The use of low cost "iButton" Temperature Logger Arrays to Generate High Spatial Resolution Tidal Inundation Regime Data

Report on CICEET grant research in coordination with:
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Abstract

Loss of wetlands within Oregon has led to strong interest in restoring wetlands that once existed. Restoration practitioners are currently using knowledge they have gained from many years of working with wetlands to design and carry out restoration projects. There is much variability between tidal wetlands within coastal Oregon and a lack of reference data on least disturbed wetlands. Scrub-shrub, emergent, and spruce forested wetlands are the major types of tidal wetlands in Oregon that wetlands practitioners and landowners are working to restore. Within scrub-shrub, emergent, and spruce forested wetlands hydrology place a large roll in the characteristics of the wetland. Using Thermochron iButtons this study attempts to see if tidal inundation regimes can be determined based on temperature changes on the wetland surface. Using the iButton temperature data in conjunction with GPS derived elevations of the iButtons/wetland surface the tidal inundation patterns can be measured. The iButtons are low cost temperature sensors, which will make it easier and more affordable for watershed councils to be able to conduct this type of study with higher spatial resolution than tide gauges allow for. The information from this study will be put into a reference data base open to the public in the hope that it will be used to help design restoration projects and help determine success of the project when compared to reference data from a similar type of wetland.

Introduction

Wetlands are lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface (Cowardin 1979). Wetlands vary due to regional and local differences in soils, topography, climate, hydrology, water chemistry, vegetation, and other factors, including human disturbance. Wetlands are found from the tundra to the tropics and on every continent except Antarctica.

For regulatory purposes under the Clean Water Act, in the United States, the term wetlands means "those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas."

Tidal wetlands are those wetlands that are not only influenced by the tides, but also that have salinity greater than .5 parts per thousand (ppt) (Adamus 2005). Tidal wetlands are areas that are periodically inundated by tidal waters, typically daily (in the case of low marsh) or once or twice a month during spring tides, but at least annually. Tidal wetlands include emergent, scrub-shrub, and forested wetland types (Brophy 2007). In Oregon estuaries play a vital role in the ecological and economic health of the state. Oregon's tidal wetlands are valued for their capacity to passively modify runoff before it reaches productive coastal waters, as well as for their key role in supporting salmon and other marine resources. People use estuaries for recreation and for commercial endeavors.

Tidal wetlands have been highly impacted by human activities. In Oregon, the estimates for the extent of tidal wetland losses vary. Based on soil type, current land cover, and topography, between 20,000 (Good 2000) and 45,000 (Scranton 2004) acres have been converted, excluding conversions in the Columbia Estuary. On a coastwide basis the amount of wetlands lost are approximately two-thirds of the pre-1850's acreage of tidal marsh. The majority of tidal marsh has been converted to agricultural land. Aside from conversion to agricultural land humans selectively harvest wetland plants and animals, and introduce nonnative organism, some being pest species. Humans dredge navigation channels in estuaries, build jetties, fill tidelands, dike tidal marshes, channelize streams, log and drain swamps, build impervious surfaces, release water contaminants, and more (Brophy 2007). Most times the alteration done to estuaries/wetlands has economic benefit, but has adverse effects to the natural working state of the wetland. The conversion of wetlands varied greatly with some estuaries losing over 90% of their original tidal marsh acreage and others losing none.

The losses of Oregon's tidal wetlands have led to strong interest in restoration of tidal wetlands, but many projects fail or cannot be evaluated, in part because of a lack of reference conditions datasets from least disturbed sites to guide restoration design, evaluation, and adaptive management. This CICEET project is an attempt to provide reference conditions datasets to help improve the success rate of restoration projects.

This study attempts to more accurately determine the tidal inundation regimes of 6 least disturbed tidal wetlands on the Oregon coast. In the past tidal inundation has been estimated through visual observations or using tide gauges. Depending on water levels on the wetland and the type of wetland it can be difficult and costly to collect visual observations regarding tide levels and inundation periods through visual observation. Tide gauges are often not right on a wetland and so the hydrological data for wetlands near a given tide gauge are broad estimates of what the inundation regime of the wetland may be.

This project determines tidal inundation of the 6 wetlands based on temperature change using a new technology called iButtons.

iButton Background

The Thermochron iButton is a thermometer and realtime clock encased in a stainless steel housing 17mm in diameter, 6mm thick and weighing approximately 3g. Recordings taken by the iButton are at a user defined rate and stored in the form of temperature values an as a histogram (number of readings at a certain temperature). Previously iButtons have not been applied to measure tidal inundation, but they have been used in many different applications.

For example, high resolution Thermochron iButtons are being used in the Mediterranean Sea to monitor the environment of the Mediterranean's *Posidonia Oceanica*. The iButton was chosen in this instance because of its ability to measure and store temperature without the need of an external wire. In a recent research study sponsored by the Innovative Pavement Research Foundation, the Transtec Group installed Thermochron iButtons into airfield pavements at the Des Moines International Airport. Transtec Group was using the iButtons to attempt to monitor the temperature history of fresh concrete during construction. This history, or maturity, can be used to accurately determine concrete strength allowing structures such as pavements, buildings, and bridges to be constructed more quickly. In a similar study conducted by the Texas Department of Transportation beginning in 1999 Thermochron iButtons were used to measure pavement temperatures while maturing.

In tropical tropical countries food storage and cost to monitor the temperatures within food storage structures can be expensive.   A study in Australia tested the use of Thermochron iButtons for monitoring temperatures in food storage devices. The Thermochron iButton provided a low cost solution to monitor food temperatures in tropical climates. Its small size means that it is easily placed in any package and its stainless steel construction has helped it survive the rough demands placed upon it. It is now possible to prove that all food shipments are correctly handled and that the food is stored and processed at correct temperatures according to international standards.

iButton software called KOOLTRAK's Thermochron software is also used worldwide by different pharmaceutical companies. One of KOOLTRAK's largest customers is VITA 34 who are involved in the individual storage of umbilical cord blood. Umbilical cord blood contains a high concentration of stem cells that require being kept at constant temperature while being transported. For this reason VITA has developed a special transport container to place the blood in during transport. The containers are also equipped with Thermochron iButtons that electronically record the container's temperature during the transportation of umbilical cord blood. If there are deviations that occur outside the temperature range needed for maximum stem cell utilization a quality control investigations are done.

Although none of the above examples are exactly what this project is trying to accomplish with the use of Thermochron iButtons, they are examples that show iButtons can be used in many different applications with high success.

Wetlands Background

With an increasing emphasis on restoration, ecosystem sustainability, and adaptive management, the development of "performance standards" for ecosystems could provide a base for judging the success of restoration efforts and how effective those efforts were at offsetting unavoidable impacts. It is argued in Brinson et al (1996) that reference wetlands should be central to the development of standards against which restoration efforts and impacts to wetlands should be assessed. In the United States, wetland regulations that deal with mitigations of damages or losses to wetlands operate within a combination of federal, state and local regulatory programs. The most well known and far-reaching is Section 404 of the Federal Clean Water Act (CWA) that was added in 1972, as an amendment to the Federal Water Pollution Control Act (FWPCA) (Kalo, et al, 2002). Section 404 has the goal of maintaining and improving the chemical, physical and biological integrity of the Nations' waters. Section 404 states that, "before a wetland can be filled, drained or otherwise degraded, the landowner must obtain a permit for the U.S. Army Corps of Engineers (CORPS)." Under §404, if the project is approved, it may be contingent on restoring, enhancing or creating wetlands to compensate for any unavoidable loss in wetland area and function. The goals of wetland restoration, creation, and enhancement are to lessen and/or reverse losses of wetlands and to reestablish natural hydrology, geochemical, and ecological processes that we have associated with various "functions" (Simenstad, et al. 1996).

At this time wetland restoration and creation are relatively new fields. Few engineers are trained in ecology and few ecologists have any experience in engineering methods. Consultants, scientists, engineers and landscape architects can and do claim to be experts with little experience or little knowledge of wetland ecology. There are no certification standards for individuals involved in wetland creation and restoration, so projects are often carried out by organizations and individuals not well versed in wetlands ecology. For this reason, a high number of “failures” mitigating wetlands can be attributed to a lack of understanding of the first principles of wetland science.

Due to this lack of knowledge, it would greatly benefit wetlands restoration and mitigation projects to have reference wetlands. Reference wetlands are sites within a specified geographic region that are chosen for the purposes of functional assessment, restoration design, evaluation of restoration effectiveness, and adaptive management of restoration sites. Reference wetlands for purposes of functional assessment generally include the known variation of a group or class of wetlands, including natural and disturbance-mediated variations. Reference standards represent the conditions exhibited by the subset of reference wetlands that mirror the highest level of functioning of the ecosystem across a variety of functions (Brinson 1996).

CICEET Project Goals

This CICEET project has several goals: 1) Test innovative technology for measuring tidal wetland ecosystem drivers; 2) Develop a pilot reference conditions database for those tidal wetland habitat classes that are most Often restored in Oregon, using six pilot study sites; 3) Contribute to regional restoration monitoring guidance; 4) Make the pilot reference conditions database available to restoration practitioners via an online web portal.

Grant funding agency

The funding for this study was provided by The Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET). Working with colleagues nationwide, CICEET develop and demonstrate the most relevant technologies and methods, and help people use these tools to promote clean water and healthy coastal environments nationwide. The CICEET toolkit contains many field ready tools to address a range of environmental challenges along the nation’s coasts.

Reference conditions data sets are lacking for the Pacific Northwest Region in part due to the expense and technical challenges of monitoring key habitat drivers across a large geographic area. To build comprehensive, broad-based reference conditions data sets and achieve successful restoration, scientists and practitioners need cost-efficient, accurate methods and technologies for measuring key physical, structural and biological attributes. Current methods used to measure certain key habitat drivers are either too costly or imprecise for most practitioners.

