-Weight Growth Rates (mg/wk)

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
34	199	254	176	49	37	215
35	29	281	70	265	310	93
36	89	D	M	104	197	176
37	186	226	28	268	300	235
38	82	187	352	230	237	308
39	213	277	243	330	M	303
40	216	346	103	248	359	429
41	239	259	334	270	303	300
42	327	287	285	288	286	372
43	327	251	294	295	357	326
44	279	141	M	232	276	29
45	M	233	220	69	262	226
46	225	146	229	104	138	310
47	167	289	145	353	82	306
48	15	76	87	31	191	55
49	M	D	71	42	323	368
50	130	211	144	312	296	145
51	171	69	326	326	270	171
52	355	231	313	158	278	170
53	328	373	243	354	19	110
54	258	319	302	354	280	322
55	309	351	91	226	369	343
56	138	229	334	205	453	260
57	340	155	322	282	265	308
58	306	324	356	304	327	319
59	387	303	372	251	440	302
60	294	297	274	314	387	304
61	70	192	346	328	257	120
62	360	246	118	137	41	224
63	353	180	269	103	273	256
64	305	276	346	241	103	M
65	207	203	D	281	362	334
66	274	215	286	290	355	416
67	225	186	409	115	154	336
68	359	58	138	311	209	412
69	267	213	378	185	327	462
70	366	312	257	75	186	162
71	329	291	233	167	340	293
72	289	388	255	237	390	120
73	278	343	296	369	266	447
74	404	280	304	278	135	215
75	259	319	199	416	255	329
76	327	135	329	196	325	M
77	197	378	439	374	377	94
78	D	319	138	220	69	358
79	D	336	280	385	434	252
80	321	289	305	301	269	345
81	260	321	80	203	377	391
82	D	273	209	286	380	356
83	332	132	182	308	494	181
84	389	263	384	339	287	307
85	392	181	358	534	45	415
86	94	229	253	484	314	348
87	394	127	265	170	136	148
88	218	295	128	319	131	491
89	269	169	197	211	352	390
90	353	260	201	335	344	313
6meter 1	198	185	168	105	92	84
2	38	241	131	192	153	168
3	206	285	275	284	231	294
4	239	24	174	231	273	244
5	178	171	245	M	252	130
6	84	60	47	45	212	209
7	205	166	273	51	162	186
8	44	46	64	240	52	219
9	164	196	179	199	226	200

Whole-Animal Wet-Weight Growth Rates (mg/wk)

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
10	342	34	20	194	185	321
11	272	221	79	D	241	133
12	D	222	204	252	188	255
13	52	207	15	228	194	193
14	174	222	88	199	D	148
15	275	137	238	163	177	232
16	258	230	68	238	D	132
17	275	134	M	242	49	216
18	38	152	158	M	143	251
19	146	M	229	78	315	172
20	182	296	234	M	287	35
21	163	239	306	95	258	57
22	192	243	179	262	M	105
23	129	86	194	119	142	23
24	187	216	22	D	262	223
25	33	236	284	289	207	140
26	240	22	43	166	267	194
27	142	M	325	222	304	155
28	237	276	202	118	184	288
29	221	167	120	254	M	274
30	78	219	214	257	238	297
31	107	143	184	22	274	262
32	208	240	37	155	240	209
33	40	237	131	254	186	111
34	239	218	237	293	176	153
35	199	170	268	230	189	292
36	M	205	196	119	258	271
37	129	D	223	197	82	305
38	188	231	49	205	139	201
39	243	55	98	184	137	222
40	230	147	72	M	130	106
41	66	334	190	271	254	232
42	224	131	226	233	327	291
43	59	185	182	14	181	164
44	209	144	211	206	56	102
45	140	190	20	16	204	233
46	287	243	277	209	25	222
47	262	37	200	222	130	212
48	115	275	178	219	73	298
49	M	228	253	180	295	305
50	325	M	172	M	58	309
51	221	39	127	233	301	340
52	70	232	168	318	296	M
53	225	190	237	140	289	264
54	203	43	172	84	169	48
55	158	268	143	286	275	M
56	90	208	320	179	64	243
57	118	38	182	245	223	191
58	D	313	228	228	242	286
59	189	210	97	220	266	239
60	134	266	326	310	230	205
61	175	100	334	256	188	163
62	287	262	259	40	338	99
63	287	231	263	268	55	192
64	278	30	207	122	258	M
65	251	D	130	53	268	254
66	166	222	249	130	303	224
67	292	306	326	77	306	240
68	305	197	279	204	184	276
69	115	320	287	84	126	127
70	272	290	79	304	238	267
71	258	322	370	80	304	271
72	304	259	139	286	344	344
73	270	299	297	33	86	208
74	56	237	279	278	66	337
75	254	170	238	206	340	34

Whole-Animal Wet-Weight Growth Rates (mg/wk)

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
76	208	203	267	297	97	354
77	113	239	206	191	102	334
78	240	291	268	319	166	384
79	134	198	222	265	105	337
80	128	79	219	209	300	96
81	211	156	244	266	231	280
82	293	329	90	281	331	324
83	230	375	373	156	345	275
84	184	74	97	242	273	245
85	315	287	309	262	331	141
86	279	94	86	354	268	255
87	142	304	149	353	390	352
88	53	D	227	208	177	304
89	300	359	305	375	272	366
90	193	261	201	307	309	296
	D = Dead					
	M = Missing					

Appendix G

End-of-Test Tissue Weights

End-of-Test Tissue Weights (g-wet)

mean	0.69	0.66	0.72	0.66	0.74	0.81
min	0.06	0.15	0.08	0.14	0.15	0.15
max	1.37	1.47	1.62	1.48	1.72	1.89
stdev	0.25	0.24	0.29	0.25	0.33	0.32
count	249	256	258	254	256	256
2SE	0.032	0.030	0.036	0.031	0.041	0.040
Cage#:	2, 10, 13	6, 17, 19	5, 7, 21	11, 15, 16	1, 9, 18,	4, 8, 14
	Station 1	**Station 2**	**Station 3**	**Station 4**	**Station 5**	**Station 6**
2meter 1	M	0.49	M	0.67	0.35	0.36
2	0.88	0.87	0.75	0.67	D	0.79
3	0.50	0.29	0.80	0.23	0.82	1.08
4	0.11	0.54	0.61	0.29	0.74	0.86
5	0.73	0.65	0.92	0.73	1.10	0.79
6	M	0.73	1.04	M	0.78	0.21
7	0.36	0.25	0.64	0.60	0.70	1.03
8	M	0.58	0.91	0.59	0.78	0.19
9	0.28	0.63	0.93	0.17	0.92	0.95
10	0.80	0.49	M	0.44	0.72	1.07
11	0.74	0.33	0.93	0.60	M	0.71
12	0.68	0.78	0.77	0.31	0.91	1.06
13	0.34	0.72	0.93	0.49	0.95	0.92
14	M	0.79	0.73	0.32	0.38	0.78
15	0.85	0.73	1.10	1.04	0.70	0.63
16	0.33	0.95	1.07	M	M	M
17	0.69	0.60	0.32	0.87	0.39	0.46
18	0.30	0.65	0.93	0.50	0.19	0.83
19	0.58	0.65	0.39	0.53	0.64	0.45
20	D	0.24	0.45	M	0.64	0.15
21	1.15	0.78	0.64	0.79	0.83	0.85
22	M	0.47	0.86	0.67	0.23	0.73
23	0.64	0.62	0.67	M	M	1.06
24	1.06	0.90	0.93	0.68	0.96	0.21
25	0.69	0.65	0.37	0.68	0.69	0.25
26	0.99	0.88	1.04	0.86	0.79	1.24
27	0.84	1.04	0.08	0.69	0.89	0.77
28	0.82	0.40	0.56	0.77	0.56	0.61
29	1.10	0.63	0.87	0.57	1.14	M
30	0.85	0.62	0.65	0.86	1.26	0.42
31	0.25	0.91	0.95	0.86	1.33	0.83
32	0.88	0.65	0.89	0.84	0.51	0.60
33	0.73	0.76	1.15	0.55	0.99	1.03
34	0.77	0.93	0.74	0.57	0.26	0.60
35	0.35	0.91	0.78	0.65	M	0.98
36	0.62	0.58	0.46	0.68	0.62	M
37	M	0.33	1.19	0.61	0.96	1.03
38	1.09	0.46	1.05	0.27	0.65	M
39	0.85	0.77	0.87	0.71	1.09	0.65
40	0.55	0.78	D	0.55	1.35	0.93
41	1.04	M	0.96	0.64	0.93	1.28
42	0.30	0.47	1.19	0.89	0.22	0.85
43	1.06	M	0.69	0.65	0.16	M
44	1.11	0.40	0.88	0.69	0.32	0.96
45	0.72	M	1.27	0.79	0.68	0.25
46	0.26	M	0.30	0.56	1.09	0.47
47	0.55	0.47	0.35	0.49	0.87	1.38
48	0.96	0.32	0.96	0.44	1.23	1.05
49	0.94	0.35	1.02	0.78	0.67	0.90
50	0.72	0.96	1.21	D	0.61	0.29
51	0.67	0.83	M	0.85	0.82	0.81
52	0.58	0.58	0.93	0.18	0.62	0.68
53	1.04	0.49	1.39	0.45	1.03	1.08
54	0.91	1.28	1.12	0.92	0.31	1.31
55	1.16	0.98	0.62	0.68	0.44	1.06
56	1.00	M	0.63	1.06	0.91	1.25
57	1.18	1.24	1.31	0.84	1.29	0.95
58	0.44	0.90	1.16	0.78	0.86	1.11
59	0.63	0.89	1.19	0.63	1.23	1.32

End-of-Test Tissue Weights (g-wet)

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
60	1.00	1.04	0.81	0.54	1.38	1.43
61	0.88	0.32	0.56	0.73	1.29	1.06
62	0.66	0.45	0.62	0.84	0.49	1.20
63	1.09	0.95	D	0.56	1.05	0.80
64	0.71	0.65	0.88	0.15	0.46	0.83
65	0.87	1.17	1.20	0.70	0.79	0.98
66	0.91	0.95	0.86	0.54	1.18	1.18
67	0.86	1.00	0.63	0.43	0.68	1.05
68	0.89	0.95	0.99	0.62	1.39	1.11
69	0.90	0.43	0.95	0.40	0.55	1.23
70	0.55	0.80	0.79	0.87	0.95	1.17
71	0.57	0.83	0.70	1.02	0.34	1.06
72	0.82	0.27	0.80	1.03	1.01	0.70
73	0.59	0.54	1.00	0.31	0.50	0.61
74	1.37	1.08	1.14	0.66	1.14	1.31
75	0.86	0.93	1.07	0.32	1.46	1.39
76	1.19	0.76	1.18	0.41	0.53	1.73
77	0.95	0.78	0.59	0.46	0.86	1.36
78	0.98	1.44	1.45	0.84	0.71	1.89
79	M	0.62	0.63	0.48	0.68	1.17
80	0.73	0.96	0.72	0.54	0.36	1.57
81	0.40	1.47	1.31	1.06	1.52	0.69
82	1.28	0.94	1.15	1.18	0.84	1.69
83	1.27	1.06	0.32	1.06	1.01	1.46
84	0.88	1.17	1.36	1.13	1.13	1.20
85	1.25	0.55	1.02	0.42	1.33	0.48
86	0.54	0.98	1.37	1.10	0.86	1.39
87	0.46	0.67	1.42	0.96	0.74	1.30
88	0.82	1.22	0.93	0.89	1.14	1.41
89	0.84	0.49	1.45	0.56	1.24	0.84
90	0.76	0.77	0.55	1.01	1.48	1.38
4meter 1	0.58	0.18	0.56	0.45	M	0.51
2	0.67	0.15	0.91	0.62	0.78	0.31
3	0.59	0.50	0.74	0.20	0.57	M
4	1.03	0.56	D	M	0.92	D
5	0.63	0.40	0.72	M	0.38	M
6	0.64	0.25	0.89	0.81	0.53	0.91
7	M	0.58	0.89	0.28	0.68	0.91
8	0.71	0.54	0.35	M	0.99	1.01
9	0.64	0.17	M	0.69	0.65	0.63
10	0.26	0.25	0.83	0.73	0.15	0.74
11	0.29	0.71	0.63	0.55	0.22	0.76
12	0.50	0.21	0.58	0.58	M	0.85
13	M	0.39	0.80	0.74	0.91	0.77
14	0.70	0.69	0.81	M	NM	0.50
15	M	0.58	0.54	0.59	0.83	0.64
16	0.79	0.69	0.85	0.83	0.81	0.45
17	0.55	0.17	0.32	0.71	0.68	M
18	0.48	0.52	0.82	0.56	1.00	0.82
19	0.76	0.45	0.76	0.36	0.62	0.68
20	0.12	0.60	0.70	0.69	0.92	0.67
21	0.71	0.66	0.57	0.66	0.98	1.18
22	1.02	D	0.51	0.24	0.69	1.02
23	0.18	0.66	0.94	0.47	1.00	0.69
24	0.78	0.56	0.65	0.59	M	0.25
25	0.82	0.69	1.03	0.73	0.97	0.96
26	0.33	0.43	0.09	0.45	0.51	0.86
27	0.48	0.68	M	0.66	0.23	0.59
28	M	0.71	0.57	0.86	0.15	0.99
29	0.58	0.45	0.73	0.40	0.52	0.67
30	0.85	0.25	0.63	0.85	0.94	0.55
31	0.68	0.42	0.57	1.00	0.83	0.73
32	0.91	0.29	0.27	0.72	0.90	0.34
33	0.15	0.22	0.70	0.78	0.50	0.58
34	0.61	0.67	0.41	0.22	0.30	0.70
35	0.20	0.72	0.31	0.78	1.03	0.44

End-of-Test Tissue Weights (g-wet)

