Shifts in student attitudes towards science while monitoring marina water quality in Friday Harbor, Washington

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Abstract:

The Friday Harbor Marina water quality project incorporates 5th grade educational outreach and the scientific testing of how anthropogenic development can increase concentrations of fecal pollution in the Friday Harbor Marina. Learning how outreach efforts are changing 5th graders' attitudes towards science may help revise future outreach projects. Additionally, understanding how development in Friday Harbor is influencing the health of the marina can target pollution management to highly-impacted areas. An attitudinal before and after survey was administered to test if students' scientific interests changed while testing six sites within the marina for fecal coliform contamination. Predictions concerning the increase in student attitudes were unfounded because before and after survey results were not statistically different. Fecal coliform levels were highest near sites of non-point and point source pollution, which corresponds with predictions about the degradation of water quality from development.

Introduction:

Anthropogenic development around coastal sites can degrade water quality by bringing terrestrial fecal matter into marine waters in high concentrations (Mallin et al. 2000). In particular, the presence of impervious surfaces and sewage systems in developed areas can directly contribute to the degradation of the marine environment. This degradation is linked to terrestrial fecal matter getting into marine waters through surface run-off and sewage leaks (Mallin et al. 1998; Mallin et al. 2000). The addition of fecal matter into coastal areas may pose a health risk for humans and organisms living in the marina (Abhirosh et al. 2011). To address these health risks, the Port of Friday Harbor

has agreed to finance equipment for the testing of the Friday Harbor Marina by Friday Harbor Elementary (FHES) 5th grade students. The Port hopes to gain a better understanding about how development in Friday Harbor is affecting the water quality while connecting the 5th grade students to the environment (J. Roberts, personal communication, 2011). Without knowledge concerning which marina sites are contaminated, future pollution prevention measures will not be localized and may not be targeted to the sites in the marina influenced most. It is also important to understand how participation in the FHM water quality project is changing scientific interests and comprehension as well. We can revise teaching methods or invest time and resources into similar projects if we understand these changes. Therefore, in this study we will look at two aspects of the Friday Harbor Marina water quality project.

First, we will look at attitudinal shifts in the 5th grade students conducting the water-sampling. This study will test if the water quality project is influencing changes in scientific interest and comprehension. I expect there will be an increase in student interest and understanding of science. These results are expected because student understanding of science oftentimes leads to the development of positive outlooks towards science and a willingness to pursue science in the future (Carvallo-Knighton et al. 2009).

Second, the 5th grade students will measure fecal coliform concentrations as an indicator of the health of the Friday Harbor Marina (FHM). Data collected will be combined with 5th grade coliform counts documented since 2002. Compiled results will be compared to the Washington State Recreational Standards. According to these standards, the surface water in Friday Harbor should not exceed 43 colonies/100mL in 10% of all samples taken. If samples exceed 400 colonies/100mL the surface water is

classified as having poor water quality. This threshold is important because when fecal coliform is present in large concentrations, pathogenic bacteria may also be present (Okeke et al. 2011). Humans in primary contact with the water like boaters and swimmers may be subjected to these harmful bacteria. I expect sites in close proximity to areas with high surface run-off or near sewage systems will most likely contain the largest fecal coliform concentrations.

Methods:

Attitudinal shifts

Attitudinal surveys were given to each participating 5th grade student before (n=47) and after (n=40) water sampling to test shifts in scientific interest and comprehension over the course of the FHM water quality project. Sample size differences between before and after surveys are attributed to student absences from school. The attitudinal survey was 13 statements long and set on a 5-point Likert Scale. For each statement, available answers were "strongly disagree", "disagree", "neutral", "agree" and "strongly agree." (See appendix 1for clarification on survey format). Students would circle the answer that corresponded with the student's attitude towards the statement.

Survey responses were analyzed by giving each available answer a numerical value. The values are as follows: Strongly disagree (1 pt.), disagree (2 pts.), neutral (3 pts.), agree (4 pts.) and strongly agree (5 pts.). Shifts in scientific interest and comprehension were understood by finding the mean numerical survey response before and after water sampling. The surveys were given three days apart from each other. Shifts in attitude were tested using a t-test.