Overall objectives of CICEET grant

1. Test and develop innovative cost-effective methods for collecting high spatial and temporal resolution data on three primary drivers of tidal wetland structure and function (tidal inundation, groundwater fluctuation, and salinity regime), thereby contributing to NOAA/NCCOS and other national monitoring efforts.

2. Pilot an Oregon contribution to the NERRS/NOAA regional restoration reference site program by collecting data from a network of representative Oregon tidal wetland habitats, using NOAA/NCCOS restoration monitoring guidance.

3. Contribute to NCCOS and NERRS efforts by testing a new internet web portal designed to provide easy access to reference site data and metadata and other relevant monitoring information to restoration practitioners.

Specific objectives of CICEET grant

1. Test and compare the utility of two innovative and cost-effective technologies:

    A) **iButton temperature logger arrays** for generating spatially explicit data on tidal inundation regimes (TIR);

    B) **Multichannel wireless sensor networks** to generate high-resolution, reliable and accurate data on water level (including TIR and groundwater fluctuation), salinity (channel and porewater) and water temperature (channel and porewater).

2. **Reference conditions database:** Establish statistically rigorous baseline datasets for key habitat drivers in a network of high priority least-disturbed tidal wetlands in coastal Oregon, for use by restoration practitioners in improving restoration design, restoration effectiveness monitoring and adaptive management.

3. **Internet-based interactive web portal:** Test and demonstrate a web portal providing restoration practitioners with easy access to reference conditions data and metadata.

4. **Restoration practitioner surveys:** Test and demonstrate methods to solicit practitioner input to prioritize reference habitat classes and to evaluate the web portal.

Field Sites

Site selection was done with the goal of adequately testing innovative methods across the full range of tidal wetland habitat classes. Six highest priority pilot study sites were selected, including one example of scrub-shrub and two examples of forested intertidal or supratidal wetlands. Scrub-shrub and forested tidal wetlands are the habitat classes for which there are currently no reference conditions data for Oregon, and these classes are prioritized for restoration because they have been disproportionately affected by coastal development. Along with scrub-shrub and forested wetlands, least-disturbed emergent (high and low marsh) wetlands were also chosen. Emergent, scrub-shrub, and forested wetlands were also identified during a practitioner survey as the habitat classes most often restored in Oregon (SSNER survey doc).

The wetland types to be studied under the CICEET grant in question are (Carder, L. et al 1979);

1. Emergent (South Slough (Hidden Marsh, photos 1 & 2), Siletz Keys (Photos 3 & 4) and Milport Slough (Photos 5 & 6))
    - Characterized by erect, herbaceous hydrophytes, excluding mosses and lichens.
    - Vegetation present for most of growing season
    - Dominated by perennial plants
    - Includes all water regimes except sub-tidal and irregularly exposed
    - Located in areas with relatively stable climate conditions
    - Maintain same appearance from year to year.

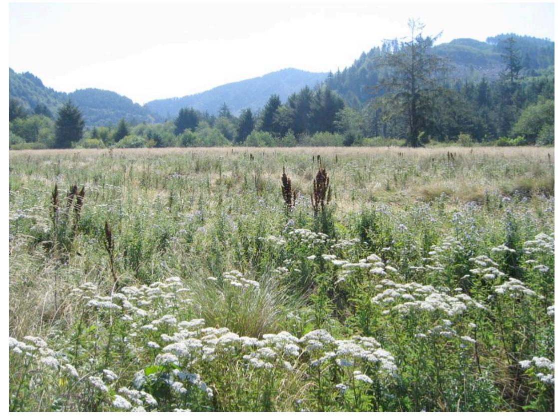
1. Hidden Marsh, Plot 4, July 2007

2. Hidden Marsh, Plot 1, July 2007

3. Siletz Bay Plot 2 June 2007


4. Siletz Bay Mudflat June 2007


5. Milport Slough, HOBO Logger & iButton Post, August 2007


6. Milport Sough August 2007

3. Scrub shrub (Blind Slough (Photos 7 & 8))

- Dominated by woody vegetation less than 6m tall
- Species include true shrubs, young trees and trees or shrubs stunted due to environmental conditions.
- Includes all water regimes except sub-tidal
- Occur only in estuarine and palustrine systems but are one of most wide-spread wetlands


7. Blind Slough May 2007


8. Blind Slough June 2007

4. Forested (Blind Slough and Coal Creek (Photos 9 & 10))

- Characterized by woody vegetation 6m tall or taller.
- Includes all but sub-tidal water regimes
- Most common in the eastern United States and sections of the West coast where moisture is relatively abundant, particularly along rivers and mountains
- Occur in palustrine and estuarine systems
- Normally possesses an overstory of tree, understory of young trees and shrubs and an herbaceous layer.


9. Coal Creek main Channel June 2007


10. Coal Creek June 2007

Objectives

Specific project objective

1. Testing iButton temperature logger arrays for generating spatially explicit data on tidal inundation regimes (TIR).

A) Why iButtons

i. Inexpensive: practitioners could monitor TIR at 20 locations on site, providing superior spatial resolution for about 50% of the cost of placing a single tide gauge ($800-

$1000 each) at each site; or they can achieve very high spatial resolution with 40 iButtons per site for the cost of a single tide gauge.

ii. Has nationwide potential to improve data needed for restoration design, evaluation and adaptive management.

iii. They are small in size, easily mounted to surfaces and detect temperature change allowing for the direct detection of wetland surface inundation at remote sites, a measurement that is not possible using current technology.

Maxim Dallas Thermochron iButtons log temperatures at specified time intervals and store the data for later retrieval. Palm and PC programs can be used to set specifications for logging, start measurements and retrieve results.

Methodology

This CICEET grant provides the first opportunity to test the use of iButton technology in the characterization of tidal inundation regime within the full range of Pacific Northwest tidal wetland habitat classes initial testing of different deployment methods was conducted to establish the best approach for gathering useful data. Two test runs of the iButtons were executed prior to using them in the 6 sites being addressed by the grant. The first trial was in Dixon Creek, Corvallis Oregon, and the second trial was at Yaquina Bay. Once the initial trials were done, the arrays were deployed on the 6 CICEET grant sites.

Dixon Creek Trial

A trial run of the iButtons was set up in Dixon creek to test a waterproofing strategy. Dixon Creek flows north to south through the City of Corvallis, Oregon. The iButtons themselves are not waterproof so it was essential to find a way that they could be made waterproof without distorting their temperature readings. Three waterproofing methods were tested: 1. Water balloons; 2. Caulking; 3. Vacuum sealing. There were two steps to the trial at Dixon Creek: 1. Bench test 2. Field trial in creek.

Bench Test

The in bench test was done using a bowl of water with known temperature encased in water balloons. This was to see if the water balloons insulated the iButtons. Insulation of the iButtons would have caused the iButton temperature values to deviate from the actual temperature of show a lag in registering the correct temperature. First the iButtons were tested reading air temperature with no water balloon over them just to see if they were working. For this test 3 iButtons were used to confirm the results of the test. The 3 iButtons were then put into separate water balloons and the balloons were tied shut. Along with the iButtons a thermometer was placed in the water. At 15 minute intervals, equal to the intervals the iButtons were taking readings at, the temperature of the water was recorded using the thermometer. Once it was determined that the reading of the iButton within the balloon was the same as the measured temperature using a thermometer, the field test was conducted.

Field trial

The Dixon Creek trial involved putting the iButtons into water balloons and tying them inside a 2.5 x 3 inch PVC pipe to see how the balloons held up under real life conditions. To tie the iButtons in the PVC pipe, 2 holes were drilled on the same side of the pipe. Heavy-duty twist ties were then tied around either end of the water balloon, put through the holes in the pipe and then the twist ties were tied together. The main purpose of this trial was not to get useful temperature data, but to see if the water balloons in fact protected the iButtons from getting when over a length of time under harsher conditions than could be simulated by the “water in a bowl” test. There were two iButtons placed out of the water in areas where they were sure not to inundate. Four other buttons were placed within the creek itself. The iButtons within the PVC pipe were anchored down by either a post (in the case of the buttons located out of the water) or attaching the pipe to an immovable object under the surface of the water. To attach the PVC to objects thick metal wire was used. The cable had to be secured and twisted together using pliers. The was also hope that the water levels within the river would fluctuate enough that temperature changes due to iButtons being unsubmerged and then resubmerged would be seen.

Results

Bench Trial

The bench trial showed that the iButtons did in fact record an accurate temperature when put in water balloons and then placed in water. During the in home trial the balloons stayed in tact keeping the iButtons dry. The water balloons producing the desired results in an isolated test led to them being tested under more stressful conditions in Dixon Creek.

Field Trial

The Dixon Creek trial was conducted during the rainy season in Oregon causing there to be no drop in water level. Due to the lack of water level change the iButtons that were placed under water within the creek were always inundated and a change in temperature of the iButtons was not seen. The test did give us valuable information about the use of water balloons under actual study area condition. Three of the water balloons leaked leaving the iButtons wet and the data irretrievable. Even after the iButtons were left to sit for a couple of days to dry out the data could not be retrieved from them. Due to these findings an alternate method for water proofing the iButtons was needed.

Yaquina River Trial (Photos 1&2; see appendix 2)

Set-up

Yaquina River is located just outside of Toledo on the way from Corvallis, Oregon to Newport, Oregon off of route 20 approximately 7 Miles from the Pacific Coast. The Yaquina Bay trial was set up and followed a different protocol than that of Dixon Creek. The Dixon Creek trial was set up to test the success of the waterproofing methods being used in the study. The Yaquina Bay trial was done to help determine, using a small well studied site, how the iButtons should be deployed at the actual project study sites. Two ideas for deployment of the iButtons were being tested. The first was a vertical post with iButtons attached at equal intervals on the post. The second were individual iButtons placed on the wetland surface and within wetland channels. Within the Yaquina site, 9 surface iButtons were set out, 4 iButtons were put in the large channel, leading from the main channel into the wetland, and 6 iButtons were put on 2 vertical posts. The 4 iButtons and the 1 vertical post were placed in the large channel coming off of the Yaquina River were located under the cover of trees. The 9 Surface iButtons were placed in a clearing west from the river. They were put at random locations in an area known to inundate. The second iButton post was placed in a channel within the clearing that the surface iButtons were on.

