USFWS Salt Marsh Surface Elevation Table (SET) Data Analyses

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STATEMENT OF ISSUE

Salt marshes are ecotonal ecosystems that form the dominant transition zone between terrestrial and marine communities and are critical for absorbing the energy of ocean storms and preserving shorelines, improving water quality in bays and estuaries, providing nutrients to marine food webs, and supplying critical habitat for both the reproduction of a suite of ocean species and for use by an entire community of breeding and migratory birds. Wildlife species that depend on salt marshes are some of the highest conservation priorities, many of which occur in coastal US Fish and Wildlife Service, National Wildlife Refuges. Most salt marshes are impacted to some extent by some type of anthropogenic alteration and are threatened by accelerated rates of sea-level. Understanding how best to measure the effects of these alterations on salt marsh condition and wildlife habitat quality of habitat were the focus of the project "Development of a Salt Marsh Assessment Tool to Monitor System Integrity and Provide Management Priorities for Wildlife Conservation in Response to a Hierarchy of Threats"(Neckles et al. 2013). This project identified monitoring metrics that were linked to both management and fundamental objectives and tested each metric to determine which method (rapid vs. intensive) was most effective and efficient.

The U.S. Fish and Wildlife Service Region 5 is implementing the Salt Marsh Integrity Monitoring Protocol (Neckles et al. 2013) to assess and track the condition of salt marsh habitats on USFWS Refuges with salt marsh habitats. To assist in the development of analytical tools using data from this long-term monitoring program we will identify priority analyses for refuge specific monitoring data. The initial analysis tool to be developed by this project is focused on the surface elevation table (SET) data collected by the US Fish and Wildlife Service and other partnering institutions. We will develop analytical tools to facilitate the current and future analysis of SET data collected within long-term ecological monitoring studies.

OBJECTIVES

1) Work cooperatively with USFWS staff and the I&M coordinator for USFWS Region 5, to identify analysis priorities for data associated with the Salt Marsh Integrity Monitoring Protocol.
2) Analyze Surface Elevation Table (SET) data to determine temporal trends in the change in salt marsh surface elevation (mm).
3) Develop analytical tools in program R (R Development Core Team 2015) to facilitate current and future analysis of SET data.
4) Conduct an exploratory analysis to estimate contributions of observer-based variance to SET readings.
5) Compare spatial patterns in SET trends within and among sampling locations.

METHODS

We developed data analysis tools in program R (Team 2016) that enables users to analyze SET data using both the methods described in the SOP 8: SET and Marker Horizon Data Analysis (Lynch et al. 2015), and within a Bayesian framework using hierarchical linear models. Within this analysis, we only used data from "Deep" SET stations, and initially removed all "Shallow" SET data from the data set. First, we converted raw SET measurements of salt marsh surface elevation (mm) to the rate of change in surface elevation (mm/year; hereafter delta SET) from the initial measurement at time (t0). We then evaluated cumulative changes in delta SET to determine whether using linear regression models would be appropriate. We developed R functions to analyze data using either freqentist or Bayesian methods. For frequentist analyses, we fit linear regression models to delta SET values at each pin over time (in this case we used 'years' (e.g., 2012.1, 2012.2, 2013.1, 2013.2, etc.) following methods described in Lynch et al. (2015). In some cases, two observers recorded data during the same visit to SET stations, which is referred to as a "double read" in Lynch et al. (2015). Since we wanted to account for observer effects on rates of salt marsh elevation change within our analyses, we removed one of the data recorders from each of these "double read" cases during the data formatting stage. As opposed to estimating an observer bias using the variation from "double read" cases, and subsequently correcting trend estimates (as is recommended in Lynch et al. 2015), we instead included observer as a random covariate within linear mixed-effects models. To calculate mean and variance estimates of delta SET at higher-levels, we averaged delta SET estimates (i.e., slopes of regression models) over the four positions, and then these were averaged to get SET station-level estimates (Lynch et al. 2015). We then computed higher-level estimation of rates (i.e., mean ± SE slope of delta SET) at the marsh site level, NWR Unit level, and at the regional scale. To account for observer (data recorder) effects on measurement bias, we used linear mixed-effects models in the 'lme4' R package (Bates et al. 2014) for cases where more than one unique observer recorded data, and included observer as a random effect. To assess contributions of observer bias to variance in estimates among scales (i.e., SET station and NWR), we compared model estimates visually by generating plots of mean±SE, differences between normalized mean delta SET values, and finally, we evaluated relative model performance by calculating the percent relative standard deviation (i.e., $sd/|mean| * 100$). We used this metric, as opposed to CV, since values for CV were often close to zero, and contained both negative and positive values, as a means to compare among four models: 1) frequentist (no observer), 2) frequentist (with observer), 3) Bayesian (no observer), and 4) Bayesian (with observer). Where "shallow" SETs occurred (i.e., within Prime Hook NWR), we analyzed these data indepently of data from "deep" SETs.