Results were further analyzed by assigning each of the 13 survey questions into one of three categories. The categories included general interest in science, understanding of scientific ideas and FHM water quality testing. Six survey statements were placed in the general interest category. Four survey statements were placed in the scientific comprehension category. Three survey statements were placed in the FHM testing category (see appendix 1 for details on survey format). The FHM water quality category was designed to test 5th grade students' attitude towards the water sampling activity.

Water Sampling

The FHM water quality testing activity took groups of FHES 5th grade students to sample water from 6 sites in the Friday Harbor Marina. Students measured fecal coliform concentrations in each sample of water. Sites were distributed across the marina with site 1 located near the ferry dock on the south side of the marina and site 6 located on the north shore of the marina. Four sampling sites, classified as moorage sites, were spatially distributed from south to north in the central marina. Water samples taken from the Friday Harbor Laboratories (FHL) controlled for background fecal coliform levels because of the absence of large-scale development at this site.

During the water quality testing activity, 5th graders collected water samples using a glass autoclaved bottle and a dipstick. Salinity and temperature of the marina water was recorded during water sampling using a portable Hach HQ40D meter. Students were then taken to Friday Harbor Labs where the students vacuumed 100mL of marina water through a disposable filter/dish (f/d) unit. Bacteria were fed M-FC Coliform broth solution and placed in a 44.5 ^{0}C incubator for 24 hours. After the incubation period,

students counted the number of fecal coliform colonies present on the f/d unit. Coliform colonies are fairly obvious to count because the M-FC solution dyes each colony blue. FHES 5th grade students had no problem identifying a coliform colony.

The coliform counts from each marina site have been documented since 2002. Coliform counts are compared against each other and the FHL control. A one-way Kruskal-Wallis ANOVA based on ranks was used to understand differences in the fecal coliform distribution across the marina. The percentage of samples with fecal coliform concentrations larger than 400 colonies/100mL was also calculated because 400 colonies/100mL represents the threshold concentration between fair and poor water quality.

The data collected by the 5th graders on temperature and salinity coupled with daily rainfall data from the Friday Harbor Laboratories Weather Station was also analyzed in this study. Comparisons were made between fecal coliform concentrations at the three most contaminated sites and these environmental factors. Stepwise regression and linear regression were used to find correlations between fecal coliform levels and temperature, salinity or rainfall.

Results:

Attitudinal shifts

5th grade students did not demonstrate a change in scientific interest and comprehension over the course of the FHM marina water quality project. The mean survey score for the before sampling survey was 3.70. The mean survey score for the complete after sampling survey was 3.71. The mean survey score before sampling was

not statistically different than the mean survey score after sampling (p=0.47). A survey response falling between three and four corresponds with a student response between neutral and agree.

When survey statements were grouped into the three categories of scientific interest, understanding of scientific concepts, and questions pertaining directly to the water sampling activity, there was again no change in student response before and after water sampling (see figure 1for results). The mean survey response testing for general interest was 3.65 before water sampling and remained 3.65 after water sampling. The mean survey response testing for understanding of scientific concepts was 3.60 before water sampling and 3.65 after water sampling. The increase in scientific understanding was not statistically significant (p=0.32). The mean survey response for statements corresponding to the FHM water quality testing was 3.92 before water sampling and 3.89 after water sampling. The decrease in these survey results was not statistically significant (p=0.40).

Water Sampling

A strong trend in fecal coliform distribution across the marina exists. Water taken from the Friday Harbor Labs represents the background concentration of fecal coliform in the marina and had a median value of 0 colonies/100mL. Samples taken near the ferry dock and the wastewater treatment plant (WWT) quite frequently contained the highest concentrations of fecal coliform colonies. The median values of fecal coliform concentration for the ferry dock site and the wastewater treatment site were 32 colonies/100mL and 4.5 colonies/100mL respectively. The coliform levels at the ferry

dock and at WWT are statistically different from each other and the other sites in the marina ($p = <0.05$). The median value of fecal coliform concentration at moorage site 1 was 2 colonies/100mL. The coliform levels at moorage site 1 are statistically different from the other sampling sites ($p<0.05$). The median value for fecal coliform concentration in moorage sites 2, 3 and 4 was 1 colony/100mL. The fecal coliform concentration at moorage sties 2, 3 and 4 are not statistically different ($p>0.05$) from each other but are statistically different from other sites in the marina ($p<0.05$).