Prior to deployment, all the iButtons used for the Yaquina River test were vacuum sealed into heavy weight plastic baggies. The vacuum sealing was done using a home vacuum sealer that can be purchased at a local kitchen appliance store. The Vacuum seal method was tested using a bowl of water as in the in bench trials before the Dixon Creek deployment. The iButtons that were put on the surface and within the channel were once again placed in 2.5 x 3 inch PVC pipes. The iButtons were put in PVC casings to; 1) Protect them from solar heat. The purpose of the study was to capture the change in water temperature so the PVC was an attempt to minimize the change in temperature to heating by the sun. 2) Protect the iButtons from damage by animals. The largest worry would be trampling by elk and one of the sites (Coal Creek) is located within an active cow pasture. The iButtons are durable but they are small and if they were to get trampled by a large animal they would be impossible to find. 3) Make them easy to locate. The iButtons are small, putting them in a white PVC casing makes it easier to locate where they are during retrieval. Holes were poked at each ends of the heavy weight plastic baggies outside of the sealed area. Twist ties were fed through the holes in the baggies, through holes in the PVC pipe and then tied. The surface buttons were then attached to tent posts, using heavy-duty metal wire, and were pushed into the ground. The channel iButtons were placed in 2.5 x 3 inch PVC and then attached to solid anchors using strong metal ties. The iButtons on the posts were attached to a 4ft 7/16-inch dowel at equal intervals. Three buttons were place on the posts; the first being 2 inches from the top of the dowel, the middle button at 2 feet from the top, and the third button was at 3ft 10in from the top. Both the bottom and the top iButtons had to be placed 2in from the ends of the dowel to the dowel to be secured in a PVC casing. To attach the iButtons to the dowel two small holes were drilled in the dowel at the above-specified intervals. Holes were again poked through the vacuum-sealed baggies outside of the sealed area. Twist ties were fed through the baggies, the dowel, and then tied together. The dowel was then placed within a 4-foot tall 2.5-inch PVC pipe. The PVC pipes had holes drilled at ½-1 inch intervals the length of them to allow water surface water to enter the tube as it rose. To hold the dowel in place and to prevent rain from entering the PVC casing surrounding the iButton post, covers were put on both ends of the PVC tube. The caps at both the top and bottom ends of the PVC casing had 7/16 holes drilled in them for the dowel to fit into and hold it in place.

Deployment

One of the vertical posts was placed on the sloping side of the largest tidal channel in the study area. Due to the tidal influence and sediment deposits, the channel bottom was not level all the way across. The other vertical post was placed in a smaller channel west from the Yaquina River in the wetland. To keep the iButton posts in place they were fastened to 6ft steel t-posts driven into the ground. The T-posts were pounded into the ground using a post pounder. To secure the PVC post, with the iButtons in it, to the T-post three zip ties were used. The T-posts had hooks/bumps on one side. The zip ties were placed so that they were either directly above or below the hooks (not all 3 in the same location with respect to the hooks) so that the PVC did not shift up and down on the T-post.

This surface iButtons were placed on the wetland surface to attempt to detect overall wetland inundation by the tides. The tent posts that they were attached to were pounded into the ground until the PVC casing that the iButton was in was flush to the ground. Any vegetation was cleared out of the way along the casing to be right on the wetlands surface. Vegetation on wetlands can be thick and if left under the PVC casing would cause the inundation data to be off by couple inches in some cases. Since this project was looking to get actual surface inundation data it was necessary to get the iButtons as close to the surface as possible. The iButtons in the large channel were intended to test whether channel filling could be detected. The vertical iButton posts served several purposes: the lowest button would detect the temperature of water in the channel as it rose; the top button would detect air temperature for comparison, and the middle buttons would allow determination of whether rising inundation could be detected through comparison to the lower and upper button temperatures when all three shared a common air temperature. If a middle button was placed at the same elevation as the wetland surface, duration of wetland surface inundation could then be measured.

Results

Vacuum sealing the iButtons proved to be effective at keeping the iButtons dry while allowing them to record accurate temperatures when tested in the home. The vacuum seal method was then used to protect the iButtons that were deployed for the Yaquina Bay trial.

The Yaquina River trial provided useful information leading to a design change with subsequent deployments. Having a cap on the iButton posts flush with the PVC tube did not allow the hot air to escape causing abnormally high temperature readings. However, to prevent rainwater from getting into the top of the PVC tube there was a need for a cap of some variety over the top. In order to alleviate that issue, a piece of hardware netting was placed over the top of the dowel sticking up out of the PVC tube and bent upward. A large plastic yogurt container was then fitted over the top and fastened to both the hardware netting and the PVC tube with twist ties. This allowed air to escape while protecting the setup from rainwater. Although vacuum sealing the iButtons did work well, this method produced a lot of waste, and made data retrieval awkward since an electric sealer was required to redeploy the iButtons. Each time a person wanted to upload the data from iButtons within vacuum-sealed bags they would have to cut the bags open to get to the iButton. After that a new bag would need to be made for that iButton. For these reasons a new technique was tested on a few of the iButton posts by sealing iButtons with silicone caulk and then putting into mesh sacks. There is a small seal on the iButtons that is not waterproof. The caulking was applied around that seal to prevent leakage. The sacks were made with a pet mesh that was sown into small bags. There was a small opening left in the bags so that it was possible to remove and replace the iButtons in the field without the need for electricity. To prevent the iButton from falling out of the bag the top was folded over and secured with twist ties.

CICEET Sites

After the initial trials, iButtons were deployed at the 6 project sites. Prior to iButton deployment, permanent plots had been established for embedded measurements of vegetation, soils, macroinvertabrates, tidal inundation, groundwater, and salinity. Plots were stratified within relatively homogeneous zones of elevation, soil conditions, tidal inundation and major plant communities (as judged by visual site analysis). At each end of all the plots PVC pipe and a wood post were put in the ground at the center point.

For each site 4 iButton posts and 12 array iButtons were deployed. Two iButton posts were put in channels within or near each of the plots on a site. Two individual iButtons were deployed near the plots, but well above potential inundation, one in direct sun (or the sunniest available location) and in full shade (or the shadiest available location). At Blind Slough, a full shade button was not put in because there was no area within the wetland that would not get inundated. A full sun iButton was not placed at Blind Slough due to lack of availability of sunny locations near plots (the entire site had tall dense vegetation), and sunny locations further from plots were unlikely to provide useful data for comparison to wetland surface iButtons. At Coal Creek, the full sun iButton was placed on a fence post near the road due to lack of full sun areas within the wetland that would be safe from inundation. Placing the iButton near a road on a fence post was not the ideal place, compared to full sun near the plots this iButton would most likely read too high, but it may still be useful for comparison's sake. Two other individual iButtons were placed within the channels, each near an iButton post. The other 4 individual iButtons left per plot were placed at the corners of the 150ft plots 15 feet from the centerline. Once again for the purpose of determining surface inundation the 4 individual buttons that were placed at the corners of the plots were put the PVC encasing the iButtons directly on the surface. In a couple of instances at Milport Slough it was not possible to get the PVC casing all the way to the surface. In those cases height from the surface was measured and recorded. By knowing the distance of the PVC casing above the surface, interpolations can be done at a later date to determine when exactly the surface was inundated.

To assure that the surface iButtons were secure to the ground and would not move, the PVC sleeves were attached to 2ft wooden surveyor's posts, which, are more sturdy and available than tent posts. The surveyor's posts cannot easily be removed from the soil, but over time they will biodegrade and become part of the soil organic matter.

Two holes were drilled in each of the wooden surveyor's posts two inches from the top. The PVC sleeves for the iButtons were attached directly to the surveyor's using twist ties that were fed through the two holes in the PVC through the holes in the posts and then tied. The iButtons were then put into the PVC sleeves by poking holes in the heavy weight plastic vacuum-sealed bags, outside of the seal, and feeding the twist ties through those holes, the holes in the PVC and the posts and then tying them off.

The iButtons were activated to start recording on the day that they were put out on the wetlands. The iButtons were set using the Dallas Semiconductor 1-Wire Driver software package. For the software to register the iButton they had to be put in a DS1402D-DR8 blue dot adaptor. The iButtons have a positive and negative probe on them. When the iButton is inserted in the adaptor a closed circuit is formed and the iButton can be read and programmed. To set the record start time using this software it needed to be done in minutes because the software does not have the ability to be set in real time. To have the iButtons start recording on a certain day the number of minutes from the time that they were being programmed needed to be calculated and then entered. Each of the iButtons was programmed to record at 15-minute intervals and not roll over. The iButtons have the option to roll over which will delete the earlier recordings and continue recording temperatures. If set to not roll over they will stop recording when they are out of space to save the data.

The iButtons were left out on the wetlands for 22 days or 2,047 temperature readings. They were then retrieved from each wetland, the data was uploaded into Microsoft Excel and analyzed. To upload the data each iButton had to be put in the DS1402D-DR blue dot adaptor. The data appeared in the form of a temperature graph. To get the data from the 1-Wire Driver software into excel it first had to exported to clipboard with labels. It was pasted into a text document. The text document could then be imported into excel for analysis.