For analyses within a Bayesian framework, we developed R code to analyze data within a that uses JAGS (version 3.2.0,(Plummer and others 2003)) along with the R package, 'rjags' (Plummer 2013) to implement Markov Chain Monte Carlo (MCMC) and Gibbs sampling processes to model delta SET trend estimates using linear mixed-effects regression models (Krushke 2011). Within a hierarchical Bayesian framework, we estimate both mean and precision estimates for all parameters (i.e., delta SET slopes for pins, positions, and stations; see JAGS models in Appendix A).

Future analyses using delta SET rate estimates could be used to evaluate the efficacy of marsh loss mitigation strategies (e.g., thin-layer sediment deposition), or how delta SET rates are related to salt marsh habitat age, structure, and composition (Chen et al. 2016). The estimates we present will further allow for the future comparison of delta SET and rates of sea level rise (using corresponding tide gauge data from National Oceanic and Atmospheric Administration's National Geophysical Data Center) in order to evaluate how acute salt marsh surface elevation trends correspond with sea level rise (Krauss et al. 2010, Raposa et al. 2016).

Notes on data quality and assurance: Within this section we point out any issues with the data that were encountered during analysis and modeling. For instance, data should be double-checked at AT&T SMI 07, 08, and 09, as these had unusually large delta height (mm) values (see Appendix D). We include any issues that we encountered related to the organization, analysis, and visualization of these data. Additionally, the code we have developed can easily be modified to fit other covariates based on user interest to incorporate into estimates of change in marsh elevation per year (or other temporal units like days, for example).

Other issues of note:

- Made change in Back Bay NWR's Long Island North 1 Latitude from 38.6722 to 36.6722.
- Very high values within Edwin B. Forsythe at the following SET stations: AT&T SMI 07, 08, 09, and Mill Crk-Cedar Run Purple 01.
- Naming conventions for SET station names (Plot_Name) differ slightly between SET raw data Lat/Long data.
- Missing Latitude/Longitude values for the following SET stations would help complete visualizing trends via maps: EBF (AT&T SMI 07, 08, and 09), ESV (Bull Plot 4 and 5), MEC (Sawyers Marsh 4), PMH (PH2-1 (Deep and Shallow), PH2-2 (Deep and Shallow), PH2-3 (Shallow), PH2-4 (Deep and Shallow), PH2-5 (Deep and Shallow), PH2-6 (Deep and Shallow), Set 1 (Deep and Shallow) , Set 2 (Deep and Shallow), Set 3 (Deep and Shallow).
- Data from Parker River NWR (and all refuges) should be modified to denote "useable"" data (or add a data quality indicator category). For example, in some instances where ice sheets have caused spurious marsh elevation data (and subsequent trend estimates) to be recorded, this should be duely notated within the data set.
- Found error in raw data from PMH NWR - at PMH2-4 (Shallow) on 11/18/2011, Arm D, Pin 3, I changed 2385 to 238.5

RESULTS

Summary of findings

1) We are continuing to work cooperatively with USFWS staff and the I&M coordinator for USFWS Region 5, and have identified the following analysis priorities for data associated with the Salt Marsh Integrity Monitoring Protocol. In this case we address priorities associated specifically with salt marsh surface elevation table (SET) data:

   - Compiling all pertinent SET data for future analyses. Upon summarizing the shared SET data, we note that three NWRs: Monomoy (MNY), Ninigret (NGR), and Stewart B McKinney (SBM) did not have sufficient data to enable analyses which use a derived change in salt marsh elevation (delta height) as a response variable to estimate trends over time. The minimum requrirements for data analysis at an SET station would be a minimum of 2 visits (so delta height (mm) can be calculated). Additionally, trends in delta height (mm) over time, require greater than 2 visits.

