Samish Indian Nation

Department of Natural Resources

Continuous Temperature Monitoring in Fidalgo Bay

Year 1- Methods and First year Results

June 2009

Introduction

Beginning in the summer of 2008, continuous temperature monitors were placed in a variety of locations within the Fidalgo Bay intertidal zone located in Skagit County, WA. The placement of these sensors was designed to determine if there were significant differences in water temperature inside and outside of eelgrass beds as well as to provide baseline temperature data to compare to Washington State Water Quality Standards. Data collection also provides for baseline data to compare over time in climate change trend analysis.

This report details the methods followed for the study as well as analysis of the first year of data. It is important to note that baseline temperature data requires much more than one year's worth of study. It is hoped that this study will be repeated to add more data so that local climate change analysis may occur.

Site Description

Fidalgo Bay is a shallow embayment located in Northern Puget Sound, northwestern Skagit County, Washington (Figure 1). It encompasses approximately 650 acres of tide flats, salt marsh, mudflats and sand and gravel beaches. It is bordered by the City of Anacortes to the west and March's Point to the east. Much of the shoreline is modified with rip rap and other development including the City of Anacortes, March's Point oil refineries, a tribally owned RV park and private residences located in near proximity to the shoreline.

Because of the diverse habitat types, including extensive eelgrass beds found within Fidalgo Bay, it supports a wide range of invertebrate, fish, bird, and mammal species. Shellfish abound in the intertidal area and large populations of crab are found throughout the bay. Surf smelt herring and other fish, including salmonids and flatfish can be found utilizing the bay for spawning and other life stages. Herons, gulls, ducks and other water birds are found year round in Fidalgo Bay and it is an important area along the Northwest Flyway for a wide range of migratory birds. There are at least three nesting pairs of bald eagles utilizing the bay and osprey and other raptors have been observed in the area. The remaining upland forests support a wide range of songbirds as well. Harbor seals frequent the bay and pups have been observed during the late spring and summer months (Samish DNR personal observations).

Weaverling Spit and the entirety of Fidalgo Bay was and continues to be an important area to the Samish Indian Nation. The area has long been utilized for camps and more permanent living long before contact and settlement by Europeans. One of the state's oldest Coast Salish archaeological sites is located within the study area. Currently, the Tribe owns an RV park with convention center in South Fidalgo Bay and its Administrative complex is located to the West in downtown Anacortes. The Samish Indian Nation's Department of Natural Resources is located at the RV park and is conveniently situated to conduct its various research projects in the bay.

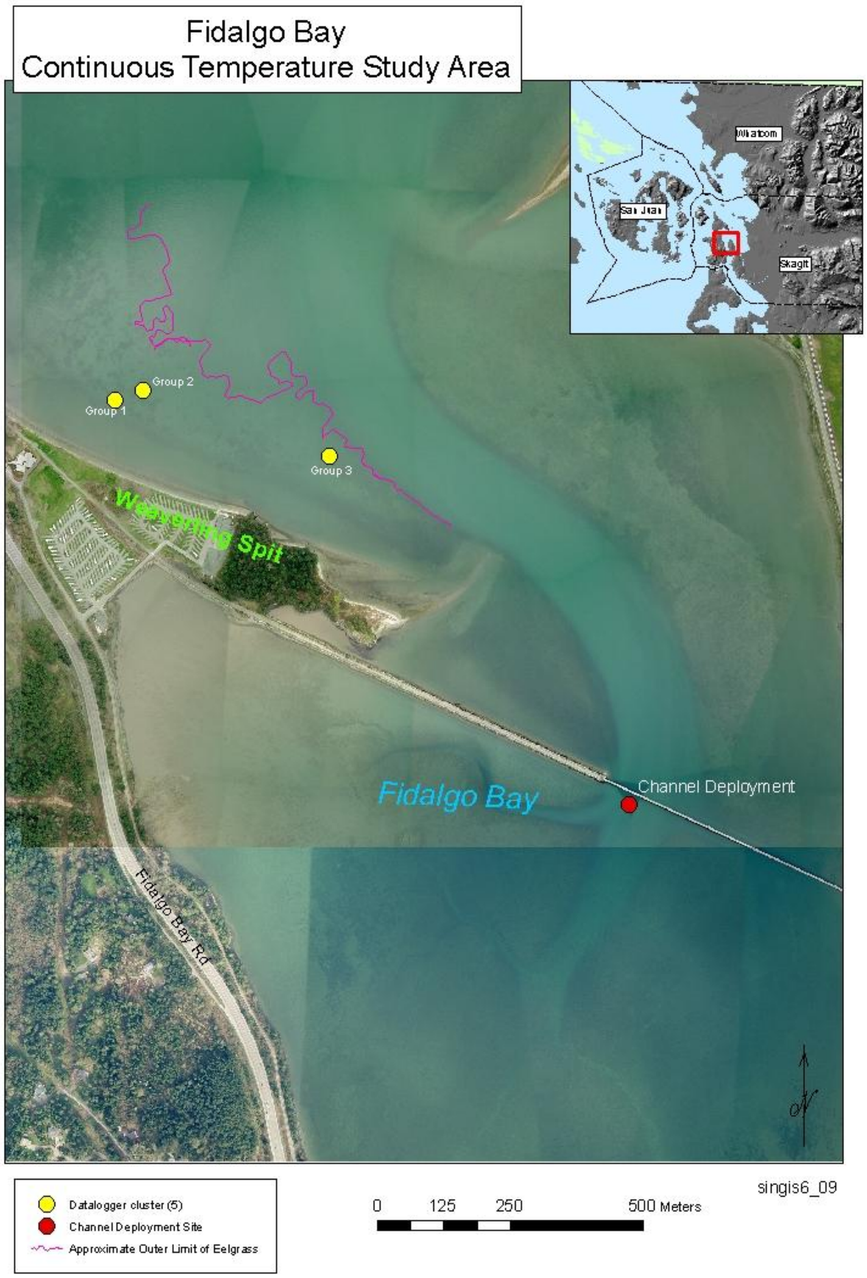
In April of 2008 at a ceremony held at the Samish Tribe's Fidalgo Bay Convention Center, 650 acres of Fidalgo Bay was signed into Aquatic Reserve status by the Washington State Department of Natural Resources. This designation has a 90-year term and its published management plan guides restoration and research activities in the bay.