Results

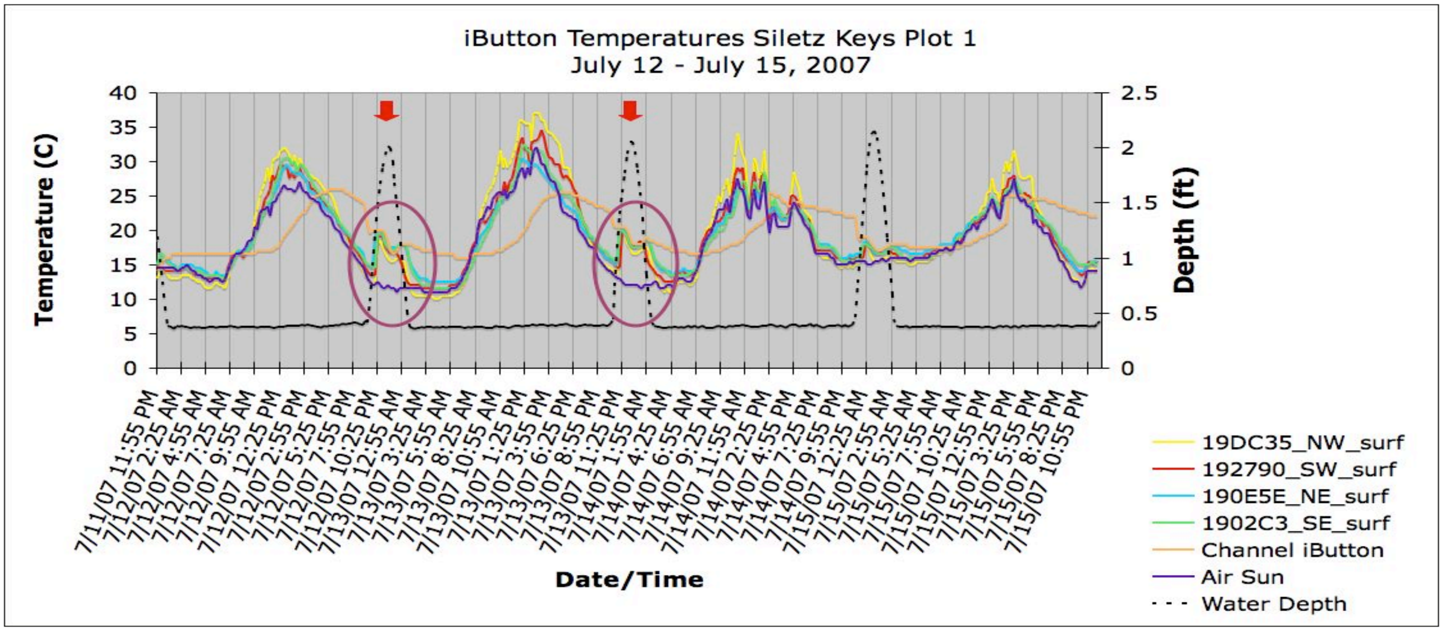
CICEET Sites

As of March 2008 there will only be one season of data. The second recording season was conducted at the end of January 2008, but that data will not be analyzed in time to add to this report. A National Geodetic Service (NGS) team went to each of the project sites to acquire elevations for each of the individual iButtons and the iButton posts. They have not yet completed the analysis of the data they were able to get and they were unable to determine elevation for both Coal Creek and Blind Slough due to lack of GPS signal. They are going attempt to get elevations for the iButtons at both the Coal Creek and Blind Slough sites during leaf off periods when they will more likely to get a satellite signal. For the purpose of this report results from the Siletz Keys and Milport Slough will be shown. Both locations have data that sufficiently show instances of the iButtons performing the desired goals of the project.

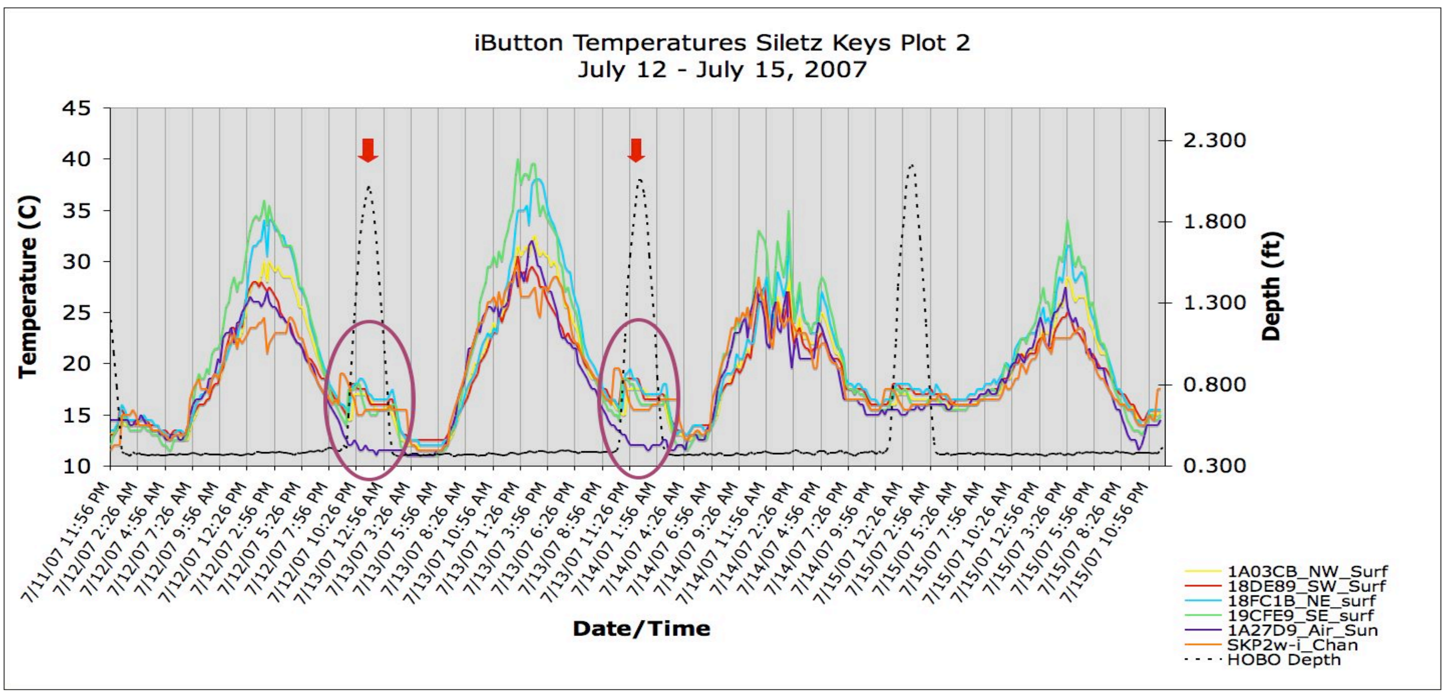
Siletz Keys

To determine if tidal inundation of the iButtons could be seen from temperature change recorded by iButtons, reference data was needed. For reference purposes HOBO data loggers were installed within a channel at the wetland sites at lowest possible elevation. HOBO loggers measure pressure, so when they were inundated with water the pressure on the HOBO increased. Those pressure readings could then be converted to depth in feet giving water depth over the HOBO logger. For the purposes of water depth accuracy and graphical representations an atmospheric pressure correction was done on the HOBO pressure data. According to predicted tide charts from NOAA (National Oceanic and Atmospheric Association) and ODFW (Oregon Department of Fish and Wildlife) July 12th through the 15th was to have the highest tide during the field data collection time for this project. As a result of this knowledge the days of July 12th through the 15th were isolated for the purposes of graphing and showing results.

The data for plots 1 and 2 of the Siletz keys (Graphs 1s & 2s) did show noticeable temperature differences between the air temperature iButton and the surface and channel temperature iButtons during peak high water depths shown by the HOBO logger data for all of the surface iButtons. During times of peak inundation occurring at night the temperatures recorded by the air temperature iButton drop while the temperatures recorded by both the channel and surface temperature iButtons increase along the same curve.