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
36	0.38	D	M	0.42	0.65	0.68
37	0.54	0.62	0.12	0.66	0.80	0.84
38	0.41	0.62	0.70	0.66	0.71	0.91
39	0.70	0.66	0.47	0.75	M	0.81
40	0.67	0.80	0.28	0.61	1.00	1.23
41	0.75	0.78	0.98	0.68	0.93	0.91
42	0.82	0.77	0.94	0.82	0.87	1.18
43	0.79	0.74	0.83	0.71	1.01	1.03
44	0.78	0.54	M	0.63	0.91	0.19
45	M	0.74	0.71	0.26	0.74	0.70
46	0.78	0.52	0.66	0.44	0.60	1.09
47	0.53	0.71	0.37	0.93	0.34	0.97
48	0.06	0.39	0.38	0.23	0.73	0.29
49	M	D	0.28	0.22	1.09	1.01
50	0.44	0.67	0.46	0.73	0.94	0.68
51	0.55	0.39	0.99	0.92	0.46	0.79
52	0.83	0.78	0.75	0.42	1.19	0.78
53	1.00	1.00	0.59	1.03	0.17	0.36
54	0.81	0.91	1.62	1.01	0.93	0.92
55	0.95	0.91	0.39	0.74	1.39	1.04
56	0.44	0.61	0.69	0.68	1.14	0.82
57	0.99	0.46	0.59	0.83	0.90	1.00
58	0.91	0.88	0.76	0.89	0.98	1.00
59	1.29	0.88	0.83	0.96	1.42	0.82
60	0.82	0.70	0.58	0.79	1.17	0.97
61	0.36	0.51	1.01	0.89	0.93	0.51
62	0.92	0.86	0.50	0.59	0.30	0.57
63	0.95	0.60	0.75	0.44	0.94	0.68
64	0.86	0.67	1.08	0.86	0.55	M
65	0.78	0.60	D	0.83	1.10	0.92
66	0.95	0.71	0.88	0.92	1.05	1.16
67	0.67	0.67	1.19	0.48	0.76	1.19
68	0.79	0.37	0.54	0.94	0.70	1.31
69	0.63	0.71	0.96	0.60	1.07	1.29
70	1.02	0.95	0.77	0.45	0.87	0.78
71	0.97	0.87	0.70	0.68	1.20	1.08
72	0.81	1.05	0.89	0.86	1.30	0.60
73	0.69	1.02	0.90	1.12	0.96	1.24
74	1.08	0.85	0.90	0.89	0.70	0.72
75	0.98	0.97	0.67	1.33	0.95	1.12
76	0.98	0.63	0.98	0.75	1.28	M
77	0.70	1.14	1.19	1.04	1.33	0.37
78	D	1.02	0.67	0.90	0.54	0.99
79	D	0.93	1.00	1.11	1.56	0.86
80	0.91	0.84	1.00	0.97	1.05	1.03
81	0.91	0.95	0.38	0.91	1.30	1.25
82	D	0.84	0.82	0.76	1.31	1.06
83	1.04	0.63	0.75	0.99	1.72	0.75
84	1.00	0.92	1.22	1.10	0.95	1.04
85	1.09	0.68	1.05	1.44	0.40	1.32
86	0.54	0.74	1.00	1.48	1.12	1.29
87	1.08	0.59	0.85	0.73	0.77	0.61
88	0.73	0.84	0.63	0.98	0.83	1.30
89	0.92	0.76	0.82	0.87	1.66	1.44
90	1.01	0.91	0.80	0.98	1.36	1.01
6meter 1	0.50	0.50	0.44	0.28	0.25	0.28
2	0.22	0.62	0.30	0.51	0.41	0.57
3	0.55	0.70	0.60	0.72	0.46	0.78
4	0.62	0.19	0.48	0.69	0.60	0.63
5	0.54	0.42	0.58	M	0.38	0.44
6	0.46	0.33	0.21	0.20	0.54	0.62
7	0.60	0.46	0.65	0.14	0.41	0.52
8	0.21	0.28	0.22	0.51	0.18	0.64
9	0.43	0.53	0.50	0.48	0.55	0.59
10	0.72	0.22	0.10	0.45	0.42	0.86
11	0.67	0.69	0.19	D	0.53	0.51

End-of-Test Tissue Weights (g-wet)

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
12	D	0.55	0.45	0.61	0.42	0.76
13	0.26	0.63	0.15	0.50	0.50	0.48
14	0.59	0.61	0.28	0.47	D	0.48
15	0.68	0.42	0.69	0.43	0.44	0.68
16	0.61	0.57	0.25	0.53	D	0.40
17	0.71	0.49	M	0.61	0.20	0.62
18	0.19	0.54	0.35	M	0.36	0.66
19	0.46	M	0.56	0.21	0.60	0.41
20	0.48	0.73	0.53	M	0.65	0.20
21	0.54	0.68	0.70	0.31	0.54	0.24
22	0.52	0.61	0.47	0.59	M	0.40
23	0.41	0.33	0.98	0.30	0.31	0.21
24	0.50	0.60	0.14	D	0.52	0.67
25	0.14	0.61	0.84	0.62	0.44	0.47
26	0.60	0.18	0.22	0.42	0.64	0.55
27	0.48	M	0.75	0.59	0.75	0.58
28	0.59	0.59	0.48	0.40	0.45	0.72
29	0.51	0.46	0.30	0.57	M	0.75
30	0.38	0.55	0.84	0.54	0.59	0.77
31	0.54	0.40	0.41	0.15	0.59	0.77
32	0.63	0.70	0.18	0.43	0.64	0.66
33	0.28	0.61	0.55	0.65	0.41	0.43
34	0.67	0.62	0.61	0.74	0.55	0.54
35	0.64	0.47	0.57	0.62	0.39	0.76
36	M	0.62	0.54	0.30	0.63	0.75
37	0.44	D	0.68	0.48	0.40	0.86
38	0.56	0.66	0.23	0.51	0.45	0.55
39	0.68	0.37	0.42	0.32	0.43	0.62
40	0.65	0.52	0.31	M	0.48	0.48
41	0.25	1.07	0.43	0.61	0.64	0.76
42	0.68	0.52	0.57	0.57	0.72	0.79
43	0.36	0.76	0.41	0.19	0.43	0.34
44	0.55	0.48	0.55	0.62	0.27	0.38
45	0.44	0.54	0.14	0.20	0.57	0.65
46	0.78	0.72	0.66	0.53	0.15	0.68
47	0.82	0.23	0.57	0.67	0.30	0.58
48	0.55	0.92	0.56	0.70	0.35	0.89
49	M	0.70	0.61	0.49	0.75	0.84
50	1.06	M	0.51	M	0.27	0.85
51	0.69	0.23	0.58	0.84	0.72	0.90
52	0.40	0.70	0.52	0.87	0.62	M
53	0.71	0.62	0.62	0.45	0.84	0.75
54	0.64	0.30	0.62	0.45	0.54	0.29
55	0.52	0.85	0.50	0.84	0.69	M
56	0.38	0.57	0.90	0.69	0.22	0.75
57	0.50	0.37	0.72	0.72	0.62	0.74
58	D	0.90	0.67	0.66	0.65	1.07
59	0.58	0.77	0.46	0.59	0.71	0.73
60	0.47	0.84	0.79	0.75	0.52	0.68
61	0.49	0.51	0.79	0.76	0.62	0.54
62	0.85	0.76	0.62	0.21	0.85	0.47
63	0.91	0.69	0.86	0.79	0.23	0.57
64	0.76	0.19	0.58	0.45	0.70	M
65	0.75	D	0.43	0.30	0.63	0.68
66	0.50	0.60	0.70	0.42	0.70	0.69
67	0.85	0.82	0.91	0.35	0.64	0.74
68	0.75	0.72	0.74	0.65	0.68	0.79
69	0.47	0.90	0.75	0.47	0.39	0.53
70	0.89	0.82	0.30	0.97	0.57	0.68
71	0.66	0.92	1.12	0.43	0.64	0.83
72	0.96	0.81	0.41	0.90	0.77	0.96
73	0.77	0.72	0.71	0.33	0.32	0.47
74	0.34	0.62	0.78	0.72	0.33	1.09
75	0.64	0.59	0.67	0.82	0.95	0.27
76	0.65	0.63	0.80	0.57	0.36	1.26
77	0.45	0.61	0.71	0.88	0.41	1.00

End-of-Test Tissue Weights (g-wet)

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
78	0.74	0.95	0.71	0.85	0.54	1.07
79	0.55	0.58	0.66	0.77	0.29	0.96
80	0.40	0.42	0.79	0.63	0.77	0.37
81	0.70	0.66	0.60	0.66	0.67	0.80
82	0.76	0.93	0.43	0.78	0.83	0.75
83	0.71	1.12	1.05	0.55	0.94	0.88
84	0.86	0.46	0.48	0.83	0.65	0.76
85	0.94	0.82	0.92	0.72	0.80	0.74
86	0.84	0.47	0.45	0.90	0.54	0.84
87	0.55	0.87	0.52	1.02	0.83	1.00
88	0.34	D	0.71	0.82	0.44	0.91
89	0.91	0.96	0.92	1.13	0.71	1.32
90	0.73	0.75	0.75	1.05	0.76	0.81
	D = dead					
	M = missing					
	NM = not measured					
		= crushed; not able to make weight or length measurements				
			but tissue still intact			

Appendix H

End-of-Test Shell Weights

End-of-Test Shell Weight (g-wet)

mean	0.91	0.91	0.98	0.94	0.96	1.00
min	0.15	0.22	0.17	0.23	0.2	0.14
max	1.73	1.84	1.89	1.98	1.9	2.03
stdev	0.31	0.31	0.32	0.31	0.33	0.33
count	248	256	257	254	256	252
2se	0.040	0.039	0.040	0.039	0.042	0.042
Cage#:	2, 10, 13	6, 17, 19	5, 7, 21	11, 15, 16	1, 9, 18,	4, 8, 14
	Station 1	**Station 2**	**Station 3**	**Station 4**	**Station 5**	**Station 6**
2meter 1	M	0.76	M	0.90	0.68	0.67
2	1.21	1.34	1.30	1.08	D	1.01
3	0.70	0.43	1.13	0.37	0.81	1.24
4	0.21	0.79	0.85	0.64	0.92	1.08
5	1.09	1.03	0.95	1.09	1.00	1.19
6	M	0.93	1.24	M	1.10	0.47
7	0.48	0.38	0.61	0.51	0.81	1.29
8	M	1.04	1.17	1.06	1.15	0.34
9	0.42	0.84	1.11	0.35	1.13	1.23
10	1.19	0.61	M	0.60	0.55	1.04
11	1.03	0.35	1.09	1.18	M	0.92
12	1.01	1.22	1.12	0.66	1.15	1.00
13	0.48	1.03	1.20	0.60	1.16	1.23
14	M	0.79	0.84	0.61	0.37	0.87
15	1.11	0.86	1.27	1.06	1.05	0.58
16	0.38	1.24	1.21	M	M	M
17	0.88	0.83	0.48	1.18	0.48	0.69
18	0.40	0.96	1.43	1.03	0.26	1.11
19	0.84	0.79	0.65	0.85	1.01	0.57
20	D	0.23	0.64	M	0.71	0.24
21	1.27	0.95	0.93	1.27	0.97	0.95
22	M	0.84	0.98	1.03	0.48	0.84
23	0.95	0.73	0.91	M	M	NM
24	1.29	1.32	0,89	0.79	1.27	0.33
25	0.76	0.94	0.54	1.03	0.92	0.40
26	1.17	1.16	1.25	1.05	0.99	1.21
27	0.96	1.11	0.17	0.98	1.28	0.74
28	0.93	0.48	0.91	0.99	0.70	NM
29	1.35	0.95	0.90	1.02	1.16	M
30	1.14	0.83	0.76	1.22	1.41	0.65
31	0.37	1.30	1.08	1.02	1.65	1.19
32	1.03	0.98	1.11	1.41	0.68	0.80
33	0.89	1.12	1.48	0.82	1.05	1.27
34	0.94	1.33	0.88	0.72	0.40	0.70
35	0.45	1.31	0.91	1.08	M	1.15
36	0.95	1.05	0.72	1.27	0.81	M
37	M	0.51	1.16	1.08	1.04	1.06
38	1.32	0.70	1.31	0.54	1.03	M
39	1.32	0.83	0.93	1.47	1.27	0.78
40	0.60	1.25	D	0.97	1.71	1.10
41	1.23	M	1.19	1.03	1.21	1.07
42	0.53	0.58	1.56	1.01	0.30	0.96
43	1.16	M	0.85	1.00	0.32	M
44	1.18	0.50	0.89	1.37	0.52	0.94
45	1.03	M	1.37	1.03	0.87	0.28
46	0.40	M	0.36	0.76	1.22	0.62
47	0.68	0.79	0.49	0.62	1.01	1.08
48	1.25	0.57	1.30	0.67	1.49	1.07
49	1.22	0.31	1.70	1.35	0.71	1.29
50	0.79	1.28	1.41	D	0.86	0.36
51	0.79	0.99	M	1.28	1.02	1.15
52	0.72	0.96	1.08	0.39	0.72	0.88
53	1.17	0.78	1.52	0.76	1.35	1.21
54	1.15	1.38	1.46	1.39	0.44	1.36
55	1.55	1.37	0.72	1.34	0.56	1.12
56	1.17	M	0.94	1.33	0.97	1.33
57	1.34	1.20	1.27	1.05	1.62	0.91
58	0.55	1.27	1.34	1.22	1.07	1.21
59	0.87	1.21	1.65	1.33	1.41	1.31

End-of-Test Shell Weight (g-wet)

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
60	1.12	1.29	1.02	1.10	1.45	1.13
61	1.16	0.43	0.93	1.52	NM	1.14
62	0.87	0.59	0.85	1.18	0.66	1.44
63	1.31	1.32	D	0.93	0.87	0.87
64	1.31	1.09	1.28	0.24	0.57	0.87
65	1.15	1.39	1.89	1.18	0.89	1.04
66	1.08	1.13	1.11	1.01	1.44	1.24
67	1.07	1.12	0.81	0.67	0.69	1.33
68	1.15	1.15	1.33	0.99	1.24	1.11
69	1.24	0.53	0.91	0.93	0.86	1.54
70	0.81	0.84	1.08	1.49	1.55	1.46
71	0.94	1.17	0.75	1.30	0.49	1.31
72	1.28	0.52	1.06	1.07	1.38	0.82
73	0.93	0.86	1.46	0.68	0.91	0.75
74	1.46	1.61	1.31	1.09	1.59	1.62
75	1.06	1.08	1.44	0.49	1.51	1.63
76	1.24	0.82	1.40	0.78	0.72	1.86
77	1.20	1.15	0.90	0.78	1.29	1.48
78	1.15	1.84	1.66	1.39	1.10	2.03
79	M	0.68	0.86	0.81	1.71	1.38
80	0.98	1.44	0.99	0.86	0.92	1.28
81	0.41	1.74	1.45	1.67	1.52	0.63
82	1.42	1.37	1.57	1.48	0.85	1.91
83	1.52	1.19	0.68	1.27	1.45	1.58
84	1.12	1.31	1.38	1.66	1.09	1.12
85	1.29	0.65	1.55	0.80	1.49	0.65
86	0.63	1.33	1.35	1.36	1.16	1.70
87	0.52	0.66	1.60	1.30	1.23	1.40
88	1.08	1.41	1.43	1.98	1.43	1.57
89	1.48	0.61	1.41	1.12	0.99	0.89
90	1.19	1.22	0.92	1.80	1.90	1.39
4meter 1	0.87	0.22	0.72	0.82	M	0.63
2	1.08	0.28	1.04	1.11	0.84	0.49
3	0.88	0.74	1.06	0.36	0.89	M
4	1.23	0.79	D	M	1.07	D
5	0.96	0.71	1.19	M	0.58	M
6	0.86	0.46	1.21	1.31	0.70	1.03
7	M	0.93	0.99	0.38	0.75	0.89
8	1.13	1.01	0.54	M	1.26	1.24
9	0.75	0.27	M	0.95	0.77	0.86
10	0.36	0.53	1.06	1.14	0.32	1.03
11	0.44	0.84	0.86	0.89	0.40	0.75
12	0.74	0.30	0.70	0.80	M	1.22
13	M	0.69	1.03	1.03	1.07	1.01
14	0.79	0.88	1.13	M	1.18	0.66
15	M	0.76	0.72	0.86	1.00	1.01
16	1.04	0.77	1.16	1.01	0.91	0.79
17	0.92	0.25	0.58	0.97	1.05	M
18	0.79	0.89	1.17	0.88	1.16	1.08
19	1.07	0.72	1.05	0.49	0.89	1.10
20	0.32	0.96	1.07	0.93	0.84	1.03
21	1.23	1.05	0.74	1.07	1.02	1.24
22	1.06	D	0.68	0.34	1.05	1.07
23	0.15	0.89	1.25	0.80	1.18	1.11
24	1.06	0.79	0.94	0.67	M	0.28
25	1.21	0.96	1.04	1.25	1.34	0.96
26	0.46	0.55	0.19	0.88	0.94	0.89
27	0.77	1.01	M	0.89	0.36	0.77
28	M	1.01	0.70	1.14	0.20	1.12
29	0.82	0.67	0.97	0.65	0.67	0.95
30	1.03	0.40	0.87	1.03	1.00	0.72
31	0.77	0.50	0.94	1.15	1.11	0.82
32	0.93	0.47	0.28	1.05	1.00	0.49
33	0.36	0.25	1.15	1.16	0.62	0.71
34	0.70	0.99	0.82	0.30	0.31	1.03
35	0.31	1.12	0.52	1.09	1.10	0.53