Figure 1: Fidalgo Bay, Skagit County, WA. Including boundary area of Aquatic Reserve.

Methods

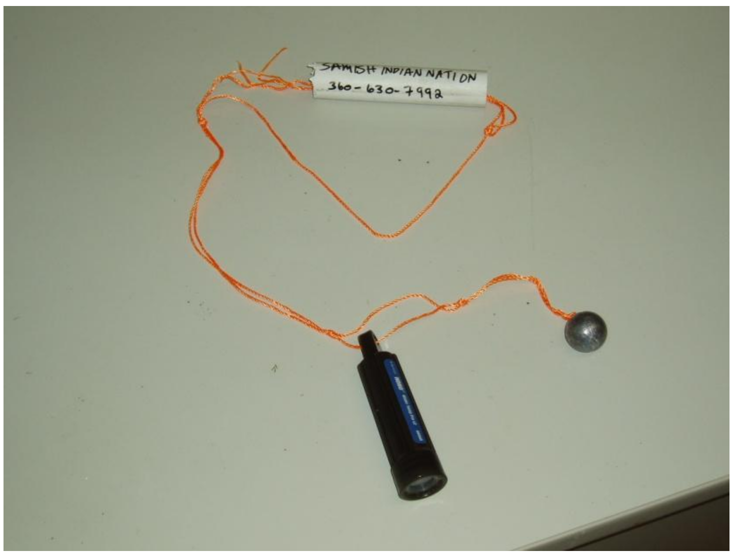
During the spring of 2008, the intertidal zone in front of the RV Park was explored via kayak in order to find areas that were suitable for deployment of sensors. Suitable deployment sites included areas of thick eel grass coverage, thin eelgrass coverage and areas with no eelgrass coverage within a circle of approximately 100 foot diameter. Three such areas were selected and mapped using GPS (Figure 2).

Figure 2: Deployment areas for continuous temperature monitors in Fidalgo Bay, Skagit County, WA.



We used Onset Hobo continuous temperature monitors that had been calibrated in both a room temperature bath as well as a zero degree ice bath to insure that the sensors were reading accurately prior to deployment. They were then assembled in a sensor package that consisted of the datalogger, a piece of PVC pipe with contact information written on it, a weight to keep the sensor in place, and a bobber to allow for easy sighting of sensor package in eelgrass (Figure 3). During deployment, the location of each sensor was marked with a 5 foot piece of PVC pipe so that at low tides, they were clearly visible.

Figure 3: assembled sensor package prior to deployment. A fishing bobber was added to enhance visibility in eelgrass beds.



Sensor packages were programmed to take hourly readings and deployed in three separate areas. Sensors were arranged in a "+" shape, with one sensor deployed centrally and the others arrayed around it with two parallel to the shore on either side, one out to sea, and one inshore of the central point. In each group, sensors were deployed in areas of thick eelgrass, thin eelgrass and no eelgrass. In addition, one sensor was deployed in the deep water channel under the Tommy Thompson Trail anchored to a piling that supports the bridge over Fidalgo Bay.

Sensors were deployed on 6/30/2008 in the eelgrass bed groups (3) and the deep water sensor was deployed on 7/15/08 anchored in a PVC housing to a piling along the bridge trestle of the Tommy Thompson Trail. Each sensor's location was recorded using a Trimble GPS. Sensors were downloaded approximately twice per month as tides allowed access to the sensor packages. At each intermediate download, the sensors were cleaned of marine growth and debris prior to redeployment in their discrete locations. All sensors with the exception of the deep water channel were recovered by 2/3/2009. Unfortunately, the sensor deployed on the bridge was lost when its PVC housing detached during a winter storm. All sensors were audited on 3/20/2009 in a room temperature and ice bath and found to be working accurately post deployment.

Results

Data analysis was conducted using *Aquarius™* software from Aquatic Informatics of Vancouver, BC. Canada. This software is adept at looking at time series data and performing graphing and statistical analysis of the large data set collected during the course of this study.