The threshold between fair and poor water quality is 400 colonies/100mL. The ferry dock site surpassed this threshold in 11.2% of the water samples. The WWT site surpassed this threshold in 5.5% of the water samples. Moorage site 1surpassed this threshold in 2.4% of the water samples. Moorage sites 2, 3 and 4 and FHL were never classified as having poor water quality.

The relationship between rainfall, salinity and temperature to the daily mean fecal coliform concentration at the ferry dock site, moorage 1 and WWT was analyzed to test if environmental conditions influence fecal coliform propagation (see figure 3 for results at ferry dock site). Stepwise regression analysis eliminated rainfall, salinity and temperature as variables influencing fecal coliform concentrations. A follow-up linear regression analysis between each environmental factor and the daily mean fecal coliform concentrations also indicate no correlations (statistics available in appendix 2).

Discussion:

Attitudinal shifts

Despite expectations, no shift in attitude was observed over the course of the FHM water quality project. The lack of attitudinal shift observed in this study leads me to several conclusions. First, attitudinal surveys are widely accepted as appropriate surveys when gathering sociological data but testing attitude is more complex than a survey can oftentimes measure (Kind et al. 2007). For instance, students may only associate science with the structured activities they are assigned at school and do not think about the science they do for fun outside of the school environment (Ramsden 1998). Therefore, preconceived notions of science may outweigh any one activity designed to increase student interest in science. Predictions about dramatic increases in interest and understanding over the course of the FHM water quality project might have been unfounded because of the short length of time spent with each student.

Second, the survey sample size might have been too small to show significant results. The sample size (before: n=47; after: n=40) in this study represented a sufficient proportion of the population of 5th grade students at FHES so I may be inclined to dismiss this conclusion. Finally, the FHM water quality project may not be an effective activity. However, I think this final conclusion is unlikely because students seem to enjoy the hands-on activity and the marina water quality category in the survey results indicates an insignificant decrease in attitude.

Hands-on education is accepted to be an effective teaching tool when it comes to increasing scientific understanding and interest (Jarvis et al. 2007). Therefore, we should further investigate the FHM marina water quality project to learn how this project is influencing Friday Harbor youth. A viable option for future research may involve studying the FHM water quality project using semi-structured interviews instead of a 5-pt

Likert survey. Semi-structured interviews may give insight to how the water sampling project is directly changing student's attitudes towards science because interviews allow for elaboration when needed (Bariball 1994). Studying the FHM water quality project through semi-structured interviews may encourage other school districts and grade levels to integrate the FHM water quality project into the curriculum.

Water Sampling

As expected, sites located closer to development had higher fecal coliform concentrations. The ferry dock is located where surface run-off from Spring Street (downtown Friday Harbor) is washing into the marina. The placement of the ferry dock site is important because surface run-off carrying terrestrial fecal matter is intensified in the presence of impervious streets and surfaces (Mallin et al. 2008). The site located on-shore near the wastewater treatment plant could be influenced by surface run-off, animal waste deposited directly into the water or leaks in the sewage pipe. According to city design, this site is located above a sewage pipe (Gray et al. 2008). Moorage site 1 seems to be contaminated more than the other moorage sites which may suggest that proximity to the ferry dock or faulty boat heads may influence fecal concentration at this site.

According to Washington State water standards, Friday Harbor should have extraordinary water and may not exceed 43 colonies/100mL in 10% of water samples retrieved (Washington 2003). The ferry dock site was classified as having poor water quality, exceeding 400 colonies/100mL in 11.2% of all samples taken. Therefore, the FHM is violating recreational use standards. Reductions in fecal coliform counts may be necessary if primary contact with the marina water is to continue.

Management of surface run-off by the Spring Street raingarden may help decrease fecal coliform concentrations in the FHM. The raingarden was established in the spring of 2011(Raingarden 2011). Long term research should be done to see if fecal contamination near the ferry dock decreases substantially after the rain garden was installed. Monitoring of water quality in future years may show less instances where the concentration of fecal coliform peaks above 400 colonies/100mL.

The design of this experiment may not be as desirable as one would hope in a scientific study. More sites, sampled more frequently as well as having sampling conducted in the same way each time would have increased the validity of the data. It would have been beneficial to target other areas around San Juan Island and see if results from the FHM correspond with the results from similar sites. However, procedures were created around an educational outreach project and thus limited to school hours, numbers of participating students and the expense of the equipment.