End-of-Test Shell Weight (g-wet)

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
36	0.59	D	M	0.62	0.80	0.73
37	0.91	0.78	0.32	0.93	0.93	1.14
38	0.45	0.88	1.19	0.88	0.87	1.14
39	0.79	1.17	0.97	1.13	M	1.05
40	0.74	1.20	0.66	0.96	1.20	1.47
41	1.02	0.96	1.14	1.04	1.09	1.02
42	0.92	0.99	1.09	1.38	1.29	1.32
43	1.18	1.04	1.02	1.23	0.90	1.22
44	0.92	0.85	M	0.85	0.83	0.28
45	M	0.86	0.85	0.57	1.00	0.85
46	0.85	0.67	1.10	0.59	0.64	1.07
47	0.73	1.06	0.68	1.27	0.56	1.10
48	0.26	0.49	0.75	0.26	0.85	0.36
49	M	D	0.45	0.31	1.04	1.19
50	0.64	0.71	0.64	1.11	1.07	0.63
51	0.75	0.55	1.06	1.50	1.02	0.81
52	1.17	1.02	1.02	0.60	1.09	0.92
53	1.30	1.43	1.22	1.19	0.20	0.59
54	1.19	1.29	1.08	1.16	1.15	1.24
55	1.33	1.26	0.68	1.06	1.38	1.30
56	0.67	0.90	1.33	0.72	1.36	1.05
57	1.44	1.03	1.26	0.95	1.01	1.13
58	1.07	1.42	1.50	0.93	1.37	1.33
59	1.32	1.09	1.50	0.96	1.40	1.19
60	1.13	1.20	1.24	1.15	1.51	1.05
61	0.66	0.95	1.26	1.06	0.91	0.73
62	1.13	1.05	0.55	0.70	0.41	0.88
63	1.09	0.84	0.93	0.67	1.18	1.12
64	1.06	1.25	1.26	0.86	0.70	M
65	0.91	0.94	D	1.18	1.28	1.13
66	1.15	0.77	1.16	1.22	1.41	1.43
67	0.87	0.90	1.22	0.76	0.82	1.19
68	1.17	0.51	0.82	1.02	1.02	1.26
69	1.27	0.96	1.38	0.89	1.19	1.43
70	1.25	1.24	1.14	0.69	0.93	0.78
71	1.43	0.96	0.94	0.98	1.34	1.17
72	1.17	1.24	1.25	1.34	1.51	0.78
73	1.11	1.42	1.35	1.44	1.14	1.40
74	1.24	1.23	1.15	0.99	0.84	1.25
75	1.31	1.31	1.10	1.41	1.11	1.27
76	1.56	0.74	1.43	1.01	1.24	M
77	1.04	1.26	1.58	1.36	1.62	0.75
78	D	1.17	0.97	0.90	0.77	1.38
79	D	1.30	1.06	1.28	1.59	1.04
80	1.17	1.14	1.05	1.01	1.13	1.41
81	1.04	1.30	0.62	0.87	1.78	1.52
82	D	1.10	NM	1.11	1.42	1.80
83	1.49	0.87	1.17	1.47	1.55	1.56
84	1.73	1.01	1.13	1.39	1.25	1.12
85	1.37	0.91	1.62	1.74	0.51	1.88
86	0.81	1.25	1.34	1.58	1.54	1.90
87	1.26	1.25	1.23	0.80	0.88	0.92
88	0.83	0.93	0.74	0.85	0.84	1.38
89	1.52	1.21	1.04	0.99	1.25	1.60
90	1.41	1.19	1.24	1.45	1.53	1.30
6meter 1	0.83	0.88	0.93	0.53	0.35	0.54
2	0.33	0.86	0.61	0.78	0.80	0.65
3	0.70	0.96	0.87	0.84	0.82	1.07
4	0.88	0.28	0.69	0.86	0.95	0.90
5	0.61	0.89	0.90	M	0.95	0.62
6	0.48	0.46	0.41	0.31	0.90	0.77
7	0.82	0.63	0.83	0.37	0.73	0.73
8	0.38	0.35	0.46	0.81	0.25	0.96
9	0.62	0.80	0.72	0.73	0.70	0.83
10	0.99	0.30	0.23	0.77	0.62	1.08
11	0.99	0.92	0.47	D	0.89	0.65

End-of-Test Shell Weight (g-wet)

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
12	D	0.83	0.71	0.94	0.74	0.91
13	0.30	1.07	0.29	0.86	0.78	0.75
14	0.67	0.98	0.55	0.81	D	0.71
15	0.99	0.67	0.98	0.81	0.68	0.86
16	0.94	0.83	0.49	0.94	D	0.67
17	1.11	0.73	M	0.93	0.32	0.82
18	0.44	0.67	0.58	M	0.46	1.11
19	0.62	M	0.83	0.39	1.03	0.39
20	0.64	0.93	0.95	M	1.05	0.17
21	0.86	0.96	1.00	0.57	0.95	0.31
22	0.78	1.02	0.72	0.75	M	0.56
23	0.59	0.60	0.71	0.51	0.61	0.14
24	0.69	0.93	0.24	D	0.97	0.76
25	0.25	0.91	0.98	0.94	0.96	0.89
26	0.79	0.25	0.41	0.68	0.87	1.04
27	0.65	M	0.96	0.83	1.01	1.02
28	0.92	0.72	0.79	0.60	0.69	NM
29	0.76	0.73	1.03	1.11	M	NM
30	0.47	0.85	1.02	0.92	0.82	0.89
31	0.52	0.53	0.86	0.26	0.74	0.96
32	0.78	1.02	0.44	0.86	0.93	0.86
33	0.43	1.01	0.62	0.93	0.75	0.63
34	0.94	1.02	0.87	1.05	0.68	0.73
35	0.67	0.74	0.81	0.98	0.95	1.19
36	M	0.86	0.91	0.52	1.04	0.93
37	0.61	D	0.86	0.98	0.51	1.10
38	0.63	0.91	0.50	0.81	0.73	0.80
39	1.00	0.45	0.64	0.64	0.63	0.87
40	0.90	0.79	0.58	M	0.70	0.55
41	0.46	1.39	0.80	1.02	0.95	0.94
42	0.79	0.64	0.89	0.93	1.27	0.97
43	0.46	0.87	0.62	0.23	0.69	0.77
44	0.73	0.77	0.79	0.80	0.42	0.61
45	0.59	0.66	0.22	0.27	0.76	0.82
46	1.00	0.95	1.05	0.69	0.29	0.89
47	1.00	0.23	0.98	0.67	0.54	0.86
48	0.60	0.96	0.75	0.76	0.50	1.26
49	M	0.92	1.13	0.72	0.94	1.07
50	0.88	M	0.81	M	0.52	1.19
51	0.96	0.38	0.72	0.99	1.26	1.31
52	0.67	0.95	0.77	0.97	1.08	M
53	0.93	0.82	1.01	0.62	0.94	1.09
54	0.78	0.41	0.79	0.52	0.84	0.47
55	0.54	1.20	0.68	1.08	1.19	M
56	0.67	1.05	1.18	0.93	0.45	0.92
57	0.25	0.46	0.98	1.04	0.82	0.91
58	D	1.31	1.12	0.77	1.17	1.09
59	0.62	0.87	0.58	1.16	0.95	0.88
60	0.61	1.36	1.16	1.14	0.82	0.88
61	1.14	0.66	1.28	0.89	0.88	0.63
62	0.88	0.94	1.04	0.41	1.22	0.61
63	1.03	0.80	1.37	0.94	0.46	0.85
64	0.98	0.26	0.80	0.58	0.98	M
65	0.59	D	0.71	0.45	0.91	1.23
66	1.26	0.70	0.83	0.61	0.99	1.00
67	1.17	0.98	1.16	0.55	1.23	0.99
68	0.70	0.82	1.09	0.87	0.96	1.02
69	0.92	1.25	1.36	0.60	0.78	0.76
70	1.00	1.10	0.59	1.23	1.02	1.18
71	1.58	1.38	1.32	0.57	1.20	1.00
72	1.18	0.98	0.67	1.00	1.18	1.42
73	1.67	1.12	1.22	0.40	0.53	0.54
74	1.02	1.09	1.05	1.12	0.45	1.24
75	0.96	0.80	1.02	0.88	1.29	0.42
76	0.73	0.84	1.04	0.80	0.42	1.24
77	1.05	0.84	0.87	1.03	0.81	1.11

End-of-Test Shell Weight (g-wet)

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
78	0.70	1.33	1.30	0.99	0.80	1.18
79	0.68	0.76	0.91	0.98	0.74	1.12
80	0.89	0.61	0.93	1.05	1.12	0.65
81	1.14	0.72	1.05	1.13	1.13	1.08
82	1.04	1.20	0.61	1.13	1.15	1.31
83	0.91	1.25	1.45	0.74	1.08	1.11
84	1.18	0.58	0.80	1.23	1.05	0.98
85	0.95	0.73	1.00	1.04	1.10	0.95
86	0.76	0.76	0.57	1.30	1.13	0.97
87	0.48	1.01	0.82	1.37	1.46	1.43
88	NM	D	0.88	1.07	0.93	1.43
89	0.95	1.25	1.21	1.37	1.12	1.24
90	0.63	1.39	0.91	1.25	1.13	1.05
	D = dead					
	M = missing					
	NM = not measured					
	(shaded)	= crushed; not able to make weight or length measurements,				
		but tissue still intact & able to weigh shell				

Appendix I

Condition Indices

Condition Indices

mean	0.157	0.150	0.151	0.155	0.173	0.178
min	0.047	0.092	0.060	0.078	0.089	0.091
max	0.418	0.237	0.291	0.308	0.297	0.309
stdev	0.035	0.025	0.036	0.032	0.034	0.038
count	248	256	257	254	255	252
2SE	0.0045	0.0031	0.0045	0.0040	0.0042	0.0047
Cage#:	2, 10, 13	6, 17, 19	5, 7, 21	11, 15, 16	1, 9, 18,	4, 8, 14
	Station 1	**Station 2**	**Station 3**	**Station 4**	**Station 5**	**Station 6**
2meter 1	M	0.135	M	0.195	0.117	0.126
2	0.149	0.136	0.129	0.162	D	0.183
3	0.147	0.142	0.159	0.163	0.230	0.204
4	0.107	0.144	0.161	0.119	0.183	0.187
5	0.137	0.133	0.217	0.175	0.250	0.156
6	M	0.165	0.188	M	0.161	0.105
7	0.154	0.138	0.235	0.308	0.196	0.187
8	M	0.117	0.174	0.146	0.154	0.131
9	0.137	0.158	0.188	0.127	0.185	0.181
10	0.138	0.169	M	0.192	0.297	0.241
11	0.147	0.198	0.191	0.133	M	0.181
12	0.138	0.134	0.154	0.123	0.180	0.249
13	0.145	0.147	0.174	0.214	0.186	0.175
14	M	0.210	0.195	0.137	0.233	0.210
15	0.157	0.178	0.194	0.257	0.151	0.255
16	0.178	0.161	0.198	M	M	M
17	0.161	0.152	0.149	0.193	0.184	0.156
18	0.154	0.142	0.146	0.127	0.166	0.175
19	0.142	0.173	0.134	0.163	0.144	0.185
20	D	0.219	0.157	M	0.205	0.147
21	0.186	0.172	0.154	0.163	0.194	0.210
22	M	0.118	0.196	0.170	0.109	0.204
23	0.138	0.178	0.165	M	M	NM
24	0.169	0.143	0.234	0.225	0.172	0.149
25	0.186	0.145	0.153	0.173	0.170	0.147
26	0.174	0.159	0.186	0.214	0.181	0.240
27	0.179	0.197	0.105	0.184	0.158	0.244
28	0.181	0.175	0.138	0.204	0.182	NM
29	0.167	0.139	0.216	0.146	0.223	M
30	0.153	0.157	0.191	0.184	0.203	0.152
31	0.139	0.147	0.197	0.221	0.183	0.164
32	0.175	0.139	0.180	0.156	0.170	0.176
33	0.168	0.143	0.174	0.176	0.214	0.190
34	0.168	0.147	0.188	0.207	0.148	0.201
35	0.160	0.146	0.192	0.158	M	0.200
36	0.134	0.116	0.143	0.140	0.174	M
37	M	0.136	0.230	0.148	0.210	0.228
38	0.169	0.138	0.179	0.131	0.143	M
39	0.132	0.195	0.209	0.126	0.195	0.196
40	0.188	0.131	D	0.148	0.179	0.198
41	0.173	M	0.181	0.163	0.174	0.281
42	0.116	0.170	0.171	0.231	0.166	0.208
43	0.187	M	0.182	0.170	0.114	M
44	0.193	0.168	0.221	0.132	0.140	0.240
45	0.143	M	0.208	0.201	0.177	0.209
46	0.133	M	0.187	0.193	0.203	0.178
47	0.166	0.125	0.160	0.207	0.196	0.300
48	0.158	0.118	0.165	0.172	0.187	0.230
49	0.158	0.237	0.134	0.151	0.214	0.164
50	0.187	0.158	0.192	D	0.161	0.189
51	0.174	0.176	M	0.174	0.182	0.165
52	0.165	0.127	0.193	0.121	0.195	0.181
53	0.182	0.132	0.205	0.155	0.173	0.209
54	0.162	0.195	0.172	0.173	0.160	0.226
55	0.153	0.150	0.193	0.133	0.178	0.222
56	0.175	M	0.150	0.209	0.213	0.220
57	0.181	0.217	0.231	0.209	0.181	0.245
58	0.164	0.149	0.194	0.167	0.182	0.215
59	0.149	0.154	0.161	0.124	0.198	0.236