Our first layer of analysis was to look at the variation between sensors within a single group. In this way, we could analyze whether sensors deployed in eelgrass beds showed a different temperature regime than those deployed in thin or no eelgrass. In each of the three groups, sensor data indicated very little difference in temperature regime inside and outside of eelgrass beds. Group 1 did not show as clean of a pattern. We suspect that this is due to the fact that sensors in this group were in the shallowest water and there were several times when some of the sensors were exposed. This has been confirmed by comparison to local ambient air temperature data and tide comparisons to be discussed later.

Figure 4: Group 1 sensor data comparison (raw hourly data sets).

Figure 5: Group 2 sensor data comparison (raw hourly data sets).

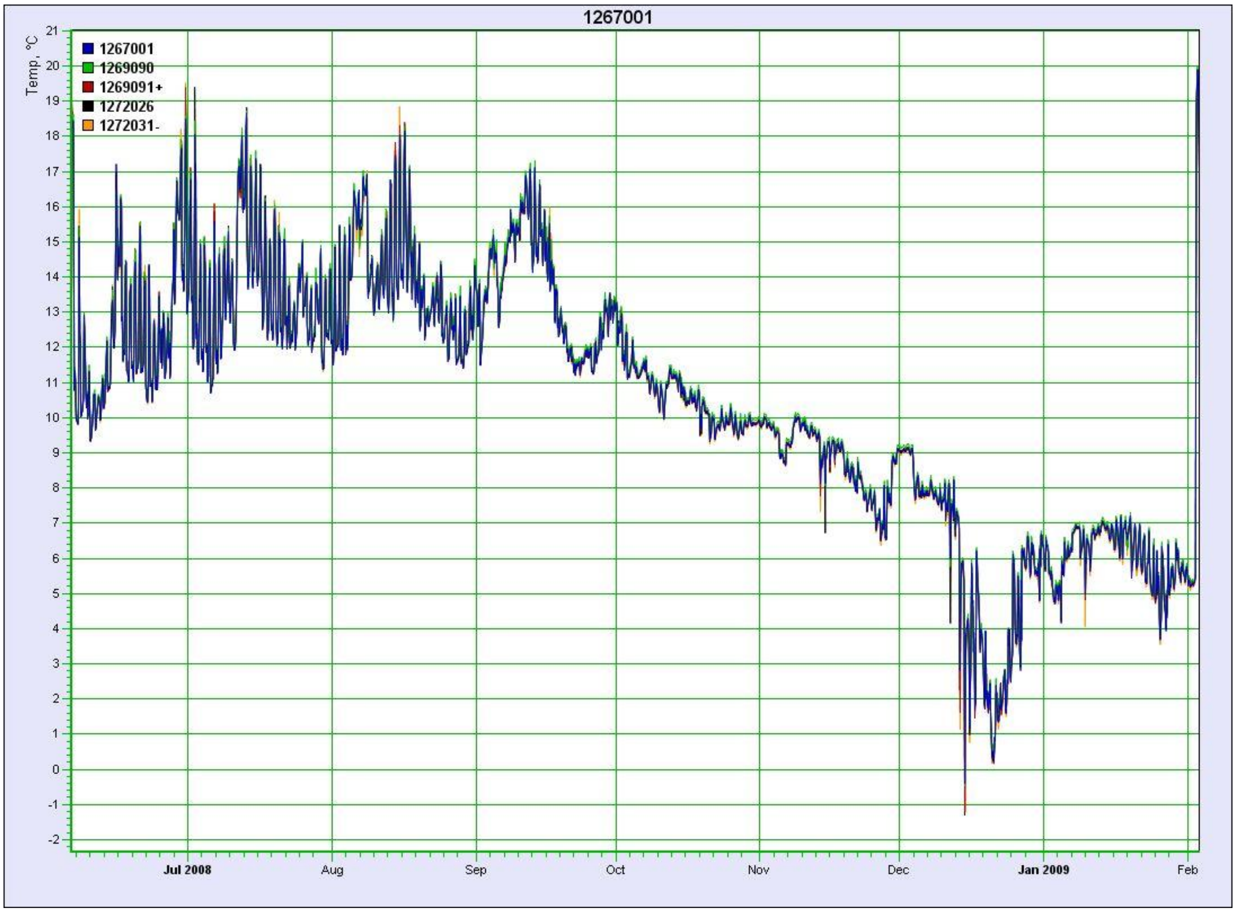
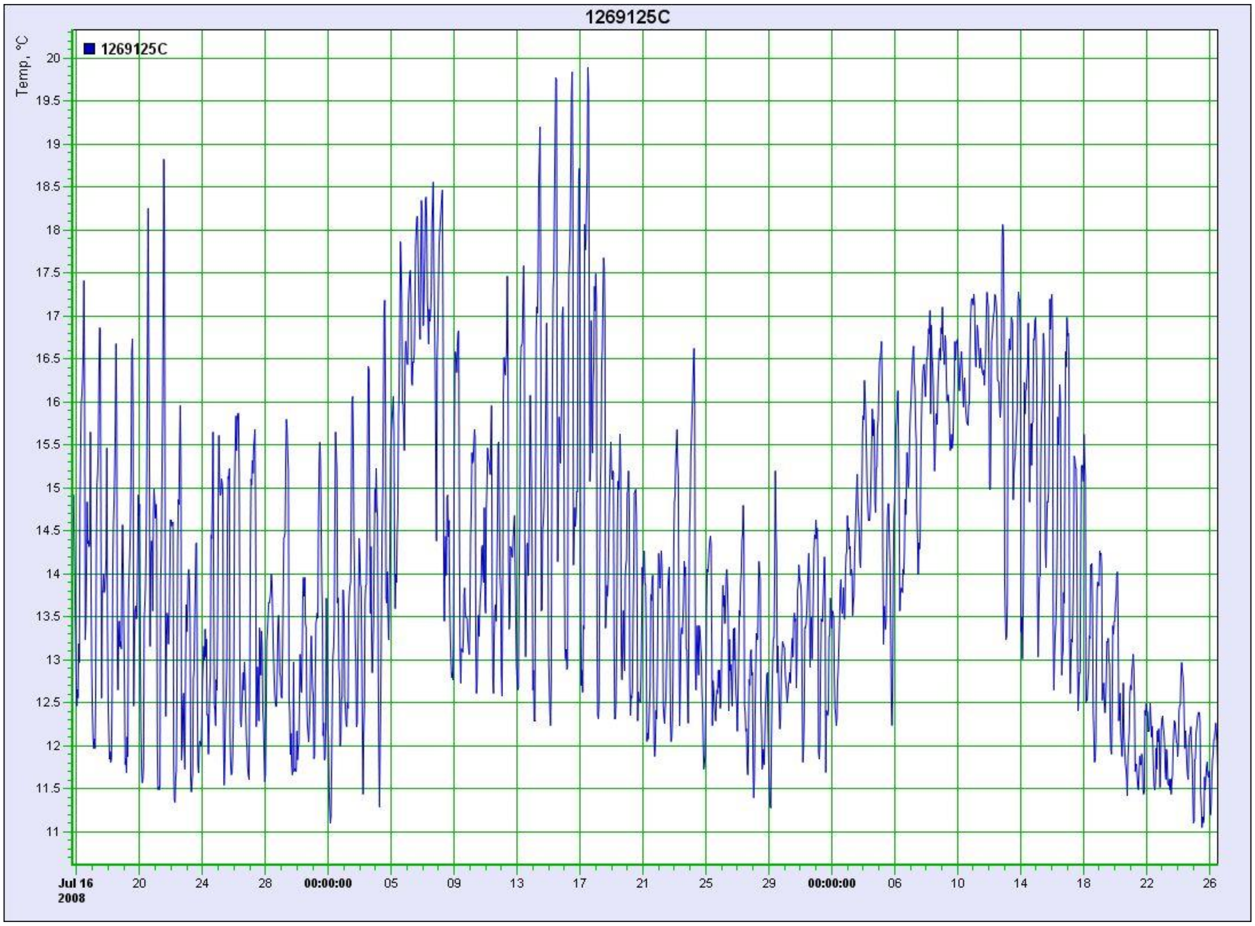