Despite the limitations in the design the results of this study can and should influence future research. Since there is no correlation between fecal coliform concentrations and environmental factors such as rainfall, temperature and salinity we can only surmise that anthropogenic development is influencing fecal contamination in Friday Harbor. The current state of the Friday Harbor Marina well exceeds recreational standards. Therefore, an understanding of how development influences Friday Harbor's coastal waters is the important first step to preserving the water quality for the enjoyment of future generations.

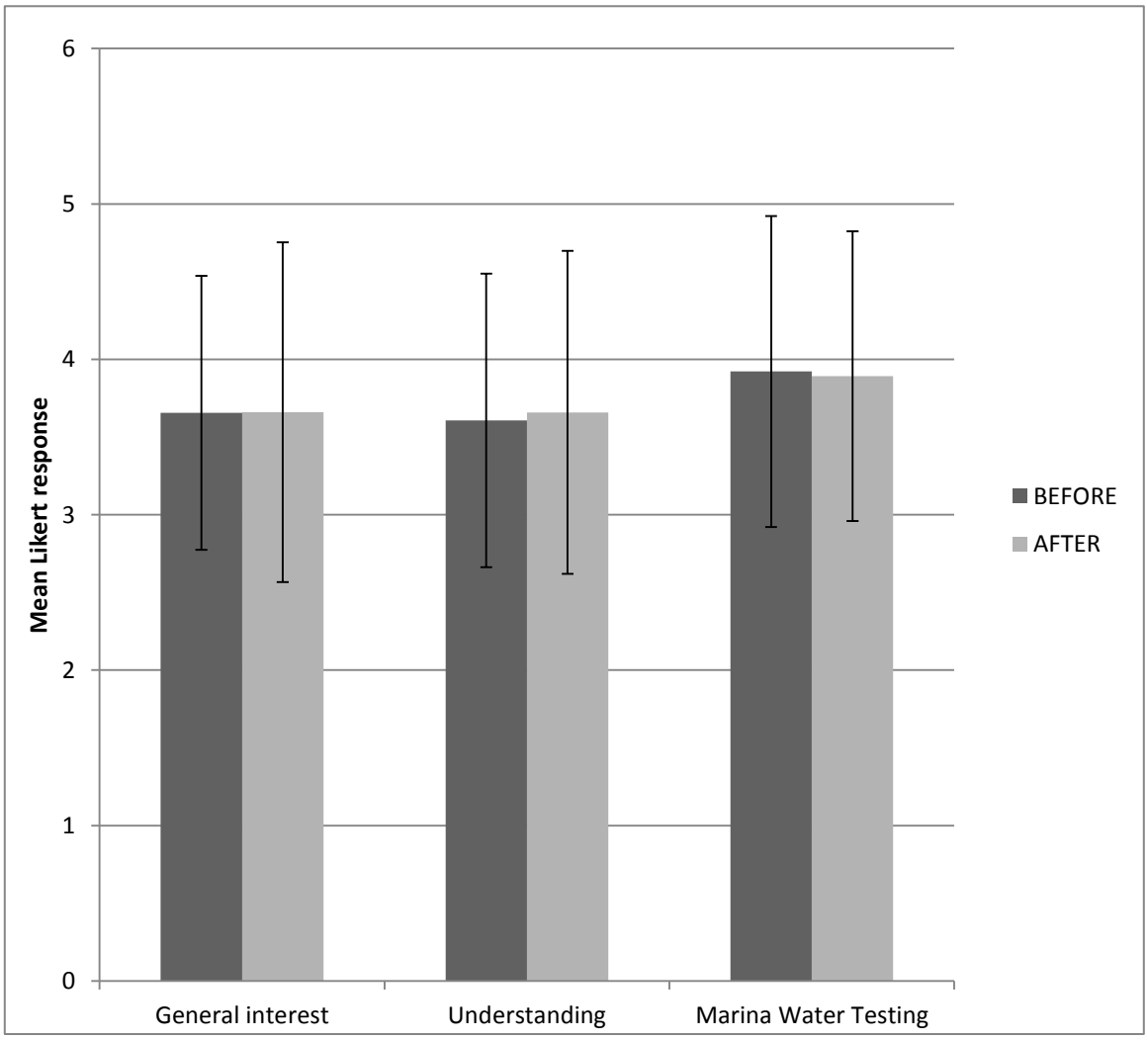

Figure 1: Mean Likert response +/- standard deviation of 13 attitudinal survey statements grouped into three categories: General interest, scientific understanding and statements related directly to the Friday Harbor Marina water quality project. The mean Likert response was measured on surveys before and after Friday Harbor Elementary 5th grade students collected water samples from the Friday Harbor Marina. (Before: n=47; After: n=40). Differences in samples taken are attributed to student absences from class. The before and after surveys were not statistically different in all three categories tested ($p=<0.05$).