   - SET station naming conventions should be standardized. This is more of a data quality assurance and data management point. However, we were unable to generate maps for all SET station trends in change in marsh elevation due to differences in naming conventions in multiple datasets. In this case, the station names within the raw SET data (Plot_Name) did not entirely correspond with the Arc GIS output datatable of Latitude and Longitude information. This issue should be easy to rectify, however, moving forward, we sugggest sticking to standarized names.

   - Incorporation of observer (data recorder) effects into trend estimation. Accounting for observer effects where this covariate could be included within models (i.e., when greater than one observer recorded data at a given SET station) to see how this may change trend estimates. As mentioned above with the methods, we did not explicity analyze data where two observers collected data during independent visits. However, inspection of these raw data gives us an appreciation of the degeree of variability among observers purely due to measurement bias (while controlling for other natrual and stochastic effects that may influence marsh elevation over time).

2) We analyzed data collected at SET stations ($n = 146$) located in 12 NWRs (Table 1) within the USFWS Northeast Region 5. These results include a summarization of SET data (delta SET height (mm)) at regional(Fig. 1), refuge, site-level (SMI unit), and SET station spatial scales, along with trend estimates of delta SET height (mm/year) at each of the aforementioned scales (see Appendices A-H).

3) We have developed analytical tools in program R (R Development Core Team 2015) to facilitate current and future analysis of SET data. Extensive R code is provided in the form of sripts (.R files) that contain functions to format data, summarize data in tabular and graphical formats, analyze data, save results (tables and figures), and R Markdown files (.Rmd) that generate .doc, .html, or .pdf reports and a thoroughly annotated code to help users through analyses using program R and R Studio.

4) We conducted an exploratory analysis to estimate contributions of observer-based variance to SET readings. We found that in cases where multiple unique observers record data from a SET station, there are discernible observer effects on the estimation of trends in delta height (mm/year). However, there was no obvious pattern at the NWR refuge level (Fig. 2), and seemed to be SET station-specific. However, due to the apparent observer bias that occurs when multiple individuals record data, we encourage the adoption of accounting for these observer effects in future SET data analysis.

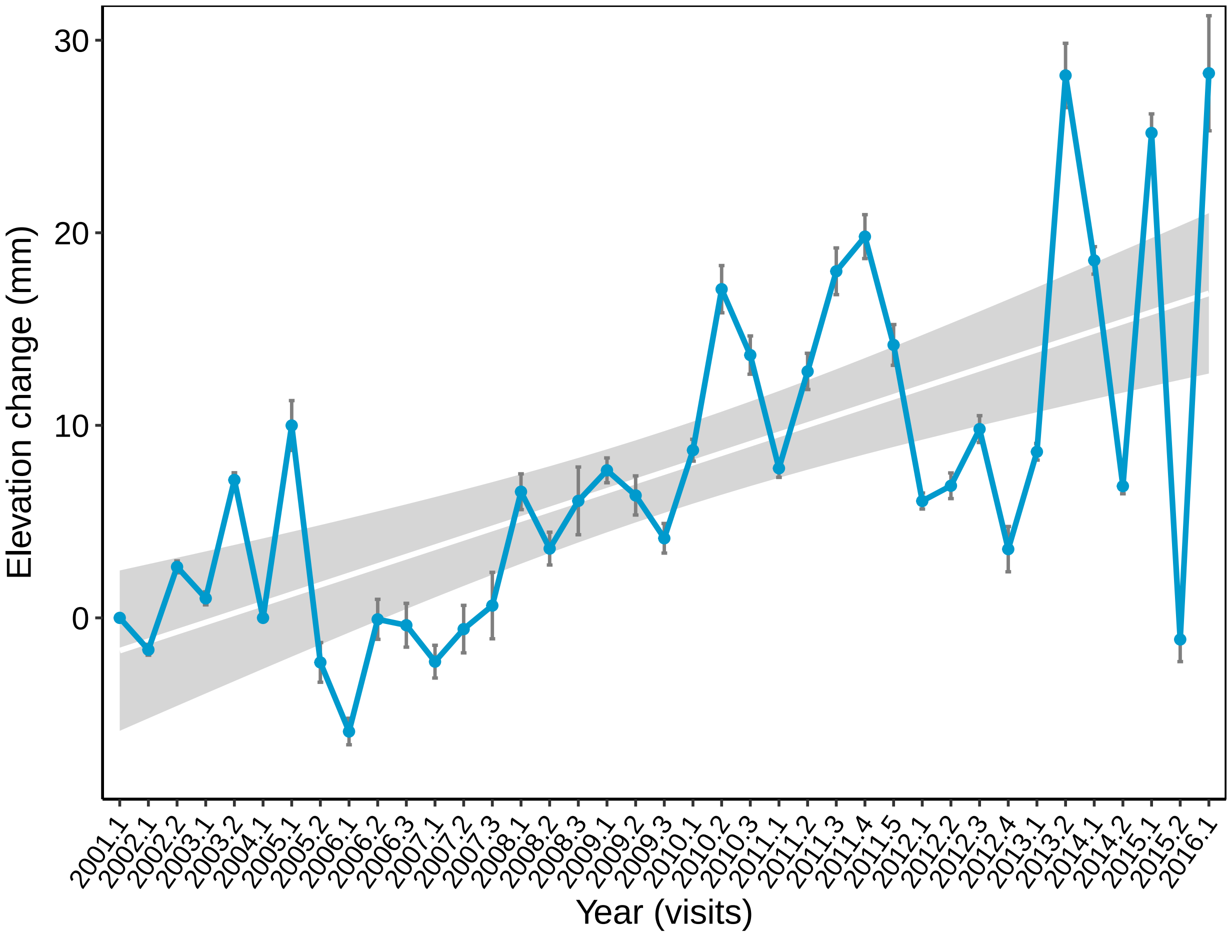
5) We compared spatial patterns in SET trends within and among sampling locations through the visualization of spatial trend estimates of delta SET rates (mm/year), by providing R code that creates maps of SET stations and displays the trend direction (positive, negative) along with the magnitude of the trend. These maps provide a nice visualization tool, that hopefully, refuge biologists can use to quickly assess patterns of marsh elevation trends at particular SET stations.