Figure 6: Group 3 sensor data comparison (raw hourly data sets).

Figure 7: Causeway Temperature data. This sensor was lost mid study in a storm event when its PVC housing detached from the piling it was anchored to and thus has a shorter duration of data.



With the sensors in a single group reading such similar temperatures, regardless of eelgrass placement or not, we decided to average the sensors in each group, giving an area temperature for additional data analysis. This means that for the purposes of temperature analysis in comparison to Washington State standards, the five sensors within a group were treated as replicates for that area.

Statistics for the averaged group sensors are as follows:

Table 1: statistical summary of temperature data over entire deployment period as indicated

	Group 1 (6/6/08-2/3/09)	Group 2 (6/6/08-2/3/09)	Group 3 (6/6/08-2/3/09)	Causeway (7/15/08-9/26/08)	Air Temp (6/6/08-2/4/09)
Min Temp °C	-2.966	-0.88	0.732	11.053	-10.08
Max Temp °C	21.809	19.893	18.012	19.888	26.3
Mean Temp °C	10.639	10.517	10.508	14.124	10.383
# of Hourly Samples (N)	5820	5820	5820	1748	5856

Table 2: statistical summary of temperature data over summer heat season (6/6/08-9/30/08).

	Group 1 (6/6/08-9/30/08)	Group 2 (6/6/08-9/30/08)	Group 3 (6/6/08-9/30/08)	Causeway (7/15/08-9/26/08)	Air Temp (6/6/08-9/30/08)
Min Temp °C	9.45	9.371	9.445	11.053	6.686
Max Temp °C	21.809	18.909	18.012	19.888	26.3
Mean Temp °C	13.719	13.415	13.394	14.124	14.73
# of Hourly Samples (N)	2807	2807	2807	1748	2711

We then created a curve that represented the daily maximum temperature for each group to compare to the "excellent" state standard assigned to waters in Fidalgo Bay by the State of Washington. For marine waters, to meet "excellent" designation, the daily maximum temperature cannot exceed 16°C.

We also needed to determine if temperatures in excess of 16°C were caused at low tides due to exposure of the sensor to ambient air. To do this, ambient air temperature data was collected from the Samish Indian Nation's weather station located on Weaverling Spit and within ¾ of a mile from the farthest sensors. The following graphs depict the daily maximum group average temperatures to the daily maximum ambient air temperature with flags located where the daily maximum water temperature exceeds 16°C.