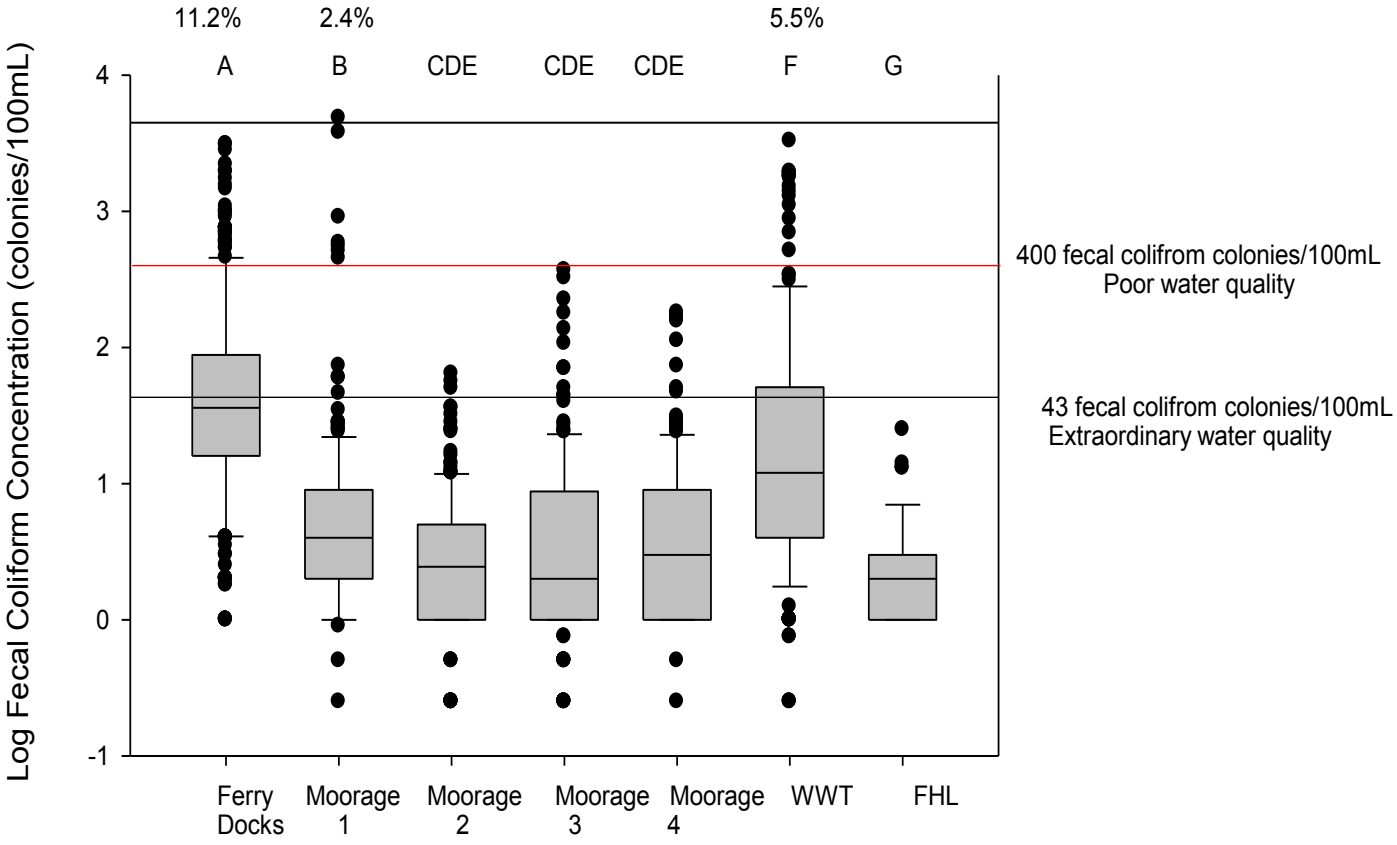

Figure 2: Fecal coliform concentrations (colonies of fecal colifrom/100mL of marina water) were measured at various sites in the Friday Harbor Marina since 2002. Site 1 is located near the ferry docks on the south side of the marina. Moorage sites 1-4 are spread spatially from south to north and are located on moorage docks. Site 6 is an onshore site on the north side of the marina near the waste water treatment plant (WWT). Coliform concentrations (y-axis) are on a Log10 scale.