Condition Indices

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
60	0.183	0.169	0.178	0.128	0.216	0.297
61	0.156	0.156	0.135	0.126	NM	0.218
62	0.156	0.160	0.163	0.186	0.169	0.196
63	0.171	0.151	D	0.158	0.274	0.216
64	0.111	0.125	0.154	0.164	0.183	0.224
65	0.155	0.177	0.142	0.155	0.201	0.221
66	0.173	0.177	0.173	0.140	0.186	0.223
67	0.165	0.188	0.174	0.168	0.224	0.185
68	0.159	0.173	0.167	0.164	0.254	0.235
69	0.149	0.170	0.234	0.113	0.145	0.187
70	0.139	0.200	0.164	0.153	0.139	0.188
71	0.124	0.149	0.209	0.205	0.158	0.190
72	0.131	0.109	0.169	0.252	0.166	0.200
73	0.130	0.132	0.153	0.119	0.125	0.191
74	0.192	0.141	0.195	0.158	0.163	0.190
75	0.166	0.181	0.166	0.171	0.219	0.200
76	0.197	0.195	0.189	0.138	0.167	0.218
77	0.162	0.142	0.147	0.154	0.151	0.216
78	0.175	0.164	0.196	0.158	0.147	0.218
79	M	0.191	0.164	0.155	0.090	0.199
80	0.153	0.140	0.163	0.164	0.089	0.288
81	0.200	0.177	0.202	0.166	0.227	0.257
82	0.185	0.144	0.164	0.209	0.224	0.208
83	0.171	0.187	0.105	0.218	0.158	0.217
84	0.161	0.188	0.221	0.178	0.235	0.251
85	0.199	0.178	0.147	0.137	0.203	0.173
86	0.176	0.155	0.227	0.212	0.168	0.192
87	0.181	0.213	0.199	0.193	0.137	0.218
88	0.156	0.182	0.146	0.118	0.181	0.211
89	0.116	0.169	0.230	0.131	0.284	0.221
90	0.131	0.133	0.134	0.147	0.177	0.233
4meter 1	0.136	0.169	0.151	0.112	M	0.177
2	0.126	0.111	0.170	0.114	0.196	0.138
3	0.137	0.140	0.136	0.114	0.135	M
4	0.171	0.147	D	M	0.182	D
5	0.134	0.117	0.117	M	0.138	M
6	0.152	0.113	0.143	0.127	0.160	0.193
7	M	0.129	0.175	0.151	0.191	0.223
8	0.128	0.111	0.126	M	0.166	0.178
9	0.174	0.130	M	0.149	0.178	0.160
10	0.147	0.098	0.152	0.131	0.099	0.157
11	0.134	0.175	0.142	0.127	0.116	0.221
12	0.138	0.145	0.161	0.148	M	0.152
13	M	0.117	0.151	0.147	0.180	0.166
14	0.181	0.162	0.139	M	NM	0.165
15	M	0.158	0.146	0.141	0.175	0.138
16	0.155	0.185	0.142	0.168	0.188	0.124
17	0.122	0.141	0.107	0.150	0.137	M
18	0.124	0.121	0.136	0.130	0.182	0.166
19	0.145	0.129	0.141	0.150	0.147	0.135
20	0.076	0.129	0.127	0.152	0.231	0.142
21	0.118	0.130	0.150	0.126	0.203	0.208
22	0.196	D	0.146	0.145	0.139	0.208
23	0.245	0.154	0.146	0.120	0.179	0.136
24	0.150	0.147	0.134	0.180	M	0.195
25	0.138	0.149	0.192	0.120	0.153	0.218
26	0.146	0.162	0.092	0.105	0.115	0.211
27	0.127	0.139	M	0.152	0.135	0.167
28	M	0.146	0.158	0.154	0.158	0.193
29	0.144	0.139	0.146	0.126	0.164	0.154
30	0.168	0.129	0.141	0.169	0.199	0.167
31	0.180	0.174	0.118	0.178	0.158	0.194
32	0.199	0.128	0.187	0.140	0.190	0.151
33	0.085	0.182	0.118	0.138	0.170	0.178
34	0.178	0.140	0.097	0.150	0.204	0.148
35	0.131	0.133	0.116	0.147	0.198	0.181

Condition Indices

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
36	0.131	D	M	0.139	0.172	0.203
37	0.121	0.165	0.073	0.145	0.182	0.161
38	0.186	0.146	0.114	0.154	0.172	0.174
39	0.181	0.117	0.094	0.136	M	0.168
40	0.185	0.138	0.082	0.130	0.176	0.183
41	0.150	0.168	0.167	0.134	0.180	0.195
42	0.182	0.161	0.167	0.122	0.142	0.195
43	0.136	0.147	0.158	0.118	0.237	0.184
44	0.173	0.132	M	0.152	0.232	0.148
45	M	0.178	0.162	0.093	0.156	0.180
46	0.187	0.161	0.117	0.153	0.198	0.222
47	0.148	0.139	0.106	0.150	0.128	0.193
48	0.047	0.165	0.098	0.181	0.181	0.176
49	M	D	0.121	0.145	0.221	0.185
50	0.140	0.195	0.140	0.135	0.186	0.236
51	0.149	0.147	0.181	0.126	0.095	0.213
52	0.145	0.158	0.143	0.143	0.231	0.185
53	0.157	0.145	0.094	0.177	0.180	0.133
54	0.139	0.146	0.291	0.178	0.171	0.162
55	0.146	0.150	0.111	0.143	0.213	0.175
56	0.134	0.140	0.101	0.193	0.177	0.170
57	0.140	0.092	0.091	0.179	0.188	0.193
58	0.173	0.128	0.098	0.196	0.151	0.164
59	0.199	0.167	0.107	0.205	0.214	0.150
60	0.148	0.121	0.091	0.141	0.164	0.202
61	0.111	0.111	0.156	0.172	0.216	0.153
62	0.166	0.170	0.177	0.173	0.155	0.141
63	0.178	0.148	0.157	0.134	0.168	0.133
64	0.165	0.111	0.166	0.205	0.166	M
65	0.175	0.132	D	0.144	0.182	0.178
66	0.168	0.191	0.147	0.154	0.157	0.177
67	0.157	0.154	0.189	0.129	0.196	0.218
68	0.138	0.150	0.128	0.189	0.145	0.227
69	0.101	0.153	0.135	0.138	0.190	0.197
70	0.166	0.159	0.131	0.134	0.198	0.218
71	0.138	0.188	0.145	0.142	0.189	0.202
72	0.141	0.175	0.138	0.131	0.182	0.168
73	0.127	0.149	0.129	0.159	0.178	0.193
74	0.178	0.143	0.152	0.184	0.176	0.126
75	0.152	0.153	0.118	0.193	0.181	0.193
76	0.128	0.176	0.133	0.152	0.218	M
77	0.137	0.187	0.146	0.157	0.173	0.108
78	D	0.180	0.134	0.205	0.148	0.157
79	D	0.148	0.183	0.178	0.207	0.181
80	0.159	0.153	0.185	0.197	0.196	0.159
81	0.178	0.151	0.119	0.214	0.154	0.180
82	D	0.158	NM	0.140	0.195	0.129
83	0.142	0.150	0.124	0.138	0.234	0.105
84	0.118	0.189	0.210	0.162	0.161	0.203
85	0.162	0.155	0.126	0.169	0.166	0.153
86	0.136	0.123	0.145	0.192	0.154	0.148
87	0.175	0.098	0.134	0.187	0.185	0.145
88	0.179	0.187	0.165	0.236	0.209	0.206
89	0.123	0.130	0.153	0.180	0.280	0.196
90	0.146	0.158	0.125	0.138	0.188	0.170
6meter 1	0.126	0.112	0.098	0.108	0.179	0.107
2	0.139	0.142	0.102	0.134	0.128	0.180
3	0.164	0.143	0.142	0.176	0.141	0.150
4	0.147	0.133	0.144	0.165	0.158	0.144
5	0.185	0.093	0.133	M	0.100	0.146
6	0.200	0.141	0.106	0.132	0.150	0.166
7	0.153	0.144	0.162	0.078	0.141	0.147
8	0.115	0.157	0.099	0.129	0.180	0.137
9	0.145	0.130	0.143	0.135	0.197	0.146
10	0.152	0.144	0.090	0.120	0.170	0.164
11	0.141	0.148	0.083	D	0.149	0.161

Condition Indices

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
12	D	0.130	0.131	0.133	0.142	0.172
13	0.181	0.116	0.107	0.119	0.161	0.132
14	0.184	0.122	0.105	0.119	D	0.139
15	0.143	0.123	0.145	0.109	0.162	0.163
16	0.135	0.135	0.105	0.116	D	0.123
17	0.134	0.132	M	0.135	0.157	0.156
18	0.090	0.159	0.125	M	0.196	0.122
19	0.155	M	0.139	0.110	0.146	0.216
20	0.157	0.154	0.115	M	0.155	0.242
21	0.131	0.139	0.145	0.112	0.142	0.159
22	0.139	0.118	0.135	0.161	M	0.147
23	0.145	0.108	0.285	0.121	0.127	0.309
24	0.151	0.127	0.120	D	0.134	0.181
25	0.117	0.132	0.177	0.135	0.115	0.109
26	0.159	0.142	0.111	0.127	0.184	0.109
27	0.154	M	0.161	0.146	0.186	0.117
28	0.134	0.161	0.125	0.137	0.163	NM
29	0.140	0.124	0.060	0.105	M	NM
30	0.169	0.127	0.170	0.120	0.180	0.178
31	0.217	0.148	0.098	0.118	0.200	0.165
32	0.169	0.135	0.084	0.103	0.172	0.158
33	0.136	0.119	0.183	0.143	0.137	0.140
34	0.149	0.120	0.145	0.145	0.203	0.152
35	0.199	0.125	0.145	0.130	0.103	0.131
36	M	0.142	0.123	0.118	0.152	0.166
37	0.151	D	0.163	0.100	0.196	0.161
38	0.186	0.143	0.095	0.129	0.154	0.141
39	0.142	0.162	0.136	0.103	0.171	0.147
40	0.151	0.129	0.110	M	0.172	0.180
41	0.113	0.151	0.111	0.123	0.169	0.166
42	0.180	0.160	0.132	0.126	0.142	0.168
43	0.163	0.172	0.137	0.169	0.156	0.091
44	0.157	0.123	0.144	0.159	0.161	0.128
45	0.156	0.161	0.131	0.152	0.188	0.163
46	0.163	0.149	0.130	0.158	0.130	0.157
47	0.171	0.197	0.120	0.205	0.139	0.139
48	0.191	0.189	0.154	0.189	0.175	0.145
49	M	0.150	0.111	0.140	0.200	0.161
50	0.252	M	0.130	M	0.130	0.147
51	0.150	0.119	0.166	0.174	0.143	0.141
52	0.125	0.145	0.139	0.184	0.144	M
53	0.159	0.149	0.127	0.149	0.224	0.142
54	0.171	0.144	0.162	0.177	0.161	0.127
55	0.201	0.139	0.152	0.160	0.145	M
56	0.118	0.107	0.158	0.152	0.122	0.168
57	0.418	0.158	0.152	0.142	0.189	0.167
58	D	0.135	0.124	0.176	0.139	0.202
59	0.195	0.174	0.164	0.104	0.187	0.171
60	0.161	0.121	0.141	0.135	0.159	0.159
61	0.090	0.152	0.127	0.175	0.176	0.176
62	0.202	0.159	0.123	0.105	0.175	0.158
63	0.184	0.170	0.130	0.172	0.125	0.138
64	0.162	0.144	0.150	0.159	0.179	M
65	0.265	D	0.125	0.137	0.173	0.114
66	0.083	0.169	0.174	0.141	0.177	0.142
67	0.152	0.165	0.162	0.131	0.130	0.154
68	0.224	0.173	0.140	0.153	0.177	0.159
69	0.107	0.142	0.114	0.161	0.125	0.143
70	0.186	0.147	0.105	0.162	0.140	0.119
71	0.087	0.131	0.175	0.155	0.134	0.171
72	0.170	0.163	0.126	0.185	0.163	0.139
73	0.096	0.126	0.120	0.169	0.151	0.179
74	0.070	0.112	0.153	0.132	0.184	0.181
75	0.139	0.145	0.136	0.191	0.184	0.132
76	0.186	0.148	0.159	0.146	0.215	0.209
77	0.089	0.143	0.169	0.175	0.127	0.185

Condition Indices

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
78	0.221	0.141	0.113	0.176	0.169	0.187
79	0.169	0.150	0.150	0.161	0.098	0.176
80	0.094	0.135	0.175	0.123	0.172	0.117
81	0.128	0.180	0.118	0.120	0.149	0.152
82	0.153	0.152	0.146	0.142	0.181	0.118
83	0.163	0.176	0.150	0.152	0.218	0.163
84	0.152	0.156	0.124	0.138	0.155	0.160
85	0.207	0.221	0.190	0.142	0.182	0.160
86	0.231	0.122	0.163	0.142	0.120	0.178
87	0.239	0.169	0.131	0.153	0.142	0.144
88	NM	D	0.167	0.157	0.119	0.131
89	0.200	0.151	0.157	0.169	0.159	0.219
90	0.242	0.106	0.170	0.172	0.168	0.159
	D = dead					
	M = missing					
	NM = not measured					
		= crushed; not able to make weight or length measurements,				
			but tissue still intact			

Appendix J

Percent Lipids, Percent Water Tissue Chemistry Results

Appendix J:

Percent Lipids, Percent Water & Tissue Chemistry Results (ug/g wet wt, as reported by laboratory)

Station/ Depth	Cage No.	IOS Lab ID	Percent Water	Percent lipid	Campesterol	Cholesterol	Stigmasterol	B-sitosterol	D6-Cholesterol Surrogate
T_0 - Rep 1		1998B	81.2	1.21	6.19	30.28	3.36	12.42	0.09
T_0 - Rep 2		1999B	82.5	1.18	4.82	21.98	2.53	9.26	0.09
T_0 - Rep 3		2000B	80.3	1.20	4.90	23.84	2.46	9.39	0.07
Mean			***81.3***	***1.20***	***5.31***	***25.37***	***2.79***	***10.36***	***0.08***
Sta 1 - 2m	2	2003B	79.5	0.96	9.73	20.48	1.42	7.25	0.07
Sta 1 - 4m	10	2011B	79.6	1.00	10.50	17.92	1.20	6.99	0.08
Sta 1 - 6m	13	2013B	79.1	0.94	7.13	12.97	0.83	4.91	0.07
Mean			***79.4***	***0.97***	***9.12***	***17.12***	***1.15***	***6.38***	***0.07***
Sta 2 - 2m	6	2006B	79.0	1.04	8.51	17.28	1.38	6.90	0.06
Sta 2 - 4m	17	2018B	79.3	1.05	7.68	12.57	0.97	5.60	0.09
Sta 2 - 6m	19	2020B	80.3	1.03	10.81	18.95	1.17	7.35	0.07
Mean			***79.5***	***1.04***	***9.00***	***16.27***	***1.17***	***6.62***	***0.07***
Sta 3 - 2m	5	2005B	77.6	1.35	7.29	25.98	1.73	8.17	0.05
Sta 3 - 4m	7	2007B	80.6	1.01	4.57	14.84	0.95	4.51	0.07
Sta 3 - 6m	21	2021B	79.4	1.06	4.31	12.20	0.92	4.53	0.06
Mean			***79.2***	***1.14***	***5.39***	***17.67***	***1.20***	***5.74***	***0.06***
Sta 4 - 2m	11	2012B	73.8	1.47	1.99	8.00	0.52	2.30	0.09
Sta 4 - 4m	15	2016B	79.5	1.03	5.75	15.14	1.75	8.10	0.07
Sta 4 - 6m	16	2017B	79.5	0.94	4.47	12.91	1.05	4.78	0.07
Mean			***77.6***	***1.15***	***4.07***	***12.02***	***1.11***	***5.06***	***0.07***
Sta 5 - 2m	1	2002B	77.3	1.82	2.84	11.72	0.88	5.19	0.09
Sta 5 - 4m	9	2010B	78.9	1.38	5.17	22.27	1.70	8.94	0.07
Sta 5 - 6m	18	2019B	75.0	1.42	5.68	26.55	2.03	10.52	0.07
Mean			***77.0***	***1.54***	***5***	***20***	***2***	***8***	***0***
Sta 6 - 2m	4	2004B	76.5	1.68	2.28	10.26	0.66	3.96	0.09
Sta 6 - 4m	8	2009B	78.2	1.39	4.34	17.84	1.46	8.09	0.09
Sta 6 - 6m	14	2014B	79.4	1.17	4.19	22.54	1.64	8.74	0.07
Mean			***78.0***	***1.41***	***4***	***17***	***1***	***7***	***0***
Detection limit (ng/g)					15	10	5	5	

Percent Lipids, Percent Water & Tissue Chemistry Results
(ug/g dry wt; conversions made using % moisture data)