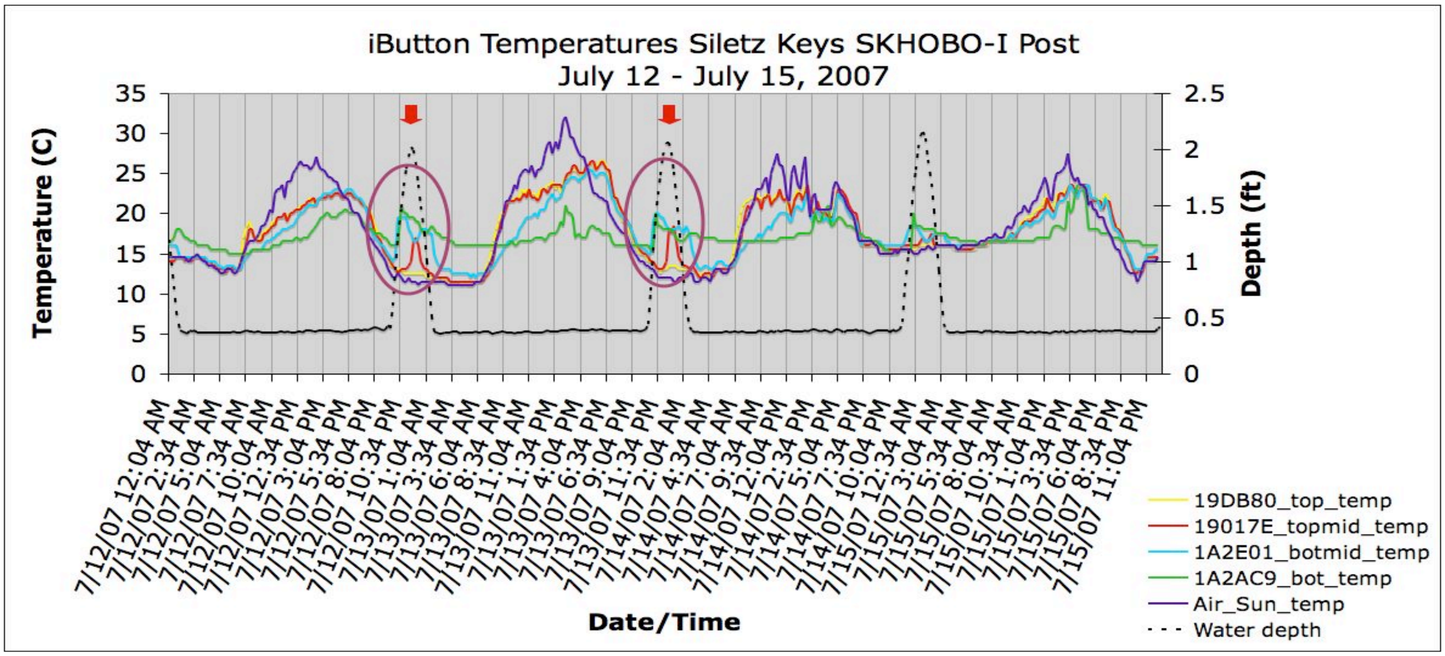


Graph 1s: This graph illustrates the comparison of an inundated (channel) iButton and non-inundated (air) iButton to that of plot 1 surface iButtons. The plot surface iButton curves are represented by the yellow, red, blue and green lines respectively. The orange curve represents a channel iButton within a channel located on the south end of plot 1. The dark purple curve is that of the air temperature iButton located in the sun. The dotted black curve is the Water depth recorded by the HOBO logger. The purple ovals depict the times when the surface button temperatures greatly deviate from that of the air temperatures illustrating possible times of plot 1 surface inundation.

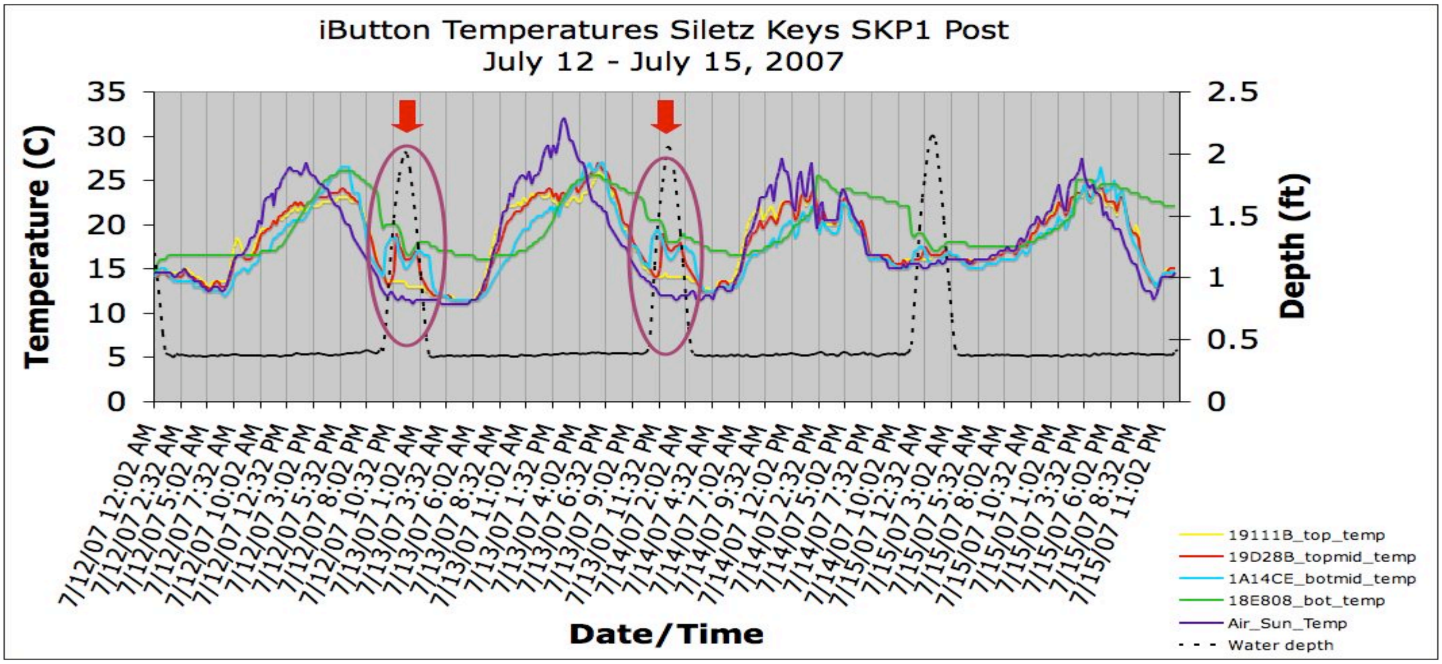


Graph 2s: This graph illustrates the comparison of an inundated (channel) iButton and non-inundated (air) iButton to that of plot 2 surface iButtons. The plot surface iButton curves are represented by the yellow, red, blue and green lines respectively. The orange curve represents a channel iButton within a channel located on the west end of plot 2. The dark purple curve is that of the air temperature iButton located in the sun. The dotted black curve is the Water depth recorded by the HOBO logger. The purple ovals depict the times when the surface button temperatures greatly deviate from that of the air temperatures illustrating possible times of plot 2 surface inundation.

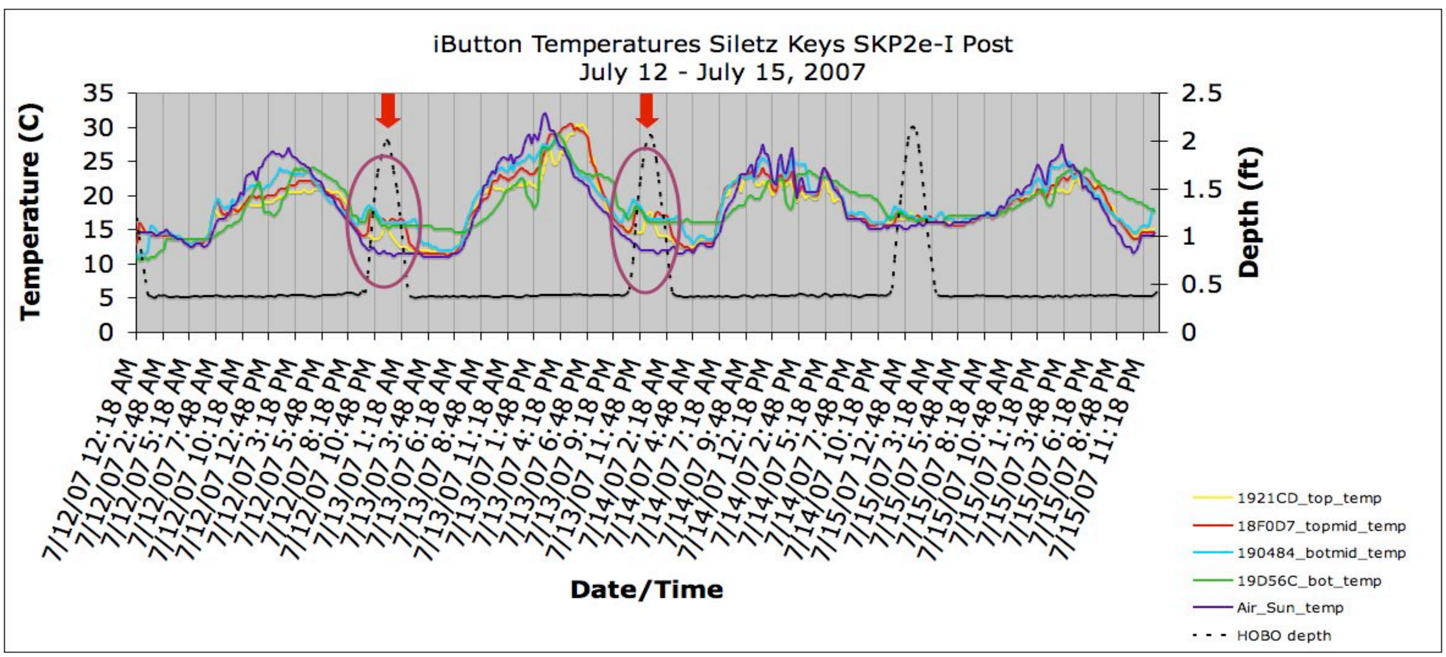
For all of the iButton posts at Siletz Keys there were noticeable differences between the temperature data recorded by the air/top iButton and bottom iButtons on all of the posts (See graphs 3s-6s). The differences were seen during peak water depth periods logged by the HOBO logger located in the Siletz Marsh. Light purple ovals on each of the graphs denote the times when the differences between iButtons are high, during peak depths logged by the HOBO logger.