Fecal Coliform concentrations below 1.61 on Log10 scale (43 colonies/100mL of marina water linear scale) indicates extraordinary water quality. Fecal Coliform concentrations above 2.64 on Log10 scale (400 colonies/100mL linear scale) indicates poor marina water quality. The Ferry dock site, Moorage 1 and WWT indicate the percentage of samples that violate the 400 coliform colonies/100mL threshold and are classified as having "poor" water quality.

Ferry dock site: n=313; Moorage site 1: n=293; Moorage site 2: n=295; Moorage Site 3: n=293
Moorage site 4: n=274; WWT: n= 265.

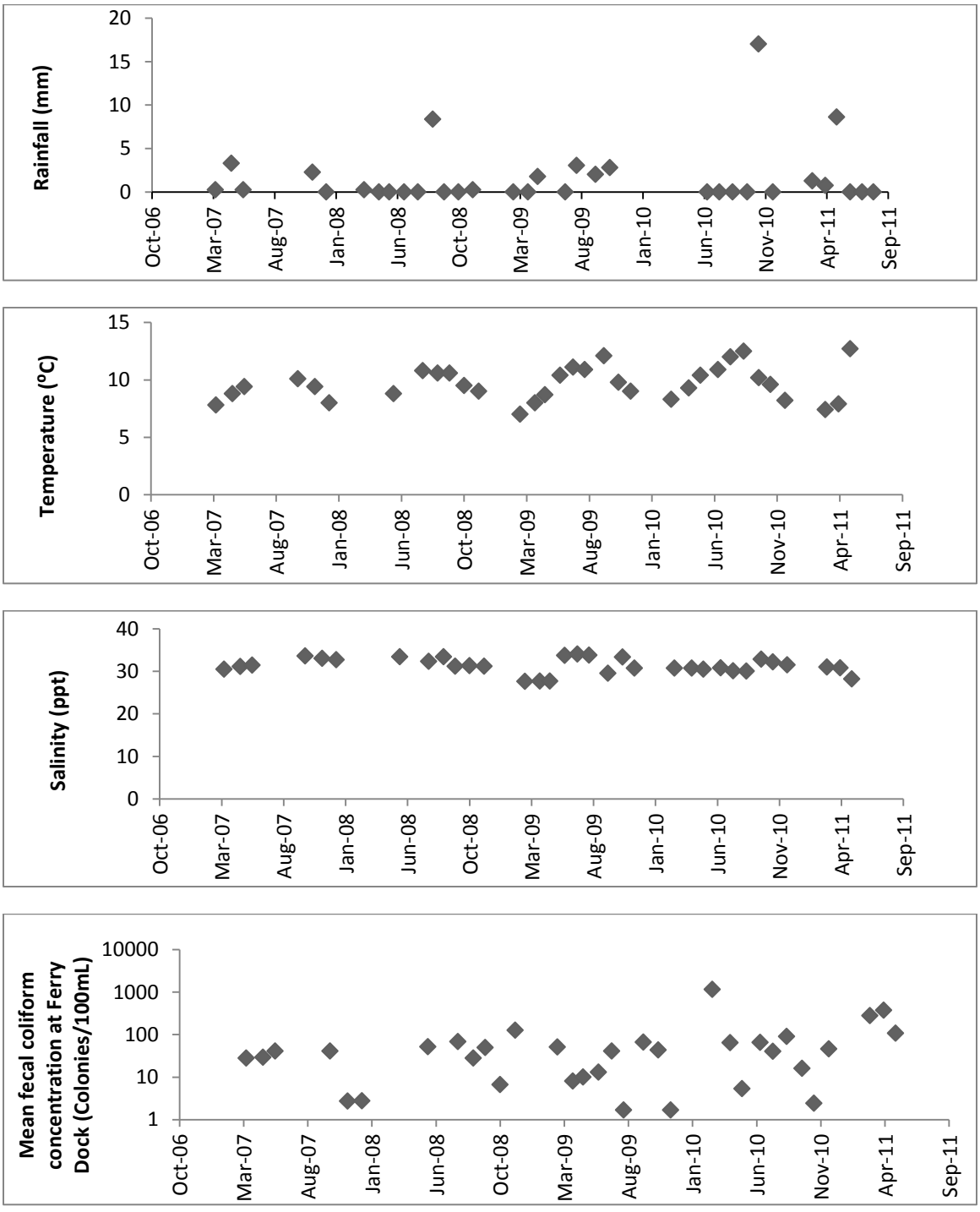

Figure 3: Fecal Coliform concentration at ferry dock site compared to the potential environmental factors. Correlations between the fecal coliform concentration (colonies/100mL) on a given sampling date and the rainfall (mm), salinity (ppt) and temperature (^{0}C) on the sampling date were tested. Regression analysis shows no correlation between rainfall and mean fecal coliform concentration (Rsqr=0.016; p=0.479). Regression analysis show no correlation between

temperature and mean fecal coliform concentration (Rsqr=0.050; p=0.210.). Regression analysis shows no correlation between salinity and mean fecal coliform concentration (Rsqr=0.012; p=0.985). n= 35.

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Appendix 1

Here is an example of the post survey given to the Friday Harbor Elementary Students after testing the Friday Harbor Marina for fecal coliform. The before survey is exactly identical to the after survey represented here but is formatted in the future tense. For analysis, the 13 statements were grouped into the 3 categories of general interest, scientific understanding and statements relating to the FHM water quality project.

General interest category: uses statements 1, 2, 3,4,6,7

Scientific understanding: uses statements 5, 8, 9, 10

FHM water quality project: uses statements 11, 12, 13

5th Grade Science Post Questionnaire for the Friday Harbor Marina Water Quality Project

Please circle the answer that applies.

1. After participating in these science activities, my interest in science is high.
   Strongly Disagree Disagree Neutral Agree Strongly Agree