Summarization of SET data.

Table 1. List of 12 US Fish and Wildlife Service National Wildlife Refuge units included in SET data analyses along with corresponding Unit code, State, count of SET stations (nSET), count of unique observers (nObservers), count of years (nYears), and ranges of years that data was collected.

Unit_Code	Refuge_Name	State	nSET	nObservers	nYears	Start_Year	End_Year
MEC	Maine Coastal Islands	ME	7	1	1	2013	2014
RHC	Rachel Carson	ME	22	2	14	2001	2015
PKR	Parker River	MA	14	3	6	2008	2014
SPT	Sachuest Point	RI	6	6	11	2004	2015
JHC	John H Chaffee	RI	7	5	4	2011	2015
OYS	Oyster Bay	NY	2	2	2	2012	2014
WRT	Wertheim	NY	12	4	5	2009	2014
EBF	Edwin B. Forsythe	NJ	20	4	12	2002	2014
BMH	Bombay Hook	DE	17	7	11	2005	2016
PMH	Prime Hook	DE	9	2	4	2011	2015
PMH_shallow	Prime Hook Shallow	DE	9	2	4	2011	2015
ESV	Eastern Shore of Virginia	VA	12	1	3	2012	2015
BKB	Back Bay	VA	9	1	3	2010	2013

Figure 1. Overall change in salt marsh elevation (mm) (mean ± SE) for Northeast Region US Fish and Wildlife Service from data collected between 2002–2016 at surface elevation table (SET) data collection stations (n = 146). Linear model-predicted mean and SE are shown by white line and gray polygon, respectively. Note that caution should be taken when interpreting this trend, as it likely does not accurately represent overall trend of marsh elevation due to inherent spatial and temporal variation associated with pooled data from SET stations.



Frequentist Analysis

Here, we used methods described by Lynch et al. (2015) to fit simple linear and linear mixed-effects models to estimate SET pin-level slopes over time (years), and then calculated mean and variance estimates at SET station, SMI unit, and NWR spatial scales. We estimated the rate of marsh elevation change for models with and without accounting for observer effects (Table 2). We also present summary figures data showing mean ± SE delta height (mm) of salt marsh elevation at every year and visit for each NWR (Appendix B), SMI unit (Appendix C), and at each SET station (Appendix D). We have included SET station-level change in marsh elevation (mm/year) estimates for comparison between both linear (no observer effect) and mixed-effects models that account for observer effects within tabular format (Appendix B). Additionally, we present figures (in Appendix C) that plot these model estimates in parallel for visual comparison, as well as figures depicting the directionality and magnitude of observer effects on estimates of salt marsh elevation change (mm/year).