Figure 8: Group 1 daily maximum water temperature compared to daily maximum air temperature. Flags are located where the daily maximum water temperature exceeds Washington State standard of 16°C.

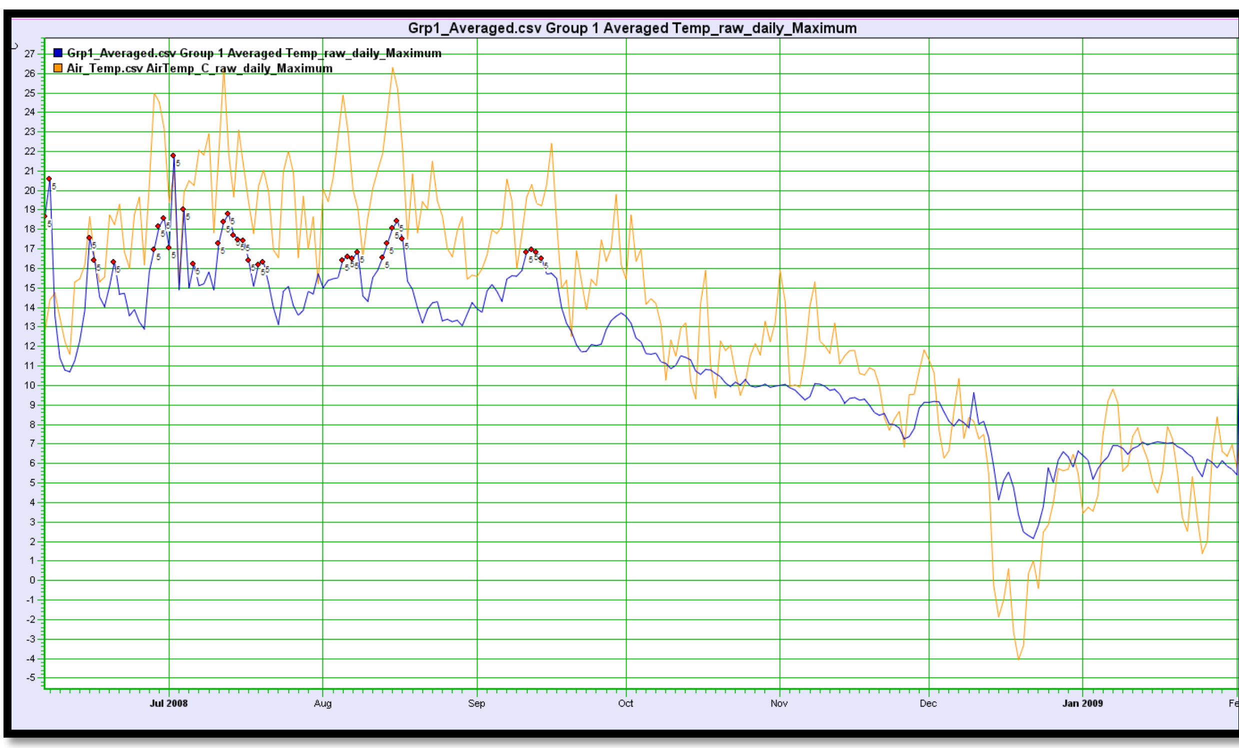


Figure 9: Group 2 daily maximum water temperature compared to daily maximum air temperature. Flags are located where the daily maximum water temperature exceeds Washington State standard of 16°C.