Station/ Depth	Cage No.	IOS Lab ID	Percent Water	Percent lipid	Campesterol	Cholesterol	Stigmasterol	B-sitosterol	D6Cholesterol Surrogate
T_0 - Rep 1		1998B	81.2	1.21	32.9	160.7	17.9	65.9	0.5
T_0 - Rep 2		1999B	82.5	1.18	27.5	125.5	14.4	52.9	0.5
T_0 - Rep 3		2000B	80.3	1.20	24.9	121.2	12.5	47.7	0.4
Mean			***81.3***	***1.20***	***28.4***	***135.8***	***14.9***	***55.5***	***0.5***
Sta 1 - 2m	2	2003B	79.5	0.96	47.5	99.9	6.9	35.3	0.3
Sta 1 - 4m	10	2011B	79.6	1.00	51.5	87.9	5.9	34.3	0.4
Sta 1 - 6m	13	2013B	79.1	0.94	34.2	62.1	4.0	23.5	0.3
Mean			***79.4***	***0.97***	***44.4***	***83.3***	***5.6***	***31.1***	***0.3***
Sta 2 - 2m	6	2006B	79.0	1.04	40.5	82.3	6.6	32.9	0.3
Sta 2 - 4m	17	2018B	79.3	1.05	37.1	60.7	4.7	27.1	0.4
Sta 2 - 6m	19	2020B	80.3	1.03	54.9	96.3	6.0	37.3	0.4
Mean			***79.5***	***1.04***	***44.2***	***79.8***	***5.7***	***32.4***	***0.4***
Sta 3 - 2m	5	2005B	77.6	1.35	32.6	116.0	7.7	36.5	0.2
Sta 3 - 4m	7	2007B	80.6	1.01	23.5	76.4	4.9	23.2	0.4
Sta 3 - 6m	21	2021B	79.4	1.06	20.8	59.1	4.5	21.9	0.3
Mean			***79.2***	***1.14***	***25.6***	***83.8***	***5.7***	***27.2***	***0.3***
Sta 4 - 2m	11	2012B	73.8	1.47	7.6	30.6	2.0	8.8	0.3
Sta 4 - 4m	15	2016B	79.5	1.03	28.1	73.9	8.5	39.6	0.3
Sta 4 - 6m	16	2017B	79.5	0.94	21.8	62.9	5.1	23.3	0.3
Mean			***77.6***	***1.15***	***19.2***	***55.8***	***5.2***	***23.9***	***0.3***
Sta 5 - 2m	1	2002B	77.3	1.82	12.5	51.6	3.9	22.8	0.4
Sta 5 - 4m	9	2010B	78.9	1.38	24.5	105.4	8.1	42.3	0.4
Sta 5 - 6m	18	2019B	75.0	1.42	22.7	106.0	8.1	42.0	0.3
Mean			***77.0***	***1.54***	***19.9***	***87.7***	***6.7***	***35.7***	***0.3***
Sta 6 - 2m	4	2004B	76.5	1.68	9.7	43.7	2.8	16.9	0.4
Sta 6 - 4m	8	2009B	78.2	1.39	19.9	81.7	6.7	37.1	0.4
Sta 6 - 6m	14	2014B	79.4	1.17	20.4	109.6	7.9	42.5	0.3
Mean			***78.0***	***1.41***	***16.7***	***78.3***	***5.8***	***32.1***	***0.4***
Detection limit (ng/g)					15	10	5	5	

Appendix J:
Content (ug/animal dry weight) of Plant Sterol in Mussel Tissues

Station/ Depth	Cage No.	IOS Lab ID	Dry Tissue (g)	Campesterol	Cholesterol	Stigmasterol	B-sitosterol	Cholesterol Surrogate
T_0 - Rep 1		1998B	0.05	1.5	7.2	0.8	3.0	0.02
T_0 - Rep 2		1999B	0.05	1.2	5.6	0.6	2.4	0.02
T_0 - Rep 3		2000B	0.05	1.1	5.5	0.6	2.1	0.02
Mean			***0.045***	***1.3***	***6.1***	***0.7***	***2.5***	***0.02***
Sta 1 - 2m	2	2003B	0.16	7.5	15.9	1.1	5.6	0.05
Sta 1 - 4m	10	2011B	0.15	7.5	12.8	0.9	5.0	0.05
Sta 1 - 6m	13	2013B	0.12	4.2	7.6	0.5	2.9	0.04
Mean			***0.14***	***6.4***	***12.1***	***0.8***	***4.5***	***0.05***
Sta 2 - 2m	6	2006B	0.15	6.3	12.7	1.0	5.1	0.04
Sta 2 - 4m	17	2018B	0.13	4.9	8.1	0.6	3.6	0.06
Sta 2 - 6m	19	2020B	0.12	6.6	11.5	0.7	4.5	0.04
Mean			***0.14***	***5.9***	***10.8***	***0.8***	***4.4***	***0.05***
Sta 3 - 2m	5	2005B	0.20	6.4	22.8	1.5	7.2	0.04
Sta 3 - 4m	7	2007B	0.14	3.3	10.7	0.7	3.3	0.05
Sta 3 - 6m	21	2021B	0.12	2.4	6.9	0.5	2.5	0.03
Mean			***0.15***	***4.0***	***13.5***	***0.9***	***4.3***	***0.04***
Sta 4 - 2m	11	2012B	0.17	1.3	5.3	0.3	1.5	0.06
Sta 4 - 4m	15	2016B	0.15	4.2	11.0	1.3	5.9	0.05
Sta 4 - 6m	16	2017B	0.12	2.6	7.5	0.6	2.8	0.04
Mean			***0.15***	***2.7***	***7.9***	***0.7***	***3.4***	***0.05***
Sta 5 - 2m	1	2002B	0.19	2.3	9.7	0.7	4.3	0.08
Sta 5 - 4m	9	2010B	0.18	4.4	19.1	1.5	7.7	0.06
Sta 5 - 6m	18	2019B	0.13	3.1	14.3	1.1	5.7	0.04
Mean			***0.17***	***3.3***	***14.3***	***1.1***	***5.9***	***0.06***
Sta 6 - 2m	4	2004B	0.22	2.1	9.6	0.6	3.7	0.08
Sta 6 - 4m	8	2009B	0.18	3.6	14.9	1.2	6.8	0.08
Sta 6 - 6m	14	2014B	0.14	2.8	15.1	1.1	5.9	0.05
Mean			***0.18***	***2.9***	***13.2***	***1.0***	***5.4***	***0.07***

Appendix K

Laboratory Analytical Methods

Appendix K. Laboratory Analytical Methods

Water Quality Parameter Methods

Caged Mussel Water Quality Parameters:

Water samples were taken three times during the caged mussel exposure period:

- August 7-9, 1997 (start)
- September 16, 1997 (middle)
- October 14-15, 1997 (end)

Water samples were collected at each caged mussel station and cage depth (2m, 4m, 6m). Dissolved oxygen was measured *in situ* using a YSI Dissolved Oxygen meter and probe on a 50 m cable (marked in one metre intervals). A 3-L van Dorn water sampler was lowered on a polypropylene rope (marked in one metre intervals) to collect water samples for total organic carbon (TOC), nonfilterable residue (NFR), nutrients (nitrates, silicates, phosphates), chlorophyll-a and salinity. Methods are summarized as follows:

Total Organic Carbon

- water samples collected in a 250 ml plastic bottle pre-rinsed with sample water, filled to exclude air; no preservative added in field
- samples stored and transported on ice in a cooler (~4°C) to Environment Canada Pacific Environment Science Centre (PESC) for analysis; samples delivered to laboratory 3-5 days from time of collection
- analytical method: combustion-infrared (Environment Canada 1996)

Non-filterable Residue (total suspended solids)

- water sample collected in a 500 ml plastic bottle pre-rinsed with sample water
- samples stored/transported on ice in a cooler (~4°C) to Environment Canada PESC for analysis; samples delivered within 3-5 days of collection
- analytical method: gravimetric, GF/C glass fibre filter, dried to 103°C (Environment Canada 1995)

Nutrients

- water sample collected in 20 ml glass test tube for silicate/nitrate analyses and 20 ml plastic test tube for phosphorus; two additional samples (one plastic, one glass) collected at each station for duplicate analyses
- test tubes filled three quarters full to allow head space for freezing and capped
- samples placed in racks in cooler (dark) on ice; frozen upright within 12 hr from time of collection; transported frozen on ice and stored at -40°C until analyzed
- samples analyzed at the Institute of Ocean Sciences (IOS) November 12-13, 1997 using a Technicon Autoanalyzer II, following methods outlined in Barwell-Clarke and Whitney (1997)
- nutrient values in µm concentrations as calculated from standard curve of known concentrations

Chlorophyll-a

- water sample collected in 500 ml plastic bottle, pre-rinsing container with sample water
- sample stored in cooler on ice (~4°C) prior to filtering sample

- 200 ml of sample filtered through Whatman GF/F filter using a plastic syringe; filter folded in half and wrapped with a larger filter
- filter samples placed in brown plastic bottle containing silica gel and frozen within 12 hr. of sample collection
- samples transported frozen on ice and stored at -40°C prior to analyses
- samples from the three sampling periods analyzed on November 20, 1997 at IOS
- analytical method: spectrometric determination using a Turner Design fluorometer calibrated using chlorophyll "a" from fresh *Fucus* seaweed from the beach at IOS
- following method in Strickland and Parsons (1972, pp.185-206)

Salinity
- remainder of sample collected for chlorophyll-a analysis used to measure salinity
- YSI salinity meter probe placed in a beaker with ~200 ml sample; temperature measured and the meter adjusted as required before taking salinity measurement

Dissolved Oxygen
- measured *in situ* using a YSI Dissolved Oxygen meter (model 58) and DO probe on a 50 m cord (marked in 1 m intervals)
- probe allowed to stabilize before recording DO in mg/l
- instrument calibrated using the Winkler method (azide modification)

Port Alice Mill Water Quality Parameters:

The Port Alice Mill monitored water quality at mid-channel stations near the caged mussel stations twice weekly as part of their routine water quality monitoring requirements. Temperature and dissolved oxygen were measured *in situ*. Water samples were collected with Scott sampling bottles to analyze for salinity, and spent sulphite liquor. Measurements were taken at surface, 2m, 4m, 6m, 8m and 10 m at each station. Methods are summarized below and described in more detail in Johnson (1998).

Dissolved Oxygen
- measured *in situ* using a YSI Dissolved Oxygen Meter (Model 58) and DO probe with 50 m cord (marked in metre intervals)
- DO probe lowered in the water to specified depth interval and allowed to stabilize before recording the DO in mg/L
- instrument calibrated using the Winkler method (azide modification) each survey day

Temperature
- measured *in situ* using the YSI Dissolved Oxygen Meter (Model 58)

Spent Sulphite Liquor
- seawater samples collected in 250 ml plastic bottles, filled to exclude air and closed tightly
- samples analyzed within 24 hr of sample collection
- analytical method: colormetric using a spectrophotometer

Salinity
- YSI Salinity Meter (Model 33) used to analyze salinity
- salinity meter probe placed in a beaker of 200 ml seawater sample; temperature measured and calibrated as required before taking salinity reading

References:

Barwell-Clarke, J. and F. Whitney. 1996. Institute of Ocean Sciences Nutrient Methods and Analysis. Can. Tech. Rep. Hydrogr. Ocean Sci. 182: vi + 43 p.

Environment Canada. 1995. Non-filterable Residue/ NFR, Version 2.3, November 7, 1995. Environment Canada Laboratories Manual, Pacific Environment Science Centre. 6 pp.

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Johnson, T.R. 1998. Western Pulp, Port Alice, Neroutsos Inlet & Mill Water Quality Data Analysis. 1990 to 1997. Prepared for Environment Canada by the Western Pulp Limited Partnership, Port Alice Operation.

Strickland, J.D.H. and T.R. Parsons. 1972. A Practical Handbook of Seawater Analysis. Fisheries Research Board of Canada, Ottawa. Bulletin 167 (2nd edition). 310 pp.

Tissue Chemistry Methods

Tissue Chemistry
(samples analyzed at the Institute of Ocean Sciences, Dr. Michael Ikonomou)

Lipids
* approximately 5 g. homogenized sample accurately weighed and dried with sodium sulphate
* extracted with 100 ml of 1:1 hexane/dichloromethane (DCM) from a glass column by gravity flow
* extract reduced to 1 mL using Tubovap and quantitatively transferred to weigh boat using Hexane/DCM
* extract placed in 40 deg C oven overnight then in dessicator to cool to room temperature and weighed
* weight of oven dried extract and original sample used to calculate % lipid

Moisture
* approximately 3 g of homogenized sample was accurately weighed in a weigh boat
* sample placed in a 40 deg C oven for at least 48 h
* dried sample placed in dessicator to reach room temperature then weighed
* weight of oven dried sample and original homogenate used to calculate % moisture

Plant Sterols
* analyzed by HRGC/HRMS in two batches
* February 18, 1998 -- 7 tissue samples and 1 procedural blank
* February 20, 1998 -- 14 tissue samples, 2 replicates and 1 procedural blank
* replicate analysis: two aliquots extracted from the same sample and analyzed separating by HRGC/HRMS (i.e., treated as two different samples)
* sterols analyzed: cholesterol, campesterol, stigmasterol and beta-sitosterol
* surrogates analyzed: 2-methoxyesterone and cholesteryl methyl ether

Resin Acids, Retene and Fichtellite
* analyzed by HRGC/HRMS in three batches
* August 4, 1998 -- 6 tissue samples, 1 replicate and 1 procedural blank
* August 20, 1998 -- 10 tissue samples, 1 replicate and 1 procedural blank
* September 3, 1998 -- 5 tissue samples and 1 procedural blank

* analyses of retene, fichtellite and resin acids (dehydroabietc, pimaric, sandaracopimaric, isopimaric, palustric, abietic, neoabietic) used a single tissue sample
* new sample cleanup procedures allowed low-ppb/high-ppt detection limits for these compounds
* replicate analysis: two aliquots extracted from the same sample and analyzed separating by HRGC/HRMS (i.e., treated as two different samples)
* surrogate compounds: d10-phenantrhrene, o-methylpodocarpic and chlolesteryl methyl ether

Appendix L

Mill Water Quality Data

Appendix L
Mill Water Quality Data

Port Alice (Western Pulp Ltd). Mill Receiving Water Monitoring during the Caged Mussel Project
(Mill WQ Stn 8 near M1 and M2; Stn 14 near M3 and M4; Stn 20 near 52 and M6)

SSL ppm	WQ Station 8					WQ Station 14					WQ Station 20				
	surf	2m	4m	6m	10m	surf	2m	4m	6m	10m	surf	2m	4m	6m	10m
5-Aug-97	35	59	78	75	55	34	36	20	14	9	14	15	15	9	3
7-Aug-97	16	39	41	61	86	35	28	28	22	23	9	9	10	8	15
12-Aug-97	31	43	51	100	120	34	36	40	73	73					
19-Aug-97	46	43	45	49	134	45	45	43	90	59	39	35	33	23	22
21-Aug-97	46	72	120	89	47	47	55	60	22	na	53	51	30	19	1
26-Aug-97	17	30	104	86	57	1	76	57	36	18	4	25	31	22	12
28-Aug-97	7	53	82	85	22	7	69	50	10	5	16	32	17	17	11
4-Sep-97	51	113	97	95	45	78	76	67	61	21	31	28	23	14	3
9-Sep-97	31	72	98	111	95	48	32	7	5	6	85	32	14	13	7
11-Sep-97	35	44	99	100	76	42	44	91	59	47	30	21	16	9	9
16-Sep-97	69	112	107	99	55	101	100	93	77	48					
18-Sep-97	8	63	141	128	73	59	46	95	130	31	40	32	26	10	4
23-Sep-97	72	82	65	60	7	74	67	27	13	8	31	29	28	28	8
25-Sep-97	59	63	81	75	44	63	59	48	41	34					
2-Oct-97	16	65	59	43	15	30	41	11	10	4					
7-Oct-97	25	83	125	101	16	15	46	62	64	8	9	9	5	6	4
9-Oct-97	5	41	45	59	74	8	39	24	12	5	17	32	17	6	10
14-Oct-97	9	37	39	31	14	20	19	9	11	10	16	15	15	15	11
average	32.1	61.9	82.1	80.4	57.5	41.17	50.8	46.2	41.7	24.1	28.14	26.1	20	14.2	8.57