Table 2. Mean estimated changes of salt marsh elevation height (mm/year) for 12 US National Wildlife Refuges from data collected at SET stations (n = 146). Where possible, means and SEs were calculated by averaging 36 (i.e., 9 pins x 4 arm positions) pin-level linear model-derived slopes. Each NWR is shown along with corresponding State, 3-letter refuge Unit_Code, and number of SET stations within each NWR. For stations with NAs for Mean and SE, there were too few repeated visits within the current data set to compute these estimates.

Unit_Code	State	nSET	nObs	Mean	SE	CV	Mean.obs	SE.obs	CV.obs
MEC	ME	7	1	4.71	3.03	1.70	4.71	3.03	1.70
RHC	ME	22	2	1.20	1.17	4.60	1.20	1.17	4.60
PKR	MA	14	3	4.86	1.21	0.93	4.05	0.97	0.89
SPT	RI	6	6	3.66	0.66	0.44	2.75	0.92	0.82
JHC	RI	7	5	1.72	0.63	0.97	1.59	0.60	1.00
OYS	NY	2	2	-1.86	0.96	-0.73	2.37	2.40	1.43
WRT	NY	12	4	4.67	0.99	0.74	4.10	1.14	0.96
EBF	NJ	20	4	21.02	10.58	2.25	24.12	10.19	1.89
BMH	DE	17	7	-2.36	2.83	-4.94	-2.46	2.81	-4.72
PMH	DE	9	2	14.49	6.21	1.28	14.54	6.20	1.28
PMH_shallow	DE	9	2	20.74	7.23	1.05	20.64	7.24	1.05
ESV	VA	12	1	3.75	0.54	0.50	3.75	0.54	0.50
BKB	VA	9	1	-9.12	1.79	-0.59	-9.12	1.79	-0.59

Model comparison and accounting for observer effects.

Figure 2. Comparison of estimates of change in salt marsh elevation (mm/year) at 12 National Wildlife Refuges (mean±SE) for frequentist and Bayesian models with and without observer effects. Note different scales on y-axes.