2. I enjoyed participating in these science activities.
   Strongly Disagree Disagree Neutral Agree Strongly Agree

3. I learned a lot from these science activities.
   Strongly Disagree Disagree Neutral Agree Strongly Agree

4. These science activities were interesting to me.
   Strongly Disagree Disagree Neutral Agree Strongly Agree

5. After participating in these activities I have a better idea of what scientists do.
   Strongly Disagree Disagree Neutral Agree Strongly Agree

6. Participating in these science activities has sparked my interest in taking more science classes.
   Strongly Disagree Disagree Neutral Agree Strongly Agree

7. I am considering becoming a scientist after participating in these activities.
   Strongly Disagree Disagree Neutral Agree Strongly Agree

8. These science activities helped me understand what a hypothesis is.
   Strongly Disagree Disagree Neutral Agree Strongly Agree

9. These science activities helped me understand how a hypothesis is tested.
   Strongly Disagree Disagree Neutral Agree Strongly Agree

10. These activities helped my understanding of scientific methods.
    Strongly Disagree Disagree Neutral Agree Strongly Agree

11. The Friday Harbor Marina Water Quality Project was exciting to me.
    Strongly Disagree Disagree Neutral Agree Strongly Agree

12. I enjoyed doing this science project.
    Strongly Disagree Disagree Neutral Agree Strongly Agree

13. I feel better prepared to do my own science project after participating in the Friday Harbor Marina Water Quality Project.
    Strongly Disagree Disagree Neutral Agree Strongly Agree

Appendix 2

Table 1: Statistics used to test correlations between mean fecal coliform concentration at the Ferry Dock, Moorage site 1 and the WWT. These statistics were derived by Linear Regression Analysis between mean fecal coliform concentration and each environmental factor. There are no strong correlations between environmental factors and the mean coliform concentration.

	Rainfall (mm)		Temperature (˚C)		Salinity (ppt)	
Site	Rsqr	P-value	Rsqr	p-value	Rsqr	p-value
Ferry Dock	0.0163	0.479	0.0503	0.21	0.0119	0.545
Moorage 1	0.0128	0.531	8.29E-11	1	0.00511	0.693
WWT	0.0000123	0.985	0.058	0.095	0.0256	0.374

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