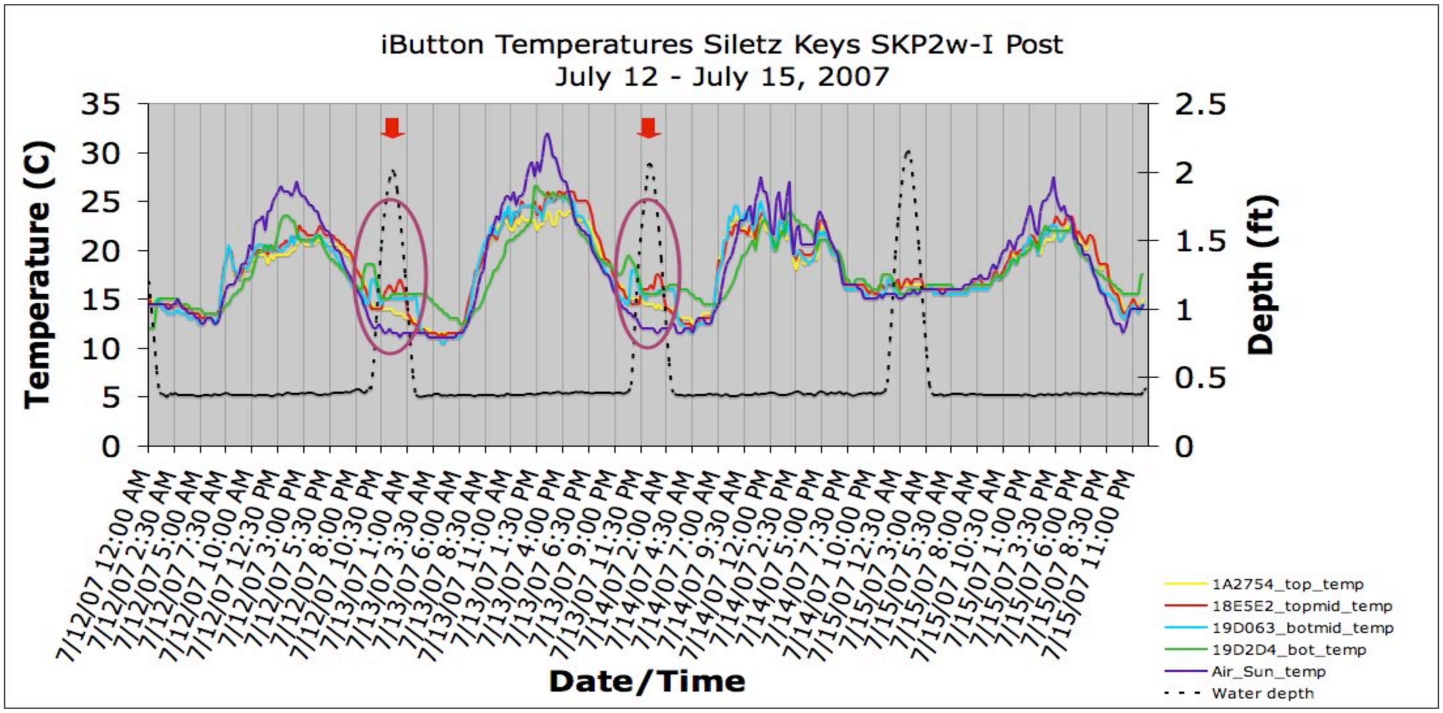
Graph 3s: This graph illustrates the comparison of the SKHOBO vertical post iButtons and non-inundated (air) iButton. From top iButton to bottom curves are represented by the yellow, red, blue and green lines. The dark purple curve is that of the air temperature iButton located in the sun. The dotted black curve is the Water depth recorded by the HOBO logger. The purple ovals depict the times when the post iButton temperatures greatly deviate from that of the air temperatures illustrating possible times of inundation.



Graph 4s: This graph illustrates the comparison of the SKP1 vertical post iButtons and non-inundated (air) iButton. From top iButton to bottom the curves are represented by the yellow, red, blue and green lines respectively. The dark purple curve is that of the air temperature iButton located in the sun. The dotted black curve is the Water depth recorded by the HOBO logger. The purple ovals depict the times when the post iButton temperatures greatly deviate from that of the air temperatures illustrating possible times of inundation.



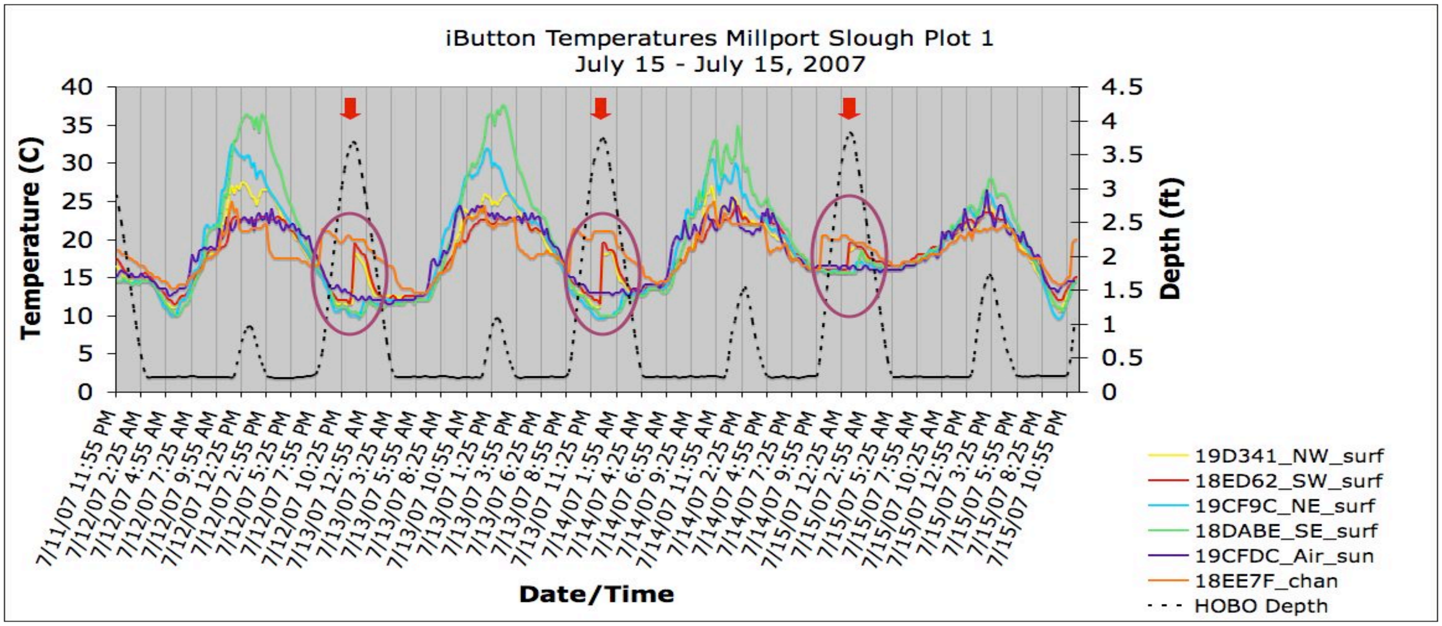
Graph 5s: This graph illustrates the comparison of the SKP2e-I vertical post iButtons and non-inundated (air) iButton. From top iButton to bottom the curves are represented by the yellow, red, blue and green lines respectively. The dark purple curve is that of the air temperature iButton located in the sun. The dotted black curve is the Water depth recorded by the HOBO logger. The purple ovals depict the times when the post iButton temperatures greatly deviate from that of the air temperatures illustrating possible times of inundation.



Graph 6s: This graph illustrates the comparison of the SKP2w-I vertical post iButtons and non-inundated (air) iButton. From top iButton to bottom the curves are represented by the yellow, red, blue and green lines respectively. The dark purple curve is that of the air temperature iButton located in the sun. The dotted black curve is the Water depth recorded by the HOBO logger. The purple ovals depict the times when the post iButton temperatures greatly deviate from that of the air temperatures illustrating possible times of inundation.

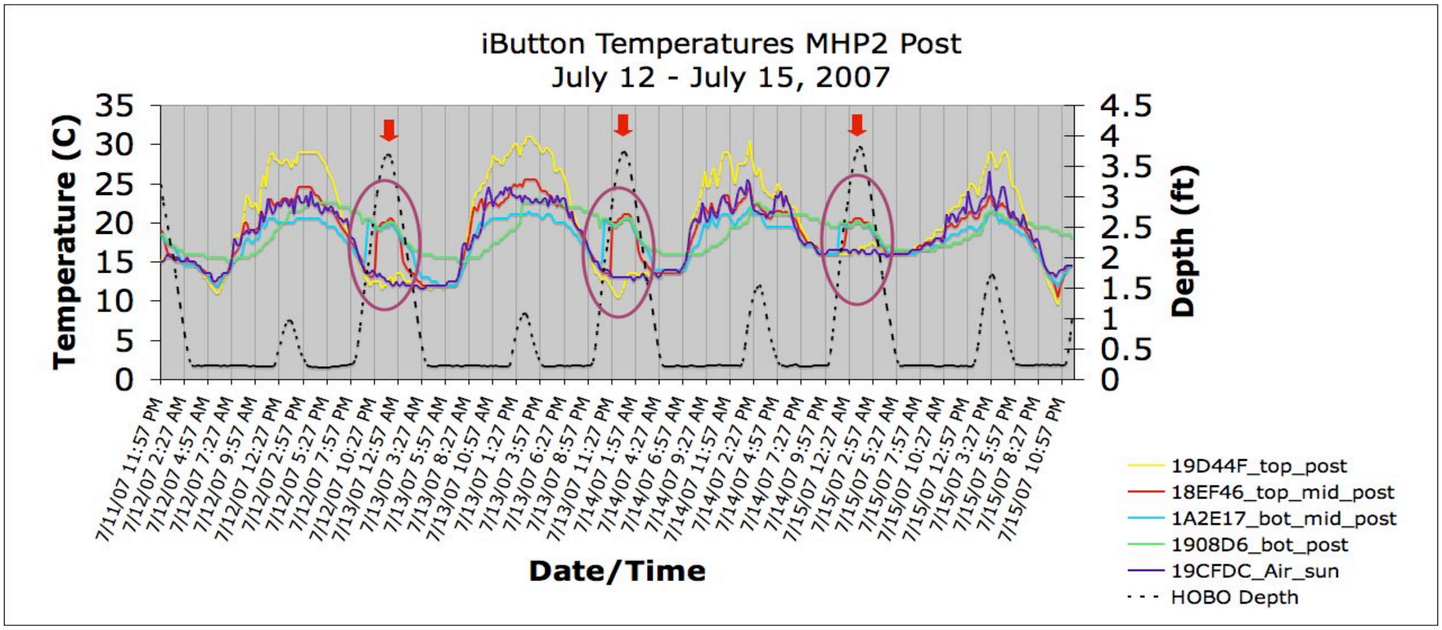
Millport Slough

When the data for Millport Slough was graphed out for the days of July 12th through 15th it was possible to observe the iButtons working to show there is in fact a noticeable temperature change when the iButtons are inundated with water. Graph 1m shows areas where inundation can be determined from temperature change of the iButtons in Plot 1. The noticeable inundation occurs at night when the temperature of the iButton recording air decreases and the temperatures recorded by both the surface and channel iButtons increases. The data plotted on the graph represents actual temperatures recorded by the iButtons. During times of high peaks (large water depths) shown by the HOBO logger data there are peaks in the actual surface iButton temperatures that are not shown by the sun temperature iButton in graph 1m. Graphs 1m also shows that the east side of Plot 1 in Milport Slough, unlike the data collected from the west side of Plot 1, does not show any signs of iButton inundation during the peak HOBO logger water depths.