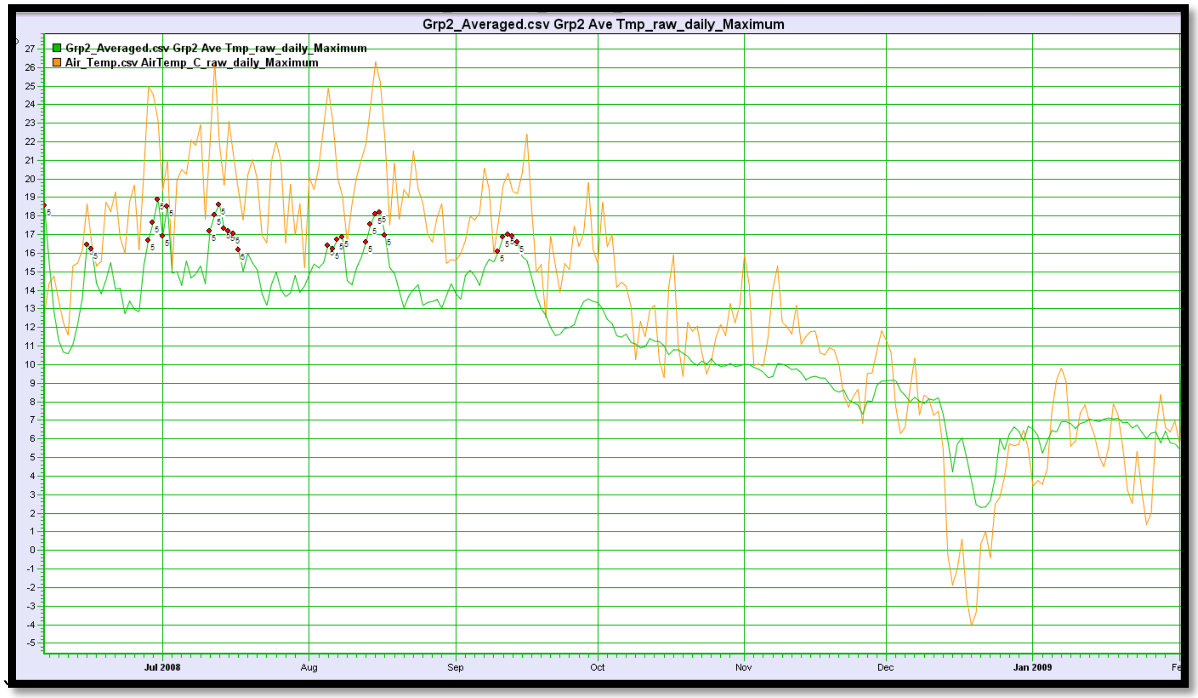


Figure 10: Group 3 daily maximum water temperature compared to daily maximum air temperature. Flags are located where the daily maximum water temperature exceeds Washington State standard of 16°C.

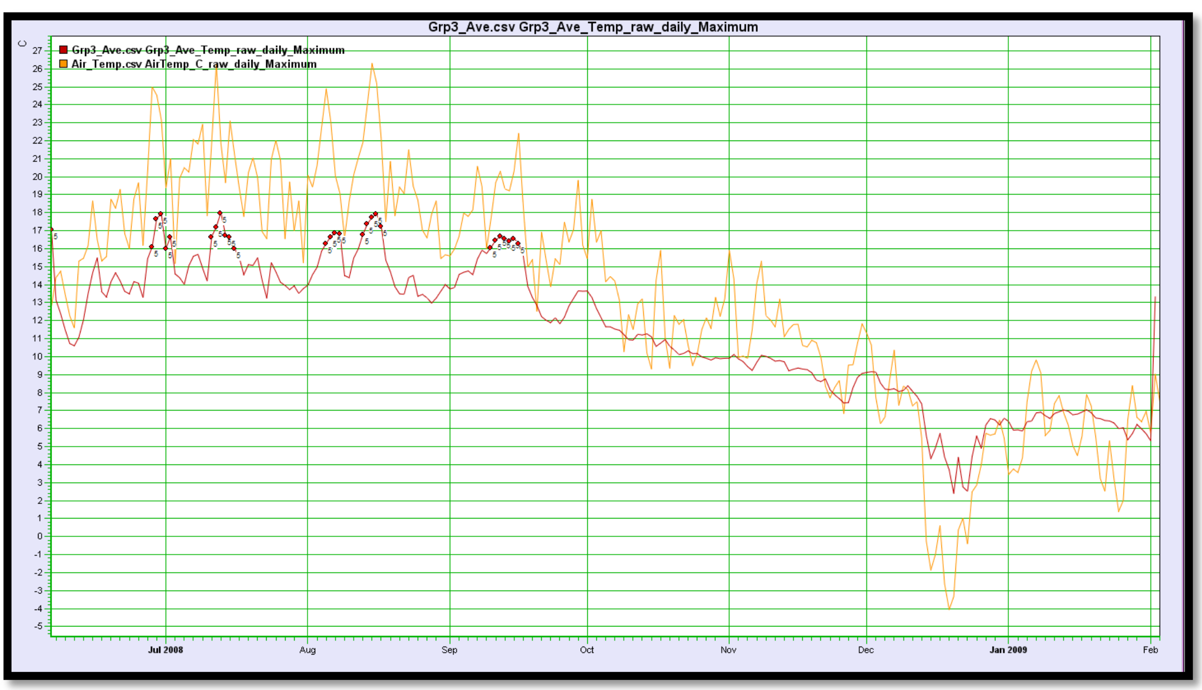
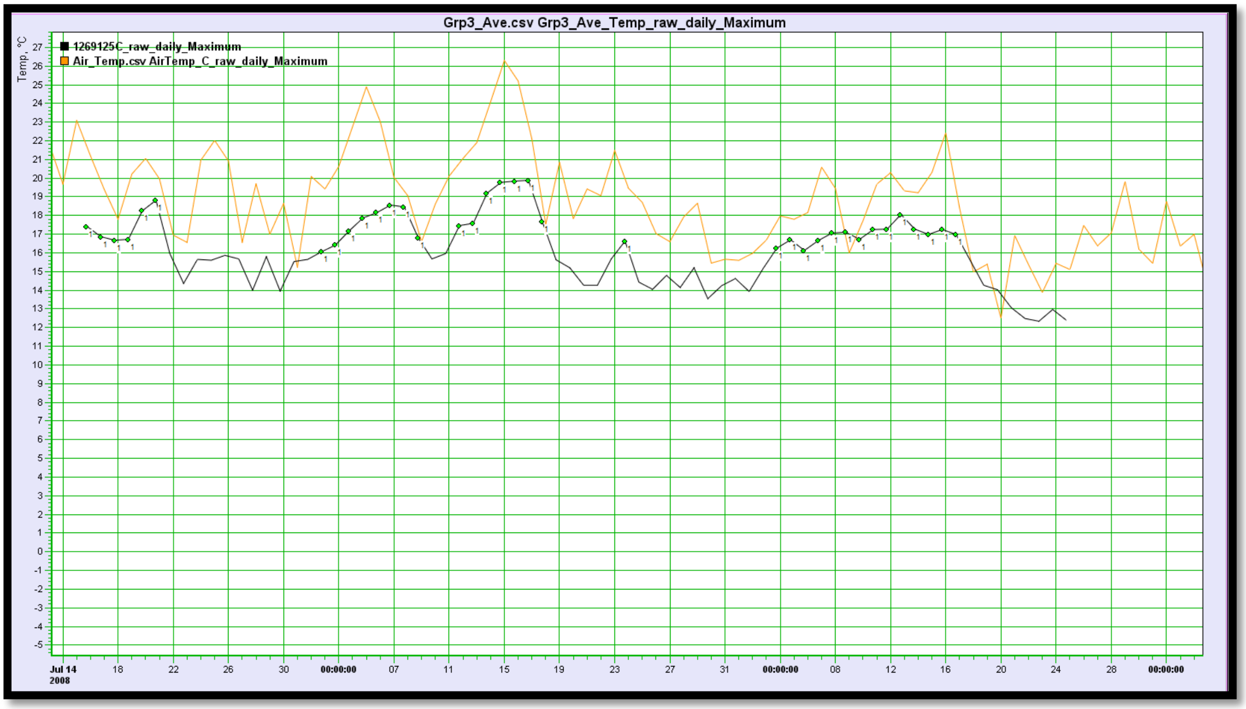