DO ppm	WQ Station 8					WQ Station 14					WQ Station 20				
	surf	2m	4m	6m	10m	surf	2m	4m	6m	10m	surf	2m	4m	6m	10m
5-Aug-97	7.9	5.9	5.6	5.5	5.0	9.1	8.2	6.2	5.9	5.7	11.6	10.7	9.9	8.8	7.8
7-Aug-97	9.9	9.8	6.4	5.0	4.7	10.2	11.1	9.9	8.8	5.6	12.2	12.0	11.0	9.0	7.4
12-Aug-97	9.5	10.1	5.6	4.2	4.3	9.8	10.4	7.1	4.6	5.3					
19-Aug-97	8.8	8.6	8.3	5.1	4.2	8.9	8.6	6.2	4.2	5.2	9.1	7.9	7.1	6.3	5.1
21-Aug-97	6.8	3.7	4.3	3.8	4.6	7.2	5.8	4.5	5.0	5.4	8.2	7.3	5.4	5.7	6.0
26-Aug-97	7.9	6.9	6.0	6.1	6.1	7.7	6.0	6.4	7.5	7.6	8.0	6.9	7.0	7.0	7.0
28-Aug-97	7.4	6.8	6.8	7.4	7.4	6.9	7.4	7.8	7.8	7.5	6.9	7.0	6.9	7.2	7.2
4-Sep-97	7.1	6.8	6.9	6.9	7.0	7.1	7.0	6.9	7.0	7.1	8.0	7.6	7.5	7.5	7.2
9-Sep-97	8.4	6.9	6.8	6.8	6.9	9.0	8.8	9.0	9.5	8.4	18.3	11.1	9.1	8.2	7.7
11-Sep-97	13.2	12.6	7.0	6.8	6.7	12.7	11.7	7.2	6.9	7.2	13.6	12.9	9.9	8.6	8.1
16-Sep-97	7.6	6.2	6.2	6.2	6.3	6.8	6.5	6.3	6.4	6.6					
18-Sep-97	8.2	6.5	6.1	6.2	6.4	9.4	7.4	6.3	6.4	7.2	11.1	9.3	8.5	8.4	8.0
23-Sep-97	6.6	6.4	6.6	6.6	7.0	7.2	6.7	7.2	7.3	7.2	8.2	7.6	7.6	7.6	7.6
25-Sep-97	7.2	6.6	6.4	6.5	6.7	7.1	7.1	7.1	7.2	7.4					
2-Oct-97	8.6	7.5	7.5	7.8	7.9	8.2	7.8	8.0	8.1	8.2					
7-Oct-97	7.9	7.2	6.7	6.6	6.7	7.9	7.2	7.0	6.9	6.9	8.3	7.8	6.9	6.8	6.8
9-Oct-97	8.9	7.4	7.0	6.9	6.9	9.0	7.6	7.5	7.4	7.2	9.3	7.8	7.2	6.9	6.8
14-Oct-97	8.8	6.7	6.6	6.8	6.9	7.9	7.1	7.1	7.1	7.1	7.5	7.3	7.4	7.4	7.3
average	8.4	7.4	6.5	6.2	6.2	8.5	7.9	7.1	6.9	6.8	10.0	8.8	8.0	7.5	7.1

Temp°C	WQ Station 8					WQ Station 14					WQ Station 20				
	surf	2m	4m	6m	10m	surf	2m	4m	6m	10m	surf	2m	4m	6m	10m
5-Aug-97	13.6	11.9	10.8	10.7	10.3	14.0	13.2	11.0	10.7	10.3	14.1	13.5	12.7	12.0	11.6
7-Aug-97	15.1	14.9	12.0	10.7	10.0	15.9	15.2	14.0	12.8	10.5	15.2	14.6	13.7	12.4	11.4
12-Aug-97	19.2	18.2	13.2	10.8	9.8	18.9	18.7	14.0	10.7	10.2					
19-Aug-97	18.5	18.1	17.4	13.1	10.2	17.8	17.1	14.1	10.1	9.9	17.1	15.0	14.0	12.6	10.0
21-Aug-97	16.3	11.7	10.5	9.8	9.6	16.2	13.4	10.5	9.9	10.0	16.3	15.9	11.3	10.2	10.6
26-Aug-97	12.3	11.2	11.1	11.2	11.1	12.2	11.0	11.3	11.9	11.9	12.5	11.9	12.1	12.1	11.7
28-Aug-97	12.2	12.1	12.0	12.1	12.2	12.8	11.8	12.4	12.4	12.3	13.0	12.6	12.3	12.3	12.2
4-Sep-97	13.0	12.9	12.8	12.7	12.6	13.1	13.0	12.9	12.9	12.8	14.0	13.9	13.6	13.5	12.9
9-Sep-97	14.9	14.2	13.5	13.4	13.3	15.0	14.2	14.1	14.3	14.0	15.7	14.8	14.3	13.8	13.4
11-Sep-97	15.4	16.1	13.6	13.0	12.9	16.0	15.9	13.9	13.3	13.2	14.9	14.9	14.6	14.1	13.5
16-Sep-97	13.4	13.1	12.9	12.8	12.7	13.2	13.2	13.1	13.1	13.1					
18-Sep-97	13.1	13.4	13.0	12.9	12.8	13.9	13.5	13.1	13.2	13.2	13.5	14.0	13.7	13.3	13.1
23-Sep-97	13.3	13.1	12.8	12.7	12.9	13.1	13.1	13.0	13.0	12.9	13.3	13.3	13.2	13.2	13.1
25-Sep-97	14.4	13.6	13.2	13.2	13.1	13.8	13.8	13.7	13.6	13.4					
2-Oct-97	11.7	13.7	14.1	14.2	14.2	12.7	14.2	14.3	14.3	14.4					
7-Oct-97	11.2	13.8	14.2	14.2	14.1	12.0	13.8	13.8	14.1	14.0	11.8	12.8	13.2	13.3	13.2
9-Oct-97	10.4	13.7	13.9	14.3	14.2	10.5	13.2	13.2	13.1	13.1	10.6	12.8	12.9	12.8	12.7
14-Oct-97	11.3	13.8	13.8	13.8	13.7	12.4	13.1	13.2	13.2	13.2	13.0	13.0	13.0	13.0	12.9
average	13.9	**13.9**	**13.0**	**12.5**	12.2	14.1	**14.0**	**13.1**	**12.6**	12.4	13.9	**13.8**	**13.2**	**12.8**	12.3

Salinity ppt	WQ Station 8					WQ Station 14					WQ Station 20				
	surf	2m	4m	6m	10m	surf	2m	4m	6m	10m	surf	2m	4m	6m	10m
5-Aug-97	25.0	25.5	25.5	25.8	26.0	26.0	26.0	26.3	26.3	26.5	25.8	25.8	26.0	26.0	26.3
7-Aug-97	14.3	28.5	29.5	28.8	29.8	24.0	27.0	27.5	27.5	28.0	27.8	28.8	28.5	28.0	28.3
12-Aug-97	25.5	26.3	26.8	28.0	28.3	26.0	26.8	27.8	28.3	28.3					
19-Aug-97	26.0	26.0	26.5	27.8	27.8	27.5	27.8	27.8	27.8	28.0	28.0	27.8	27.8	28.0	28.0
21-Aug-97	27.0	29.0	30.0	30.0	30.0	27.3	28.0	30.3	30.3		27.3	29.5	29.5	30.0	29.5
26-Aug-97	2.3	14.5	29.3	29.5	30.0	3.0	23.0	29.0	29.0	30.0	5.0	17.3	28.0	28.3	29.8
28-Aug-97	6.3	22.5	27.5	25.0	28.8	5.5	26.0	30.8	30.0	30.0	10.0	23.8	28.5	29.0	30.0
4-Sep-97	17.5	27.0	27.8	28.0	28.3	25.3	27.0	27.5	27.8	28.0	27.5	27.5	27.3	27.3	27.5
9-Sep-97	14.3	25.0	25.8	26.0	26.5	18.0	25.0	25.8	26.0	26.3	23.3	24.5	25.3	25.8	26.0
11-Sep-97	20.0	25.5	27.8	28.3	28.5	24.0	26.0	27.0	28.8	29.0	27.[illegible]	28.0	28.5	29.0	29.3
16-Sep-97	23.5	26.8	27.0	27.3	27.5	26.8	26.8	27.0	27.3	28.0					
18-Sep-97	5.5	26.5	27.0	27.5	27.3	21.0	27.0	27.5	27.5	27.5	26.0	26.3	26.5	27.0	27.5
23-Sep-97	27.5	28.5	28.8	28.5	29.5	28.3	28.5	29.8	29.5	29.8	29.0	28.3	28.0	29.0	29.3
25-Sep-97	24.8	26.5	27.0	27.0	27.3	26.5	26.5	26.8	27.0	27.0					
2-Oct-97	8.5	25.0	26.5	28.3	28.5	12.0	27.8	28.5	29.8	28.0					
7-Oct-97	21.5	22.5	23.5	24.0	24.5	19.0	22.3	23.0	24.0	24.5	19.5	21.5	22.0	23.3	24.3
9-Oct-97	6.5	22.0	22.8	26.8	28.0	7.3	24.3	26.0	27.0	27.3	11.5	25.0	25.8	26.5	26.8
14-Oct-97	7.0	24.0	26.8	27.3	27.3	19.0	24.5	24.8	26.5	27.3	25.0	25.5	25.8	25.8	26.0
average	16.8	25.1	27.0	27.4	28.0	20.3	26.1	27.4	27.8	27.8	22.4	25.7	26.9	27.3	27.7

Appendix M

Environment Canada
Mussel Station Water Quality Data

Appendix M
Environment Canada Water Quality Measurements
Port Alice Caged Mussel Study 1997 — Chlorophyll-a

Beginning of Test Chlorophyll-a (ug/L) (8/7/97)

Depth (m)	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
2	0.78	3.29	2.61	5.11	1.04	3.03
4	3.48	1.88	3.11	4.67	1.63	2.94
6	1.41	1.60	3.43	4.78	1.41	2.78

Mid-Test Chlorophyll-a (ug/L) (9/16/97)

Depth (m)	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
2	0.37	0.28	2.09	3.53	0.90	0.81
4	0.40	0.13	1.12	1.62	0.78	0.69
6	0.12	0.07	0.63	0.71	0.28	0.27

End of Test Chlorophyll-a (ug/L) (10/15/97)

Depth (m)	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
2	0.32	0.30	0.35	0.29	0.50	0.37
2	0.32	0.33				
4	0.33	0.17	0.27	0.18	0.44	0.41
4	0.33	0.28				
6	0.21	0.13	0.20	0.20	0.35	0.43
6	0.23					

Port Alice Caged Mussel Study 1997 — Total Organic Carbon

Beginning of Test TOC (mg/l) (8/7/97)

Depth (m)	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
2	8	7.8	9.5	10.5	3.8	4.2
4	8.2	9	9.9	10.1	3.9	4
6	11.2	9.4	8.7	8.5	3.9	3.9

Mid-Test TOC (mg/l) (9/16/97)

Depth (m)	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
2	12.3	11.8	7.9	7.8	5.9	5.9
4	12.4	10.9	7	7	2.8	4.5
6	11	9.9	5.9	5.8	2.8	2.8

End of Test TOC (mg/l) (10/15/97)

Depth (m)	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
2	2.8	2.5	2.3	2.3	2.8	2.7
4	2	2.4	2.1	2.1	2.6	2.6
6	2.5	2.1	2.1	1.9	2.6	2.8

Port Alice Caged Mussel Study 1997 — Total Suspended Solids

Beginning of Test Total Suspended Solids (mg/l) (8/7/97)

Depth (m)	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
2	18	22	6	21	30	26
4	9	21	21	18	35	26
6	19	21	23	30	28	23

Mid-Test Total Suspended Solids (mg/l) (9/16/97)

Depth (m)	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
2	25	31	25	44	30	13
4	24	36	44	34	26	40
6	34	24	26	22	24	29

End of Test Total Suspended Solids (mg/l) (10/15/97)

Depth (m)	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
2	12	11	12	5	5	58
4	6	8	5	7	51	62
6	7	17	8	5	55	58

Port Alice Caged Mussel Study 1997 — Nitrate

Beginning of Test Nitrate (uM) (8/7/97)

Depth (m)	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
2	7.16	5.60	14.60	16.91	0.07	1.64
2	5.22	5.54				
4	6.31	9.64	18.60	16.69	3.07	3.58
4					3.22	3.58
6	17.96	19.99	17.69	16.17		
6			15.63	16.07	3.43	6.32

Mid-Test Nitrate (uM) (9/16/97)

Depth (m)	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
2	23.47	23.58	15.78	13.38	10.07	9.94
2	23.22	23.78				
4	23.69	23.46	14.45	13.95	9.59	7.98
4			14.39	13.92		
6	22.90	22.10	13.12	13.29	8.77	8.67
6					8.83	8.28

End of Test Nitrate (uM) (10/15/97)

Depth (m)	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
2	15.78	13.90	11.43	8.42	11.67	10.96
2	15.80	14.02				
4	11.78	12.37	11.73	11.93	11.49	11.53
4			11.76	11.81		
6	11.66	12,07	11.91	11.86	11.36	11.46
6					11.45	11.43

Port Alice Caged Mussel Study 1997 — Silicate

Beginning of Test Silicate (uM) (8/7/97)

Depth (m)	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
2	9.26	12.84	22.06	23.61	4.98	5.67
2	13.28	12.82				
4	13.45	15.67	25.57	23.66	12.77	11.77
4					11.65	11.28
6	25.08	27.41	26.27	24.44	13.65	15.73
6			23.50	25.66		

Mid-Test Silicate (uM) (9/16/97)

Depth (m)	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
2	23.33	22.64	22.28	20.77	22.76	22.85
2	23.21	22.79				
4	22.91	22.55	22.43	21.57	22.84	22.83
4			22.22	21.91		
6	22.15	21.98	22.19	21.72	22.46	22.46
6					22.71	21.54

End of Test Silicate (uM) (10/15/97)

Depth (m)	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
2	27.24	27.30	27.98	23.69	28.02	27.77
2	27.13	27.10				
4	27.54	27.08	28.20	28.03	27.91	27.85
4			27.95	27.67		
6	27.52	27.06	27.10	27.95	27.53	27.76
6					27.60	27.31

Port Alice Caged Mussel Study 1997 — Phosphate

Beginning of Test Phosphate (uM) (8/7/97)

Depth (m)	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
2	0.526	0.710	1.135	1.328	0.309	0.306
2	0.486	0.561				
4	0.416	0,653	1.365	1.215	0.471	0.560
4					0.457	0.575
6	1.280	1.478	1.473	1.364	0.563	0.711
6			1.383	1.486		

Mid-Test Phosphate (uM) (9/16/97)

Depth (m)	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
2	1.396	1.423	1.095	0.936	0.676	0,713
2	1.400	1.428				
4	1.504	1.518	0.995	0.991	0.699	0.664
4			0.993	0.926		
6	1.634	1.512	1.095	1.112	0.970	0.989
6					0.971	1.000

End of Test Phosphate (uM) (9/16/97)

Depth (m)	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
2	1.496	1.352	1.252	1.169	1.123	1.093
2	1.756	1.350				
4	1.224	1.277	1.163	1.202	1.133	1.113
4			1.252	1.256		
6	1.301	1.165	na	1.176	1.238	1.153
6					1.135	1.134

Appendix N

Statistical Models

APPENDIX N. DETAILED STATISTICAL MODELS

Full Statistical Model. The statistical model for the pilot caged mussel study was a split-plot or repeated measures design (Figure 12). In a split-plot, one treatment is applied to whole "plots" or replicates while another treatment is applied within plots or replicates. In this study, there were three locations, each with two paired or replicate moorings. Stations 1 and 2 were replicates within the near-field (NF) location (≈ 0.3 km distance); stations 3 and 4 (≈3 km distance) and stations 5 and 6 (≈ 10 km distance) were pairs or replicates within the far-field (FF) location. Each mooring contained three cages, situated at depths of 2, 4 and 6 m. Locations were the treatment applied to whole plots or moorings, with only one location present at each mooring. Depths were the treatment applied within plots, with all three depths present at each mooring. The moorings acted as blocks for testing differences among depths. Finally, within each cage at a single depth, there were 90 mussels initially, and 80-90 at the end of the exposure period due to escape or mortality. Individual mussels acted as lower-level replicates for testing differences among moorings and/or cages.