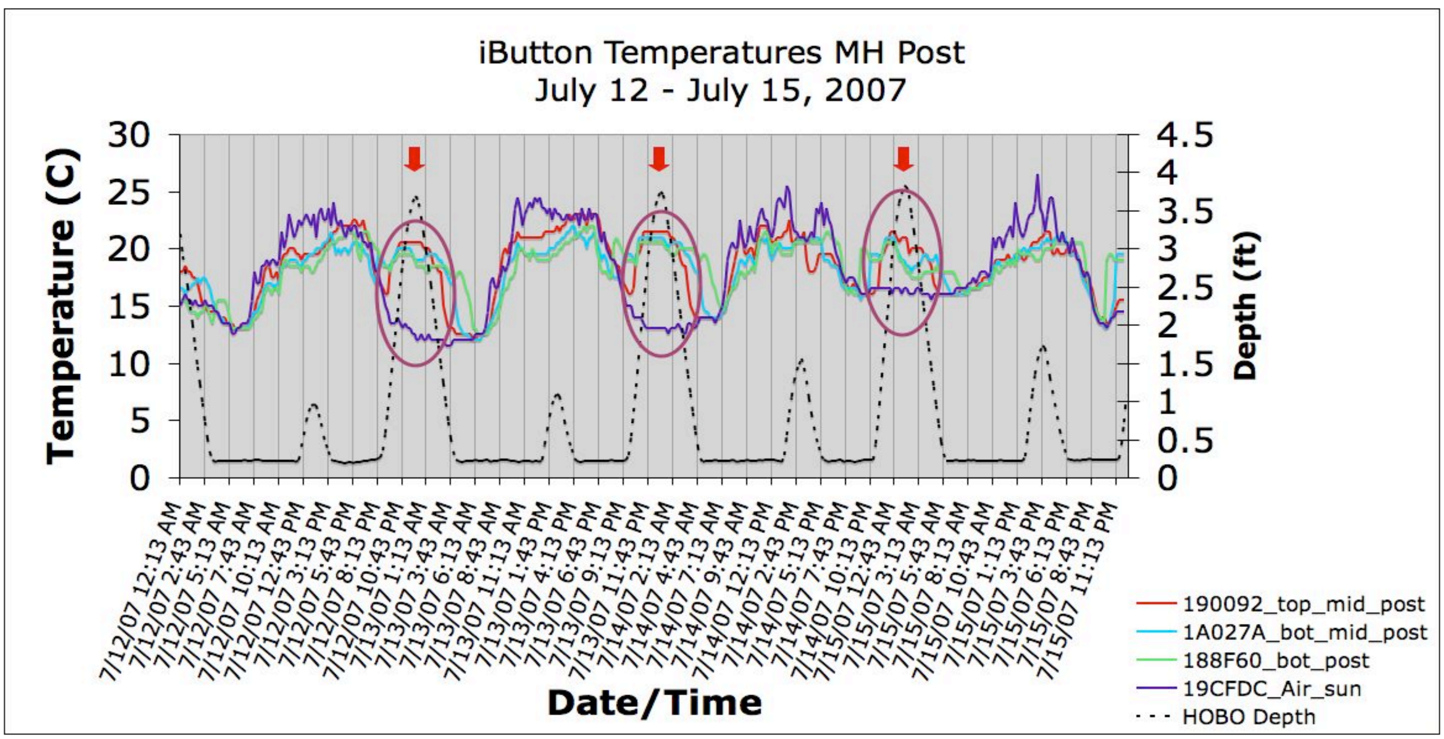


Graph 1m: This graph illustrates the comparison of an inundated (channel) iButton and non-inundated (air) iButton to that of plot 1 surface iButtons. The plot surface iButton curves are represented by the yellow, red, blue and green lines respectively. The orange curve represents a channel iButton within a channel located on the south end of plot 1. The dark purple curve is that of the air temperature iButton located in the sun. The dotted black curve is the Water depth recorded by the HOBO logger. The purple ovals depict the times when the surface button temperatures greatly deviate from that of the air temperatures illustrating possible times of plot 1 surface inundation.

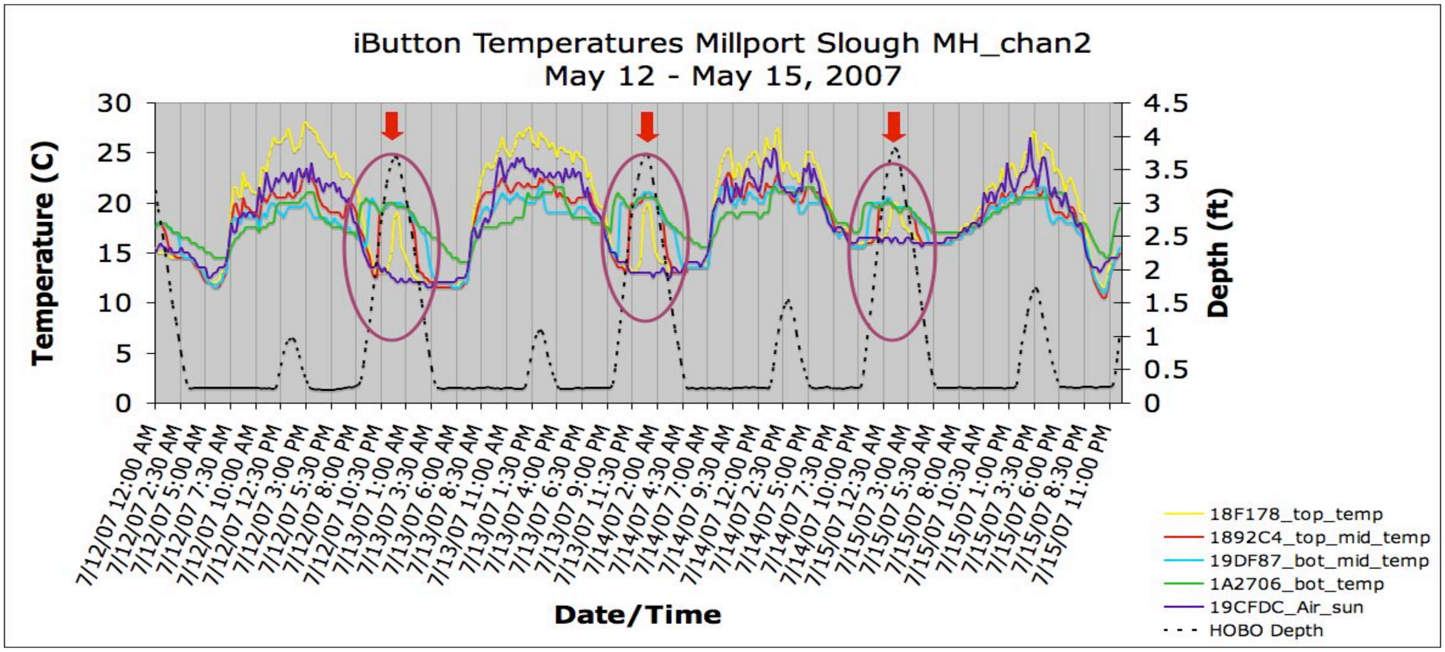
The iButtons located on the iButton posts, although not good for high spatial resolution, worked well for showing inundation of channels. Graphs and 5m show definite temperature differences between the iButton at the top of the post and the iButton at the bottom of the post. In the case of the data shown by the MHP2_70 post (Graph 5m) there was also difference between the top middle iButton on the post and the bottom iButton on the post. The MH post did not show any differences in temperature between the iButtons above the bottom iButton and the bottom iButton, however there were no readings from the top iButton on the post. This lack of difference could be due to all of the iButtons being inundataed or the channel being dry and none of the iButtons being inundated. Based on the air curve that shows decreases in temperatures while the iButtons on the MH post show increases in temperature recordings the iButtons are most likely all inundated at the same time causing the lack of difference between them.