Figure 11: Causeway sensor daily maximum water temperature compared to daily maximum air temperature. Flags are located where the daily maximum water temperature exceeds Washington State standard of 16°C.



Washington State Standard Comparison Results

Group 1 recorded a total of 34 days where the daily maximum water temperature exceeded the Washington State Standard of 16°C during the summer warm period from 6/6/08-9/30/08. There was a period of 7 days in a row where daily high standards were exceeded in July. This was within a period where 9 out of 10 consecutive days were above state temperature thresholds. There were also 5 consecutive day violations in the end of June into July and again in August and a 4 consecutive day violation in September.

Group 2 recorded a total of 29 days where the daily maximum water temperature exceeded Washington State Standards between 6/6/08-9/30/08. This included a 5 consecutive day violation during the end of June into July, a 7 consecutive day violation in mid July, two separate 4 consecutive day violations in August and one 5 consecutive day violation in September.

Group 3 recorded 28 days where the daily maximum water temperature exceeded Washington State Standards between 6/6/08-9/30/08. This included a 6 consecutive day violation in the end of June into

July, a 6 consecutive day violation in mid July , a 5 consecutive day violation and a 4 consecutive day violation in August (part of a 9 out of 13 consecutive days above state standards), and a 7 consecutive day violation in September.

The deep water causeway sensor recorded 36 days out of only a 70 day deployment where the daily maximum water temperature exceeded Washington State Standards. This included a 5 consecutive day violation in July, an 8 consecutive day violation and a 7 consecutive day violation in August (totaling 15 out of 17 consecutive days), and a 14 consecutive day violation in September.

Conclusions

During this initial year of deployment, no significant differences in temperature were observed between deployments within eelgrass and areas that were open without eelgrass. Group 1 did not show as clear of a relationship due to the fact that some of the sensors in that group were exposed during very low summer tides. This was confirmed via comparison to local ambient air temperature from our weather station on Weaverling Spit located at most several hundred yards away from the sensors. In addition, times where some of the Group 1 sensors read temperature equal to or greater than the ambient air temperatures coincided with low tide as read from local tide charts.

All groups of sensors including the deep water causeway probe showed violations in Washington State's Water Quality Standards during the summer warm period from June through September. Each group of sensors recorded at least one period where the daily maximum was above the 16°C standard for at least 7 consecutive days. The deep water causeway probe recorded a 14 consecutive day violation in September despite being deployed in the deepwater channel under the causeway.

Discussion

While the Washington State Water Quality Standards classify Padilla and Fidalgo Bay as "excellent" and therefore subject to meeting the 16° C temperature standard, there is an important aspect of the rule that bears discussion. The actual verbage from the State Water Quality Standards is as follows:

Table 210 (1)(c) Aquatic Life Temperature Criteria in Marine Water

Category	***Highest 1-DMax***
Extraordinary quality	*13°C (55.4°F)*
Excellent quality	*16°C (60.8°F)*
Good quality	*19°C (66.2°F)*

Fair quality	*22°C (71.6°F)*

i. When a water body's temperature is warmer than the criteria in Table 210 (1)(c) (or within 0.3°C (0.54°F) of the criteria) and that condition is due to natural conditions, then human actions considered cumulatively may not cause the 7-DADMax temperature of that water body to increase more than 0.3°C (0.54°F).

ii. When the natural condition of the water is cooler than the criteria in Table 210 (1)(c), the allowable rate of warming up to, but not exceeding, the numeric criteria from human actions is restricted as follows:

A. Incremental temperature increases resulting from individual point source activities must not, at any time, exceed 12/(T-2) as measured at the edge of a mixing zone boundary (where "T" represents the background temperature as measured at a point or points unaffected by the discharge and representative of the highest ambient water temperature in the vicinity of the discharge).