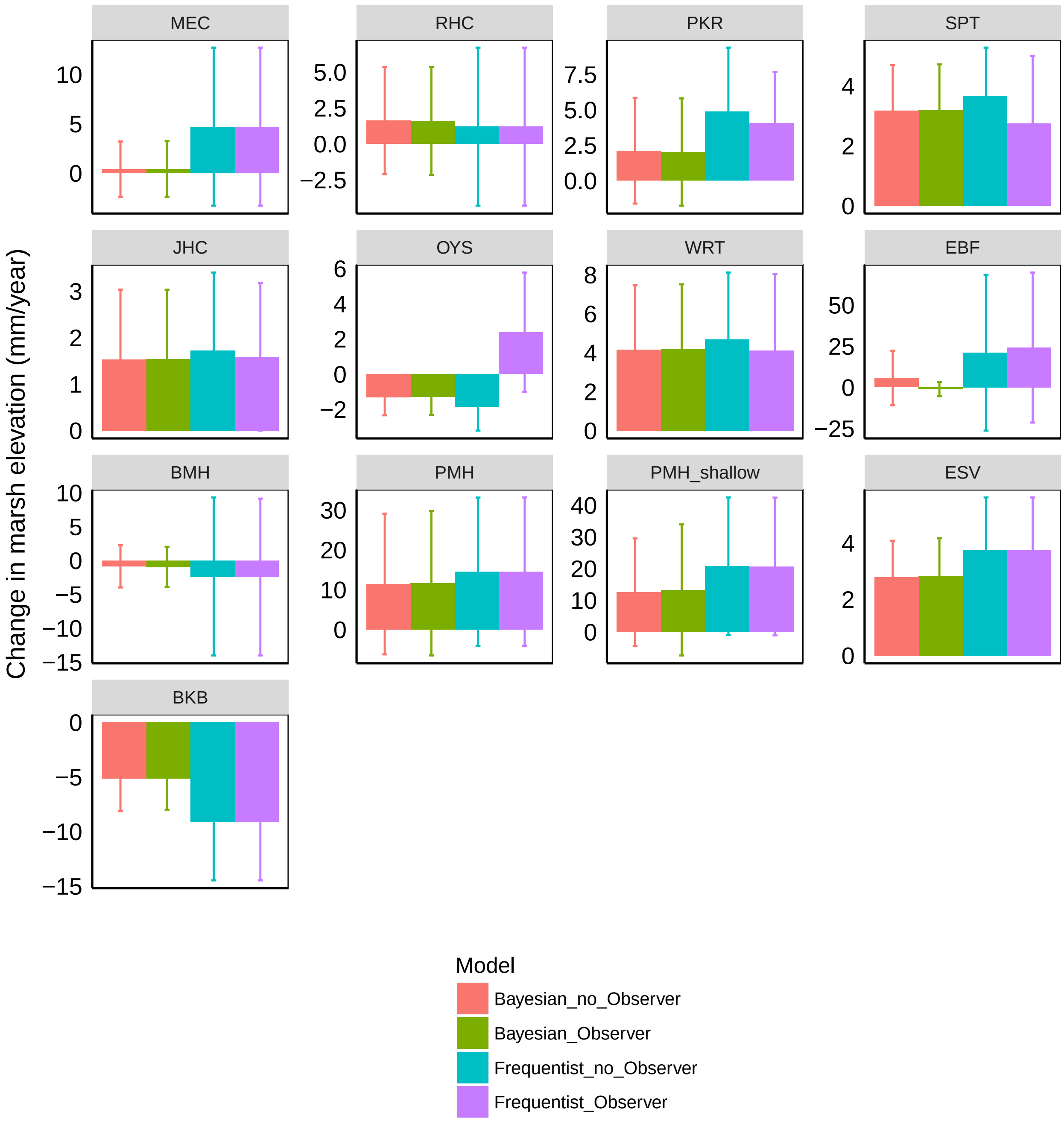
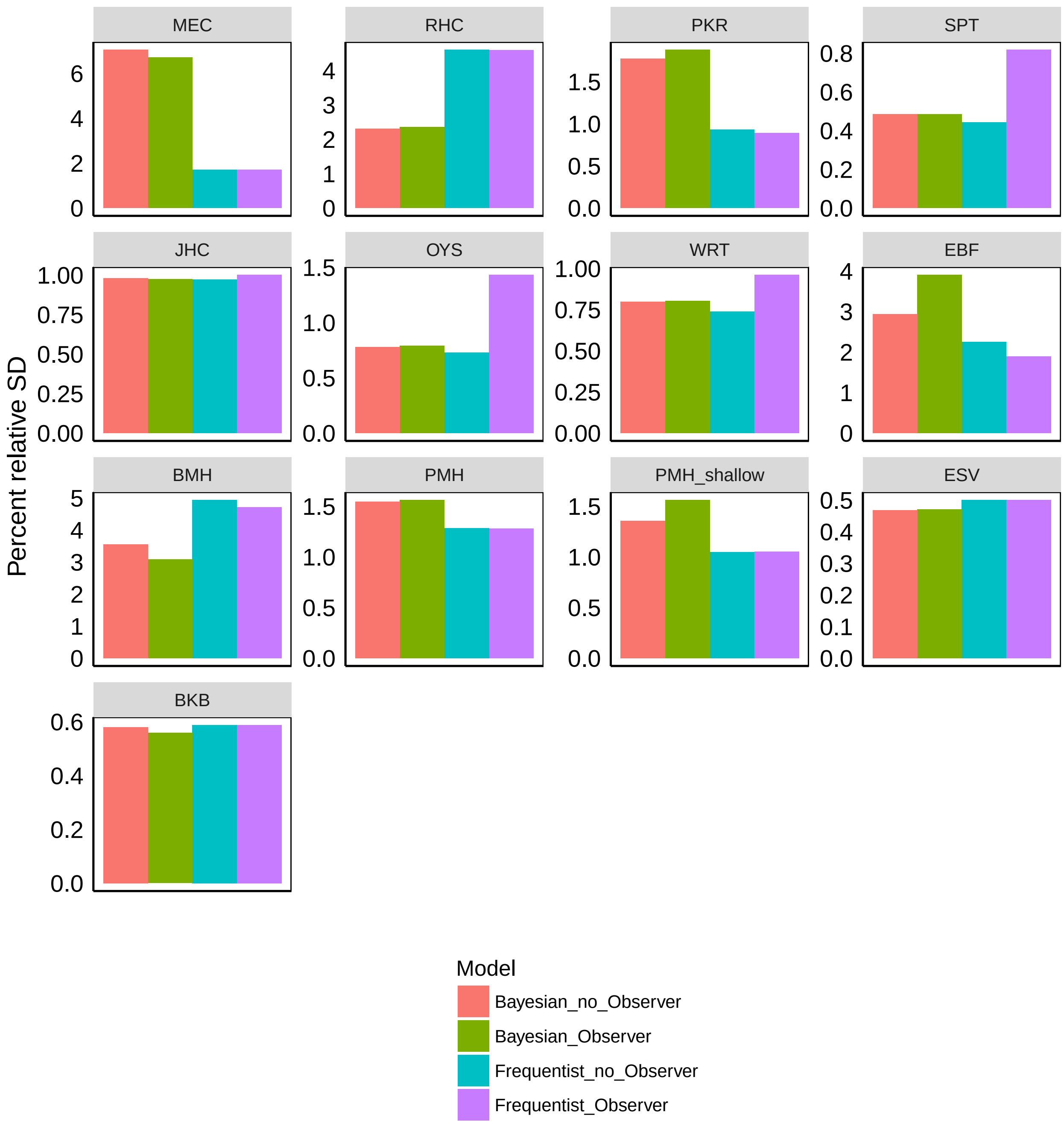