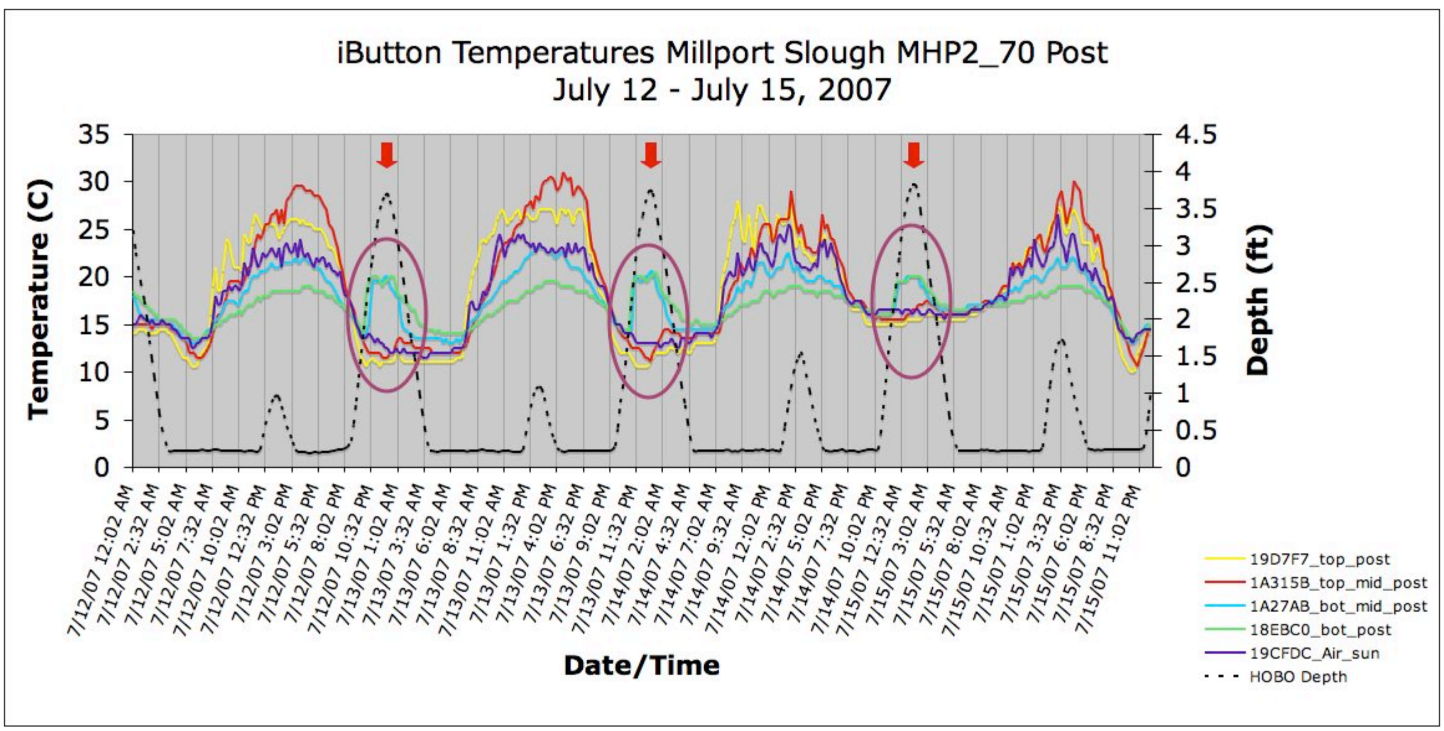
Graph 2m: This graph illustrates the comparison of the MHP2 vertical post iButtons and non-inundated (air) iButton. From top iButton to bottom the curves are represented by the yellow, red, blue and green lines respectively. The dark purple curve is that of the air temperature iButton located in the sun. The dotted black curve is the Water depth recorded by the HOBO logger. The purple ovals depict the times when the post iButton temperatures greatly deviate from that of the air temperatures illustrating possible times of inundation.



Graph 3m. This graph illustrates the comparison of the MH vertical post iButtons and non-inundated (air) iButton. From top iButton to bottom the curves are represented by the yellow, red, blue and green lines respectively. The dark purple curve is that of the air temperature iButton located in the sun. The dotted black curve is the Water depth recorded by the HOBO logger. The purple ovals depict the times when the post iButton temperatures greatly deviate from that of the air temperatures illustrating possible times of inundation.



Graph 4m: This graph illustrates the comparison of the MH_chan2 vertical post iButtons and non-inundated (air) iButton. From top iButton to bottom the curves are represented by the yellow, red, blue and green lines respectively. The dark purple curve is that of the air temperature iButton located in the sun. The dotted black curve is the Water depth recorded by the HOBO logger. The purple ovals depict the times when the post iButton temperatures greatly deviate from that of the air temperatures illustrating possible times of inundation.



Graph 5m: This graph illustrates the comparison of the MHP2_70 vertical post iButtons and non-inundated (air) iButton. From top iButton to bottom the curves are represented by the yellow, red, blue and green lines respectively. The dark purple curve is that of the air temperature iButton located in the sun. The dotted black curve is the Water depth recorded by the HOBO logger. The purple ovals depict the times when the post iButton temperatures greatly deviate from that of the air temperatures illustrating possible times of inundation.

Discussion

One of the hypotheses of this study was that the temperatures recorded by iButtons would be different when the tides rose inundating the wetland surface as well as the iButtons. The original thought was that the temperature difference that would be seen would be a decrease in temperatures upon inundation of the iButtons.
To analyze the data recorded by the iButtons, the data from July 12th through July 15th was isolated out because it was the time frame of the highest projected tides for the 3 weeks that the iButtons were deployed.

The inundation detected by the iButtons was not by a decrease in temperature upon inundation as originally hypothesized. Temperature deviations between the iButton measuring air and the iButtons measuring wetland surface and channel temperatures were seen at night. During nighttime periods there was an increase in channel and surface iButton temperatures recorded during the peak high tide depths recorded by the HOBO logger at each site. This phenomenon is most likely due to the fact that Pacific Ocean temperature off the coast of Oregon does not change much from day to night. The air temperature at night on the Oregon coast does drop significantly at night so the increase in temperatures logged by the iButtons at night fits. By looking at graph 4m it can also be seen that period of inundation may also be able to be determined by the temperature change recorded by the iButtons. While the bottom to top middle iButtons follow the same general curve the top iButton (yellow curve) on the post has a peak in temperature later and then a drop in temperature sooner than the other three iButtons on the post. From the curve it would appear that the top iButton was inundated after the other iButtons and that it's period of inundation lasted a shorter amount of time than that of the other iButtons on the post.

During the day when the sun is shining the iButton temperatures for both the air and the surface rose and fell with daily changes in sun intensity. When the HOBO loggers showed peaks in water depth within the wetland there were no drastic changes in temperatures recorded by the surface iButtons. This could possibly be due to the wetland surface heating up because of the suns UV rays hitting the highly organic soil drastically increasing wetland surface temperatures. When the water inundated the wetland surface if it was not deep enough to cause any change in temperature. The water may in fact also be warmed by the surface causing there to be no change in the temperature recorded by the iButtons.

Although there were differences seen between the air temperature iButton and the surface temperature iButtons on the Siletz Marsh there may be an issue with the data from the HOBO logger due to in potentially being at a higher elevation than the plots. The HOBO logger was put in a channel at a spot that was thought to be lower in elevation than both plots on the Siletz Marsh. It is necessary for the HOBO to be lower in elevation than that of the plot surfaces so that it captures the water height that would inundate the surfaces of the plots. With the Siletz HOBO logger potentially being at a higher elevation than the surfaces of the plots it is highly likely that it did not capture the water depth when the plots would have initially inundated. Since this first field season the HOBO logger on the Siletz has been moved to a lower elevation where is will capture the water depth that is equivalent to the elevation of the plot surfaces within the wetland.

For this first field season elevation data for the iButtons and HOBO loggers at each of the sites has not yet been received from the National Geodetic Survey team that went to each of the sites putting in bench marks and recording elevations for each individual iButtons, iButton posts, and HOBO loggers. Without the elevation information, although differences in iButton temperatures can be seen, comparisons between water depth recorded by the HOBO loggers and elevation of iButtons cannot be made. Assumptions have been made about the temperature differences between the air temperature iButton and the surface temperature iButtons being times where the surface is inundated, but until elevations and water depth can be compared inundation is not 100% certain and cannot be modeled.

Conclusion/Recommendations

Although based on the graphs times of inundation during nighttime periods are fairly certain one of the major purposes of this project was to test and either accept or reject the use of iButtons to accurately determine wetland surface inundation based on temperature change. Without the elevation data for the iButtons conclusive evidence that the iButtons will work for the purpose intended by the project cannot be found. To go beyond seeing the change in temperature recording by the iButtons elevations at all of the sites for all of the buttons will be needed. Due to the large variability of wetland surfaces it is not possible to visually tell if an iButton in a plot is higher in elevation than another iButton within the same plot. To model the tidal inundation of a wetland one needs to know the elevations of the iButtons to compare to the water depths recorded by the HOBO loggers. The Yaquina test site, which had known elevations for each of the iButtons, did show that there was a temperature change when the iButtons were inundated and when the inundated temperatures were compared to temperatures of a non-inundated iButton a deviation in the curves could be seen. It is recommended that when NGS is finished analyzing the elevation data and turns that over to the project comparisons similar to those done at Yaquina Bay be done in an attempt to prove the initial assumptions made in this document. By comparing the temperature, elevation, and depth data one should be able to tell at what water depths the surface will inundate.

At the moment the iButtons are cheap but not waterproof. For future wetland studies using the iButtons it would be a benefit to discuss how much it would increase the cost of the iButtons if MAXIM DALLAS were to make the iButtons waterproof. The increase in cost may outweigh the time and money put into vacuum sealing or caulking the iButtons each time they needed to be deployed. The software provided by MAXIM DALLES was also insufficient for this project because absolute times could not be entered for record start times. The software also lacked graphing applications requiring the data to first be saved as a text file and then imported into Microsoft Excel or some other spread sheet program. The need to move the data around that much leaves greater room for the data to be lost. Since the initial deployment new software program (MicroT) put out by NEXSENS was found. This new software enables data from multiple iButtons to be saved individually in one project. For instance the data for all of the Millport Slough iButtons can be saved as individual iButtons in a Millport Slough project folder. The software has it's own graphing capabilities and will allow data to be directly exported into Excel without first saving as a text file. An all in one software packages allows for greater certainty that data will not be lost.

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