This split-plot design was more complex than the designs likely to be used in EEM programs, because depth as well as location effects were examined. Therefore, the appropriate ANOVA model for analyses was also more complex (Table N1). The model is discussed in some detail below, because there is disagreement among statistical theoreticians on the appropriate statistical analyses to be performed. These designs should not be treated as two-way factorial ANOVA with location and depth as fixed factors, and moorings as replicates. The "between moorings" component of the split-plot (Table N1) is a three-level nested ANOVA with location as a fixed factor, moorings as replicates within locations and mussels as replicates within moorings. Similar nested designs (i.e., without the "within moorings" component) would be commonly used in EEM programs. In the split-plot, and in any nested design, the appropriate error term for testing location (L) effects is the MS for moorings (i.e., replicates) within locations (M{L}). Complete moorings of three cages each were assigned to locations. With only two moorings within each location, and only 3 error df, the test of location effects had little power. The test of the L effect is equivalent to a one-way ANOVA comparing locations, with mooring means over all depths and mussels within a mooring site used as individual observations.

Differences among moorings within locations (M{L}) were tested against the residual MS (i.e., variance among mussels within cages). A significant M{L} effect could be attributable to some micro-scale difference(s) between mooring sites or attributable to some difference(s) between the actual cages themselves. Mooring site and cage effects are impossible to separate because two cages can never be placed at exactly the same micro-location. If the M{L} effect is not significant, some investigators would pool the M{L} and residual MS to provide a more powerful test of the L effect (i.e., with >1500 error df). However, there is some controversy about the appropriateness of pooling terms in ANOVA, and especially about the decision rules to use when doing so (see below).

The within moorings component of the split-plot design in Table N1 can complicate analyses and interpretation. However, it does provide effective tests for depth effects, and the interaction between location and depth (L × D). A significant depth effect would indicate that the variable of interest differed among depths; a significant L × D interaction would indicate that depth effects were not the same at each location (or alternatively, that location effects were not the same at each depth). The D × M{L} interaction reflects differences in depth effects between mooring each depth). The D × M{L} interaction reflects differences in depth effects between mooring sites within locations, and is rarely of interest. The term is tested only to see if it is small enough to be dropped or pooled with the residual. If the D × M{L} interaction is small, then D and L × D can be tested against the residual MS, increasing power.

As noted above, if the appropriate error term in Table N1 is any term other than the residual, tests may not be powerful or robust because error df will be small. Power can be increased by pooling the higher-order error term with the residual whenever the former is small, and using the pooled MS for testing. For one set of analyses in this study, the residual error was used instead of higher-order error terms whenever $p>0.25$ for the latter, following Wiener (1971). The higher-order MS were not actually pooled with the residual MS prior to testing, since pooling an MS with 3 or 6 df with an MS with ~1500 df will not alter the latter. The pooling rule used was a compromise between the extremes of never pooling or pooling only when $p>0.5$ for higher-order error terms (Sokal and Rohlf, 1981) versus pooling whenever $p>0.05$ (Underwood, 1995). "Never pool" is the only strategy which cannot be criticized on statistical grounds, but it can reduce power to the point where impacts go undetected.

Reduced Statistical Model. Cage means, rather than data for individual mussels, can also be analyzed using the model in Table N1; the bottom row (variance among mussels or residual) is deleted. Tests and df are as indicated in Table N1, except that M{L} is tested against D × M{L}, which cannot be tested itself (i.e., there is no lower-order error term). When cage means are used, the test for M{L} is potentially suspect because of a phenomenon known as restriction error (Sokal and Rohlf, 1981). Thus, the test would only be conducted if one was interested in pooling M{L} with D × M{L} to improve power for tests of location (L) effects. In such cases, using the pooled MS, rather than simply testing L against only D × M{L} will significantly increase df and power (i.e., re-run the analyses with M{L} dropped or calculate the pooled MS by hand). Since the reduced model has fewer df than the full model (i.e., with individual mussels analyzed) power can also be increased for the remaining terms by pooling all terms with $p>0.25$ with D × M{L}.

Effects Data

The mussel effects data were analyzed in several ways to examine the relative statistical power and the validity of slight deviations from the assumptions in the various statistical models. Different approaches were used for the analysis of effects data (mussel growth) and exposure data (tissue chemistry). Since the tissue chemistry data must have replicates for statistical comparisons and tissues from each cage must be pooled to have sufficient tissue for chemical analyses, the reduced model must be followed to make these comparisons. To take advantage of the increased statistical power associated with paired measurements of individual mussels, individuals were treated as replicates for the effects data (mussel growth) and growth data for individual mussels was pooled across "depth" replicates for each station. It should be emphasized that for EEM monitoring there would be three replicate cages per site (mooring) at the same depth. Replicate cage means of tissue chemistry would be used to compare exposure across stations using the reduced model and pooled individual mussel growth data would be used to compare effects across stations.

The mussel growth data were first analyzed on a station-by-station basis (maximum n/station =

270); the analyses were repeated on data pooled by site (i.e., Site 1 = Stations 1 and 2; Site 2 = Stations 3 and 4, and Site 3 = Stations 5 and 6) (maximum n/site = 540), and by depth (maximum n/depth = 90). After confirming for normal distributions, a one-way Analysis of Variance (ANOVA) was used to evaluate for differences among the individual stations and among sites; the Student-Newman-Keuls multiple range test was used to identify statistically (α = 0.05) significant differences among sites.

Variables were also analyzed with the full model in Table N1, using data for individual mussels, and with the reduced model, using cage means. Some other approaches to analyses were also examined, and are described in results. When $p>0.25$ for higher-order error terms, L, D and L × D were tested against the residual MS. Variables were then re-analyzed using cage means in the reduced model. To demonstrate the results which would be obtained with the most statistically defensible analyses, pooling of terms was not used (i.e., tests were as in Table N1, except for M{L}).

Full Model

Table N2 provides detailed results of statistical analyses of biological variables, using the full split-plot model in Table N1. Table N3 summarizes the results. As noted in Methods, various terms were tested against the residual MS when the appropriate higher-order error terms were small ($p>0.25$).

Location Effects

End-of-test shell and tissue weights were the only variables for which $p\leq0.25$ for moorings within locations (M{L}). Differences among locations were not significant at $p\leq0.05$ for these two variables, largely because location effects were tested against M{L}, which was not a powerful test. Tissue weights differed significantly among moorings within locations ($p\leq0.01$). These differences could indicate small-scale spatial variation in size of the internal tissue, but could also indicate some minor biases in procedures. For example, the delay between shucking and weighing may have been greater for mussels from one mooring than for mussels from another, and some moisture may have been lost during the delay.

As noted in methods, the between moorings component of the split-plot is equivalent to a one-way ANOVA comparing locations with moorings as replicates. To illustrate that, a one-way ANOVA comparing locations was conducted with shell and tissue weight means for each mooring used as individual observations. For shell weight, *F* and *p* for location effects from the one-way ANOVA were 4.68 and 0.12 versus 4.37 and 0.13 from the spit-plot. For tissue weight, *F* and *p* for location effects from the one-way ANOVA were 3.50 and 0.16 versus 3.41 and 0.17 from the split-plot. The differences between results for the one-way ANOVA and those for the split-plot were a function of small differences in sample sizes within cages plus some rounding error associated with using means rounded to three decimal places. The agreement between the two ANOVA will not be as good if sample sizes are more unbalanced.

End-of-test shell lengths and WAWW, and the change in those variables over the exposure interval (growth), differed significantly among locations (all $p\leq0.01$; Table N3). Differences between moorings within locations were small ($p>0.25$) for these variables, so location effects could be tested against the residual MS. For all four variables, and shell and tissue weights, size or growth increased with increasing distance from the mill discharge.

Depth Effects

Depth effects were always significant at $p \leq 0.01$ (Table N3), even when tested against D × M{L} (i.e., as for tissue weight). Depth and location effects were independent and additive, as the interaction between the two was never close to significant (all p for L × D in Table N2 were >0.25 and close to 0.5). Thus, depth differences were similar at all locations, and location differences were similar at all depths. Size and growth decreased dramatically with increasing depth, despite the narrow depth range tested. The depth or vertical differences over only 4 m within locations were generally larger than horizontal differences among locations separated by 5-10 km (Table N4).

Reduced Model

Table N5 provides complete results for analyses conducted using the reduced model and cage means; Table N6 summarizes gross results (i.e., for comparison with Table N3). Remember that no terms were pooled, so these are the most statistically defensible results presented.

First, when L, D or L × D are tested against the appropriate higher-order error terms from Table N1, results (F, p) are virtually identical regardless of which model is used. For example, F and p for L for shell weight were 4.41 and 0.13 for the reduced model versus 4.37 and 0.13 for the full model. Results will be identical for the two models if sample sizes are balanced (i.e., the same for every cage), which can easily be verified by analyzing initial lengths or weights. Therefore, if higher-order error terms are not pooled or dropped prior to testing effects of interest, or if higher-order error variances (MS) are too large to allow pooling or dropping, conducting analyses on data for individual mussels is pointless.

Second, with two relatively trivial exceptions, gross results from the reduced model (Table N6) were similar to those from the full model (Table N3). Depth effects were always significant at $p \leq 0.01$ in both models. Location effects for shell and tissue weights were not significant in both models because the test used was the same. Location effects for the other four variables (end-of test length and WAWW, and growth increments for those variables) in the reduced model were less significant (i.e., higher p; 0.03-0.06) than for the full model (all four $p<0.01$ and most <0.001). These results do indicate that the full model will be more powerful when location effects can be tested against the residual MS instead of M{L}. However, if terms with $p>0.25$ from the reduced model were pooled with D × M{L} , and the pooled error term used to test location effects for the last four variables in Table N5, all p would be ≤ 0.05, and some would be ≤ 0.01. It would be illogical to argue that pooling was justified for the full model but not the reduced model. Even with no pooling, most investigators would conclude from Table N6 that there were location effects on end-of-test length and weight, and growth for those variables.

Third, for tissue weight, M{L} was significant when tested in the full model but not when tested in the reduced model. In the reduced model, D × M{L} must be used as the error term for testing M{L}. Since D × M{L} was large relative to the residual in the full model (Tables M2 and M3), M{L} was no longer significant when tested against D × M{L} in the reduced model. Because of potential problems with restriction error, M{L} would normally not be tested in the reduced model unless one were interested in pooling M{L} and D × M{L} to provide a more powerful test of location effects. The significance of M{L} is otherwise of little interest; SYSTAT does not even provide significance tests for this term in its subroutine for repeated measures/split-plot designs.

Finally, cage means are not the only summary statistics which can be analyzed in reduced models. Medians could be analyzed if distributions of individual values were decidedly non-normal, and could not be normalized using transformations. This would be crudely equivalent to conducting a non-parametric test, and would be useful if outliers occurred frequently. Other summary statistics such as SD, skewness, and extremes (e.g., 95th percentiles) can also be analyzed in the reduced model. Comparing medians and summary statistics other than means in a full model is difficult if not impossible.

There are some potentially serious problems with analyses of growth based on whole cage rather than individual weights. In this study, results for analyses of growth based on subtracting initial from end-of-test cage means were virtually identical to those obtained using cage means of individual growth differences. This may not be the case in other studies. Initial whole cage weights will include some unrecovered individuals (usually mortalities) not included in weights at the end of the test. If mortality is higher than in this study and size-dependent, growth estimates based on whole cage weights could be less accurate and/or precise than those based on averaging individual growth increments for survivors only. If individual initial and end-of-test weights are highly correlated, then mean growth increments based on averaging individual increments will be more precise than increments based on whole cage weights. In other words, mean (Y - X) will be less variable than mean (Y) - mean (X) (Snedecor and Cochran, 1980). This has been shown in almost all previous studies using this approach.

In this study, growth increments were only slightly less variable than end-of-test weights. WAWW increased ~4-fold over the exposure interval, so differences in initial WAWW had a negligible effect on differences in end-of-test weights. If growth is more limited during exposure, then growth variables may be much less variable and more powerful than end-of-test size variables. Again, differencing (i.e, calculating growth increments) is more effective when the two variables used to calculate the difference are highly correlated. Correlations between initial and end-of-test sizes will usually be higher when growth is more limited.

Comparing regressions of end-of-test sizes on initial sizes in ANCOVA will usually be superior to comparing growth increments in ANOVA (i.e., differencing) (Cohen, 1987). The ANCOVA approach should be more powerful, and takes into account size-dependent growth and other phenomena which bias differencing. In this study, the ANCOVA approach was not noticeably superior to differencing, but it may be in other studies. There are also other ways of expressing and analyzing growth (Ricker, 1975).

The two-way factorial design in Figure M1 would provide a more powerful test of location effects than the split-plot, assuming the same number of cages. However, testing only one depth at each replicate mooring might increase costs substantially (i.e., 18 rather than 6 moorings would be required for the two-way factorial). The most powerful design would be a nested design, with 6 replicate moorings per location, and all cages at the same depth, although that again would require 18 moorings from the viewpoint of the statistical purist.

Regardless of the design used, moorings within locations, with one or more cages per mooring, will be the true units of replication from the viewpoint of the statistical purist. In the absence of cost considerations, the most powerful design would replicate only at the highest level. With *M* mussels, the best design would have one mussel per cage, and one cage only at each of *M* moorings. This is not a reasonable approach. Since costs increase from mussel → cage → moorings, the optimal replication at each level in terms of power-per-unit cost can be calculated using specialized formulae (Snedecor and Cochran, 1980). If costs are lower at lower levels, and variance low at higher levels, increasing the number of lower-level replicates can be more effective than increasing the number of higher-level replicates. However, increases in power are much larger when sample sizes are smaller (<20 and especially <10) than when sample sizes are larger. Thus, power equations will generally show that increasing replication at higher levels with the smallest sample sizes (e.g., moorings) will still be optimal even if the higher-level replicates are much more costly than lower-level replicates. For example, increasing the number of replicate moorings within locations from 2 to 5, and reducing the number of mussels per mooring, would usually be more effective than increasing the number of mussels per cage from, e.g., 90 to 180. Since this is not practical however, replicates per mooring at the same depth should be between 2 to 5.