B. Incremental temperature increases resulting from the combined effect of all nonpoint source activities in the water body must not, at any time, exceed 2.8°C (5.04°F).

iii. Temperatures are not to exceed the criteria at a probability frequency of more than once every ten years on average.

iv. Temperature measurements should be taken to represent the dominant aquatic habitat of the monitoring site. This typically means samples should not be taken from shallow stagnant backwater areas, within isolated thermal refuges, at the surface, or at the water's edge.

v. The department will incorporate the following guidelines on preventing acute lethality and barriers to migration of salmonids into determinations of compliance with the narrative requirements for use protection established in this chapter (e.g., WAC 173-201A-310(1), 173-201A-400(4), and 173-201A-410 (1)(c)). The following site-level considerations do not, however, override the temperature criteria established for waters in subsection (1)(c) of this subsection or WAC 173-201A-612:

A. Moderately acclimated (16-20°C, or 60.8-68°F) adult and juvenile salmonids will generally be protected from acute lethality by discrete human actions maintaining the 7-DADMax temperature at or below 22°C (71.6°F) and the 1-DMax temperature at or below 23°C (73.4°F).

B. Lethality to developing fish embryos can be expected to occur at a 1-DMax temperature greater than 17.5°C (63.5°F).

C. To protect aquatic organisms, discharge plume temperatures must be maintained such that fish could not be entrained (based on plume time of travel) for more than two seconds at temperatures above 33°C (91.4°F) to avoid creating areas that will cause near instantaneous lethality. (D) Barriers to adult salmonid migration are assumed to exist any time the 1-DMax temperature is greater than 22°C (71.6°F) and the adjacent downstream water temperatures are 3°C (5.4°F) or more cooler.

vi. Nothing in this chapter shall be interpreted to prohibit the establishment of effluent limitations for the control of the thermal component of any discharge in accordance with 33 U.S.C. 1326 (commonly known as section 316 of the Clean Water Act).

The two areas highlighted could certainly be deemed to affect our study. First, at low tide, all sensors are in water often less than 1 foot deep in the tidal flats where the eelgrass is located. In the case of the shallowest (Group 1), at least two of the sensors were exposed for brief periods during very low tides. Tides, of course, are natural so the temperature violations observed could be deemed "due to natural conditions." Section iv could also be applicable in that we are monitoring a shallow embayment, although we would not characterize it as "stagnant" or generally near the water's edge. Since we are monitoring tidal areas, sensors were placed in areas that "represent the dominant aquatic habitat." With no standard depth for monitoring defined in the state standards, there is some question as to what the standardized placement of temperature monitors should be in a study like this. Additional thought will be undertaken to adjust the placement of sensors during subsequent deployments.

For the purpose of analysis, all of the sensors within Group 2 and Group 3, as well as the deep water causeway sensor, remained submerged throughout the entire study. Therefore, there is some concern that there are many consecutive days where the state temperature standard was not met. More analysis will be needed to determine the length of time per day that the temperatures are in excess of 16°C and what possible effects that could have on the eelgrass habitat and its myriad of inhabitants.

Of particular interest is that the deepwater causeway sensor recorded the most days above state standards, as well as the largest number of consecutive day violations at 14 days. This is particularly interesting because the sensor was deployed in a deepwater channel of the bay and maintained a depth of at least 4 feet throughout its seventy day deployment during the summer. In trying to explain how this could occur, we turned to the characteristics of Fidalgo Bay south of the causeway deployment. The area of the bay south of the causeway is some of the shallowest waters in Fidalgo Bay. During very low summer tides, nearly the entire area empties out, leaving vast mudflats exposed until the tide returns. On the outgoing tide, this water is concentrated and flows out through the channel where the sensor was deployed. Our theory is that the waters of the southern lobe of the bay reach shallow temperatures above the state standard, and then flow out past the sensor into the deeper areas of the bay during the outgoing tide. This could explain why temperature violations occurred in such numbers and durations as observed in the data.

Areas of Future Study

At the time this report was written, we have redeployed temperature sensors in Fidalgo Bay for the second year of our monitoring effort. The following adjustments have been made to our deployment locations:

- Only 5 sensors in total have been deployed this year. This adjustment was made in light of the insignificant differences in temperatures observed in open versus eelgrass covered areas. 4 sensors have been deployed at the deepwater edge of the eelgrass beds to insure that all sensors remain submerged during very low summer tides. One sensor has been anchored to a buoy placed in the middle of the deepwater channel farther out to sea from the previous causeway deployment, at a depth of approximately six feet.
- Sensors were deployed earlier this year to insure that we start the study during cooler times. This is an adjustment made because we did record daily maximum temperatures in excess of 16°C on the first day of deployment last year. All sensors were deployed on May 8^{th} 2009.
- We plan to retrieve sensors earlier this year, most likely by early to mid October. We did not experience high water temperatures after October first last year and by November, winter tides are such that sensor recovery becomes difficult.

This study will hopefully continue to gather baseline temperature data for current conditions in Fidalgo Bay. Data can be immediately used to learn more about the temperature regime in the bay and any deleterious effects that high temperatures in excess of state standards may have on biota and plant life in the bay. Over time, enough data will allow for local temperature trend analysis and local information that could be utilized in climate change modeling.

References

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