In this study, added variance at higher levels (cages or moorings) was small, indicating that individual mussels could arguably be treated as units of replication for analyses of depth or location effects for some or most variables. Emphasis might then be on increasing the numbers of mussels per cage or mooring. However, that would produce rapidly diminishing returns in terms of increased power whenever more than 20 mussels were placed in a cage. Furthermore, variance at higher levels was deliberately reduced in this study by the semi-random procedures used to assign mussels to cages. Since mussels were systematically distributed to cages and cages were randomly assigned to moorings the spirit of the random distribution has been met. Therefore, individual mussel data can be used for the analyses. Statistical theoreticians could argue that since the assumptions of the ANOVA and F-tests are violated the results are not scientifically defensible. Nevertheless both the ANOVA and F-tests have been shown to be fairly robust to these minor deviations and have routinely provided useful and defensible information. If mussels were assigned randomly to cages, higher-order variances would almost certainly increase, and variance among mussels within cages decrease. Consequently, there may be few cases where higher-order error terms in Table N1 or in similar designs can be pooled with the variance among mussels to improve power. If so, there is no advantage to increasing replication in terms of number of mussels per cage, unless the costs of adding cages or moorings is prohibitively large.

If cage means, rather than individuals, are analyzed (i.e., as in the reduced model), there is no need to randomly assign mussels to cages. Mussels need only be assigned to cages using the same procedure for each cage; *the key is to randomly assign cages to moorings and locations.* Procedures which deliberately reduce the variance among cage means, such as those used in this study, will then be legitimate and will increase power if analyses are based on cage means. Theoretically, systematic assignment of mussels to cages, and analysis of cage means, could provide a more powerful design than random assignment of mussels to cages, and analysis of data for individual mussels, even if the same numbers of cages and mussels per cage were used. However, the data from over 30 such studies has shown the advantages of individual mussel growth rates as the most discriminating metric over 80% of the time.

Finally, despite using only two replicate moorings per location and a split-plot design (suggested by the statistical theoreticians) which was not efficient for detecting location effects, this pilot study was still able to detect relatively small differences in growth among locations (Table N4) with the most conservative statistical analyses possible (i.e., reduced model; no pooling). Therefore, adequate power can probably be achieved by minor increases in the number of moorings (e.g., to 3-5, if three locations are compared), using 3 to 5 replicate cages and one depth per mooring. The number of mussels per cage should remain the same to provide sufficient tissue for chemical analyses and to examine individual mussel growth rates.

Statistically Correct Conclusions & Recommendations

(1). Complex designs should be avoided in caged mussel studies conducted for EEM programs. Emphasis should be on designs which focus on differences among locations since the primary purpose of the monitoring is to evaluate the effectiveness in the regulations in protecting fishery resources from potential adverse effects from mill related chemicals. From a regulatory monitoring perspective then, depth effects are almost irrelevant just as they are in the laboratory bioassays currently used to test effluent toxicity. Pooling means for cages can still be done.

(2). Since location is the primary parameter of interest, this is where maximum replication should occur. Statistical theory suggests that replication should be maximize by cages. However, the weight of evidence from over 30 separate studies shows that replicating at the individual level by mussel is important for discriminating differences among sites. Individual mussels should remain as the basic unit of replication with a compromise reached between maximizing the number of moorings per site and the number of animals per cage.

(3). From a statistical standpoint it would be nice to maximize the number of moorings but this is not a cost effective approach due to the time and effort involved in establishing each mooring. Again, compromise between pure statistical theory and practicality is necessary to remain scientifically defensible and still fit into the EEM program. If sufficient tissues are available to support the chemical analyses necessary to confirm exposure in the EEM monitoring program with fewer mussels per cage, reducing the number of mussels per cage and increasing the number of cages per mooring should be considered. Suggestions by statistical theoreticians that the increasing the number of cages per mooring is not scientifically defensible is unreasonable. Suggestions that individual mussels must be held in individual PVC frames to be considered true replicates may be statistically appealing but are also unreasonable. There is no reason to believe that individual mussels separated by plastic cable ties inside a mesh tube will be any less of a replicate than individual mussels separated by a PVC frame. Caged mussel surveys probably are a cost-effective tool for the EEM program - relatively small growth differences were detected in this pilot study using analyses which would be accepted by any statistician despite the under-replicated and inefficient study design used.

(4). **Flexibility.** Considering the evaluation criteria of flexibility within the EEM program, caged mussel surveys are probably a cost-effective tool. Relatively small growth differences were detected in this pilot study using several different types of statistical analyses, despite a statistical design suggested by theoreticians that was under-replicated and inefficient for detecting differences among sites. Within the generic approach of using caged bivalves as a monitoring tool, mills and consultants should be given flexibility in approach as they have in their approaches to other elements of the program such as laboratory bioassays, benthos, and adult fish surveys or other alternatives approaches such as wild mussels and Fucus baskets.

(5). **Tissue Chemistry.** The need to have sufficient mussels per cage for chemical analyses has been cited by some as unimportant. They cite the primary objective of the EEM program as being biological effects and not chemical differences. The regulations define effects as significant differences measured in an environmental variable between a receiving area and a reference area. While bioaccumulation of mill-associated chemical in itself cannot be considered an effect *per se* (depending on how the regulations are interpreted) this approach is consistent with the risk assessment format and is a crucial element of characterizing exposure. This has been difficult to demonstrate using fish for the EEM program because of their mobility and ability to metabolize many of the chemicals of concern. Caged bivalves provide a unique opportunity to characterize exposure by combining measurements of potential exposure in the water column and in sediments with actual exposure in tissues that is much closer to the ultimate receptor. The next step is to pair these exposure measurements with effects measurements for more accurate dose-response predictions. This is a potentially powerful tool for the EEM program that cannot be provided using current approaches. If it is decided that confirmation of exposure through tissue accumulation is not important to EEM it removes one of the major strengths of the caged bivalve approach; i.e., measuring exposure and effects in the same organism at the same time with a defined exposure period. *It is therefore strongly recommended that the caged bivalve approach include chemical measurements of exposure in water and sediment, and chemical measurements of the dose in mussel tissues in combination with mussel growth and other metrics such as reproduction to quantify effects.* Other modifying factors such as temperature, salinity, DO, and food (e.g., chlorophyll) should also be measured. Contaminant measurements in water or sediment may provide useful information at some other applications outside of pulp and paper.

Table N1. Split-plot ANOVA model for the pilot caged mussel survey

Source		df	Error term[1]
Between moorings			
Location	L	2	M{L}
Moorings within locations	M{L}	3	Resid.
Within moorings			
Depth	D	2	D × M{L}
Location × Depth	L × D	4	D × M{L}
Depth × Moorings	D × M{L}	6	Resid.
Residual (among mussels within cages)	Resid.	18 ($\sum\{m-1\}$) ≈ 1500	

NOTE: df = degrees of freedom

[1] - *F* values would be the mean square (MS) for the term of interest divided by the MS for the error term. For example, *F* for location effects would be [MS (L)]/[MS (M{L}].

Table N2. Results of statistical analyses of biological variables using data for individual mussels (= full model)

Shell weight (g)

Source		df	SS	MS	Error term	F	p
Between moorings							
Location	L	2	1.32	0.660	M{L}	4.37	0.13
Moorings within locations	M{L}	3	0.453	0.151	Resid.	1.56	0.20
Within moorings							
Depth	D	2	9.929	4.965	Resid.	51.40	<0.01
Location x Depth	L x D	4	0.375	0.094	Resid.	0.97	0.42
Depth x Moorings	D x M{L}	6	0.371	0.062	Resid.	0.64	0.72
Residual (among mussels within cages)	Resid.	1505	145.357	0.097			

Tissue weight (g)

Source		df	SS	MS	Error term	F	p
Between moorings							
Location	L	2	3.159	1.580	M{L}	3.41	0.17
Moorings within locations	*M{L}*	*3*	*1.391*	*0.464*	*Resid.*	*6.61*	*<0.01*
Within moorings							
Depth	D	2	12.554	6.277	D x M{L}	16.73	<0.01
Location x Depth	L x D	4	1.203	0.301	D x M{L}	0.80	0.57
Depth x Moorings	D x M{L}	6	2.251	0.375	Resid.	5.35	<0.01
Residual (among mussels within cages)	Resid.	1513	106.119	0.070			

End-of-test shell length (mm)

Source		df	SS	MS	Error term	F	p
Between moorings							
Location	L	2	234.7	117.3	Resid.	5.45	<0.01
Moorings within locations	M{L}	3	33.2	11.1	Resid.	0.51	0.67
Within moorings							
Depth	D	2	699.8	349.9	Resid.	16.24	<0.01
Location x Depth	L x D	4	68.6	17.1	Resid.	0.80	0.53
Depth x Moorings	D x M{L}	6	85.3	14.2	Resid.	0.66	0.68
Residual (among mussels within cages)	Resid.	1512	32,573.0	21.5			

Table N2 (Continued).

End-of-test whole animal wet weight (g)

Source		df	SS	MS	Error term	F	p
Between moorings							
Location	L	2	22.83	11.42	Resid.	10.68	<0.01
Moorings within locations	M{L}	3	2.46	0.82	Resid.	0.77	0.51
Within moorings							
Depth	D	2	78.16	39.08	Resid.	36.55	<0.01
Location x Depth	L x D	4	4.28	1.07	Resid.	1.00	0.41
Depth x Moorings	D x M{L}	6	5.91	0.98	Resid.	0.92	0.48
Residual (among mussels within cages)	Resid.	1512	1,616.51	1.07			

Growth in length (end-of-test minus initial)

Source		df	SS	MS	Error term	F	p
Between moorings							
Location	L	2	241.5	120.8	Resid.	5.99	<0.01
Moorings within locations	M{L}	3	42.5	14.2	Resid.	0.70	0.55
Within moorings							
Depth	D	2	699.2	349.6	Resid.	17.34	<0.01
Location x Depth	L x D	4	70.7	17.7	Resid.	0.88	0.48
Depth x Moorings	D x M{L}	6	104.6	17.4	Resid.	0.86	0.52
Residual (among mussels within cages)	Resid.	1512	30,478.1	20.2			

Growth in whole-animal wet weight (end-of-test minus initial)

Source		df	SS	MS	Error term	F	p
Between moorings							
Location	L	2	23.55	11.77	Resid.	11.77	<0.01
Moorings within locations	M{L}	3	2.60	0.87	Resid.	0.87	0.46
Within moorings							
Depth	D	2	78.25	39.12	Resid.	39.10	<0.01
Location x Depth	L x D	4	4.20	1.05	Resid.	1.05	0.38
Depth x Moorings	D x M{L}	6	7.12	1.19	Resid.	1.19	0.31
Residual (among mussels within cages)	Resid.	1512	1,512.94	1.00			

Table N3. Summary results for statistical analyses of biological variables using data for individual mussels (=full model; see Table N2 for detailed results)

Source	Variable					
	Shell weight	Tissue weight	Shell length	Whole animal wet weight (WAWW)	Growth (SL)	Growth (WAWW)
Between moorings						
L	NS	NS	**	**	**	**
M{L}	NS	**	NS	NS	NS	NS
Within moorings						
D	**	**	**	**	**	**
L × D	NS	NS	NS	NS	NS	NS
D × M{L}	NS	**	NS	NS	NS	NS

NOTE: Higher-order error terms were pooled with the residual MS if $p>0.25$

** - $p \leq 0.01$; NS = not significant ($p>0.05$)

Table N4. Comparison of growth differences among depths and locations

Variable	Location	Depth			Max. diff. (%)
		2 m	4 m	6 m	
Growth in shell length	Near-field	12.2	12.2	11.1	9.91
	Intermediate	13.5	12.8	11.2	20.54
	Far-field	13.3	13.2	12	10.83
	Max. diff. (%)	9	8	8	-100.00
Growth in WAWW	Near-field	2.26	2.20	1.88	20.21
	Intermediate	2.6	2.37	1.91	36.13
	Far-field	2.65	2.50	2.11	25.59
	Max. diff. (%)	18	14	12	

NOTE: Max. diff. = maximum difference between depths or locations, as a % of the smallest value

Table N5. Results of statistical analyses of biological variables using cage means (=reduced model)

Shell weight (g)

Source		df	SS	MS	Error term	F	p
Between moorings							
Location	L	2	0.016	0.008	M{L}	4.41	0.13
Moorings within locations	M{L}	3	0.005	0.002	D x M{L}	2.55	0.15
Within moorings							
Depth	D	2	0.117	0.059	D x M{L}	83.74	<0.01
Location x Depth	L x D	4	0.004	0.001	D x M{L}	1.58	0.29
Depth x Moorings	D x M{L}	6	0.004	0.001			

Tissue weight (g)

Source		df	SS	MS	Error term	F	p
Between moorings							
Location	L	2	0.037	0.019	M{L}	3.42	0.17
Moorings within locations	M{L}	3	0.016	0.005	D x M{L}	1.24	0.38
Within moorings							
Depth	D	2	0.147	0.074	D x M{L}	16.71	<0.01
Location x Depth	L x D	4	0.014	0.004	D x M{L}	0.80	0.57
Depth x Moorings	D x M{L}	6	0.026	0.004			

End-of-test shell length (mm)

Source		df	SS	MS	Error term	F	p
Between moorings							
Location	L	2	2.774	1.387	M{L}	10.55	0.04
Moorings within locations	M{L}	3	0.394	0.131	D x M{L}	0.78	0.55
Within moorings							
Depth	D	2	8.190	4.095	D x M{L}	24.36	<0.01
Location x Depth	L x D	4	0.805	0.201	D x M{L}	1.20	0.40
Depth x Moorings	D x M{L}	6	1.009	0.168			

Table N5 (Continued)

End-of-test whole animal wet weight (g)

Source		df	SS	MS	Error term	F	p
Between moorings							
Location	L	2	0.270	0.135	M{L}	13.87	0.03
Moorings within locations	M{L}	3	0.029	0.010	D x M{L}	0.84	0.52
Within moorings							
Depth	D	2	0.915	0.458	D x M{L}	39.39	<0.01
Location x Depth	L x D	4	0.050	0.013	D x M{L}	109	0.44
Depth x Moorings	D x M{L}	6	0.070	0.012			

Growth in length (end-of-test minus initial)

Source		df	SS	MS	Error term	F	p
Between moorings							
Location	L	2	2.855	1.428	M{L}	8.49	0.06
Moorings within locations	M{L}	3	0.504	0.168	D x M{L}	0.82	0.53
Within moorings							
Depth	D	2	8.184	4.092	D x M{L}	19.84	<0.01
Location x Depth	L x D	4	0.829	0.207	D x M{L}	1.01	0.47
Depth x Moorings	D x M{L}	6	1.237	0.206			

Growth in whole-animal wet weight (end-of-test minus initial)

Source		df	SS	MS	Error term	F	p
Between moorings							
Location	L	2	0.278	0.139	M{L}	13.52	0.03
Moorings within locations	M{L}	3	0.031	0.010	D x M{L}	0.74	0.57
Within moorings							
Depth	D	2	0.916	0.458	D x M{L}	32.78	<0.01
Location x Depth	L x D	4	0.050	0.013	D x M{L}	0.89	0.53
Depth x Moorings	D x M{L}	6	0.084	0.014			

Table N6. Summary results for statistical analyses of biological variables using cage means (=reduced model; see Table N5 for detailed results)

Source	Variable					
	Shell weight	Tissue weight	Shell length	Whole animal wet weight (WAWW)	Growth (SL)	Growth (WAWW)
Between moorings						
L	NS	NS	*	*	NS (p=0.06)	*
M{L}	NS	NS	NS	NS	NS	NS
Within moorings						
D	**	**	**	**	**	**
L × D	NS	NS	NS	NS	NS	NS

* - $p \leq 0.05$; ** - $p \leq 0.01$; NS = not significant ($p > 0.05$)