Figure 3. Comparison of percent relative standard deviation from model estimates of change in salt marsh elevation (mm/year) at 12 National Wildlife Refuges for frequentist and Bayesian models with and without observer effects. Note different scales on y-axes.



Bayesian Analysis

Results from Bayesian linear and mixed-effects models have been compiled for each NWR (Table 4). Bayesian model estimates for SET station-level rate of marsh elevation change (mm/year) for comparison between both linear (no observer effect) and mixed-effects models that account for observer treated as a random effect (Appendix D). We also present figures that plot Bayesian model estimates in parallel for visual comparison, as well as figures depicting the directionality and magnitude of observer effects on estimates of salt marsh elevation change (mm/year) for each SET station by refuge (Appendix E).

Table 4. Bayesian-estimated mean changes of salt marsh elevation height (mm/year) for 15 US National Wildlife Refuges from data collected at SET stations ($n = 146$). Where possible, means and SEs were calculated by averaging 36 (i.e., 9 pins x 4 arm positions) pin-level linear model-derived slopes. Each NWR is shown along with corresponding State, 3-letter refuge Unit_Code, and number of SET stations within each NWR . For stations with NAs for Mean and SE, there were too few repeated visits within the current data set to compute these estimates.

	Unit_Code	State	nSET	nObs	Mean	SE	Mean.obs	SE.obs
1	MEC	ME	7	1	0.40	1.06	0.42	1.07
2	RHC	ME	22	2	1.62	0.79	1.59	0.80
3	PKR	MA	14	3	2.10	1.00	2.01	1.01
4	SPT	RI	6	6	3.16	0.63	3.18	0.63
5	JHC	RI	7	5	1.53	0.57	1.53	0.57
6	OYS	NY	2	2	-1.32	0.72	-1.30	0.73
7	WRT	NY	12	4	4.15	0.96	4.17	0.96
8	EBF	NJ	20	4	5.64	3.71	-1.10	0.96
9	BMH	DE	17	7	-0.88	0.76	-0.97	0.72
10	PMH	DE	9	2	11.42	5.88	11.59	6.03
11	PMH_shallow	DE	9	2	12.54	5.66	13.24	6.89
12	ESV	VA	12	1	2.78	0.38	2.84	0.39
13	BKB	VA	9	1	-5.15	1.00	-5.14	0.96

Refuge-level Summaries

Maine Coastal Islands NWR

Surface elevation table (SET) data was collected within Maine Coastal Islands NWR at the following 7 SET stations (Gouldsboro Marsh 1, Gouldsboro Marsh 2, Gouldsboro Marsh 3, Sawyers Marsh 1, Sawyers Marsh 2, Sawyers Marsh 3, Sawyers Marsh 4) between 2013 and 2014. Trends ranged from -3.42 to 18.61. Overall, the average refuge-level trend was 4.71 ± 3.03 (mean ± SE).

Trends of changes in Salt marsh Elevation (mm)

Figure 1. Map showing locations, trend directionality, and trend magnitude of SET stations within Maine Coastal Islands. Radii of positve (blue) and negative (red) points show the magnitude of linear trends.

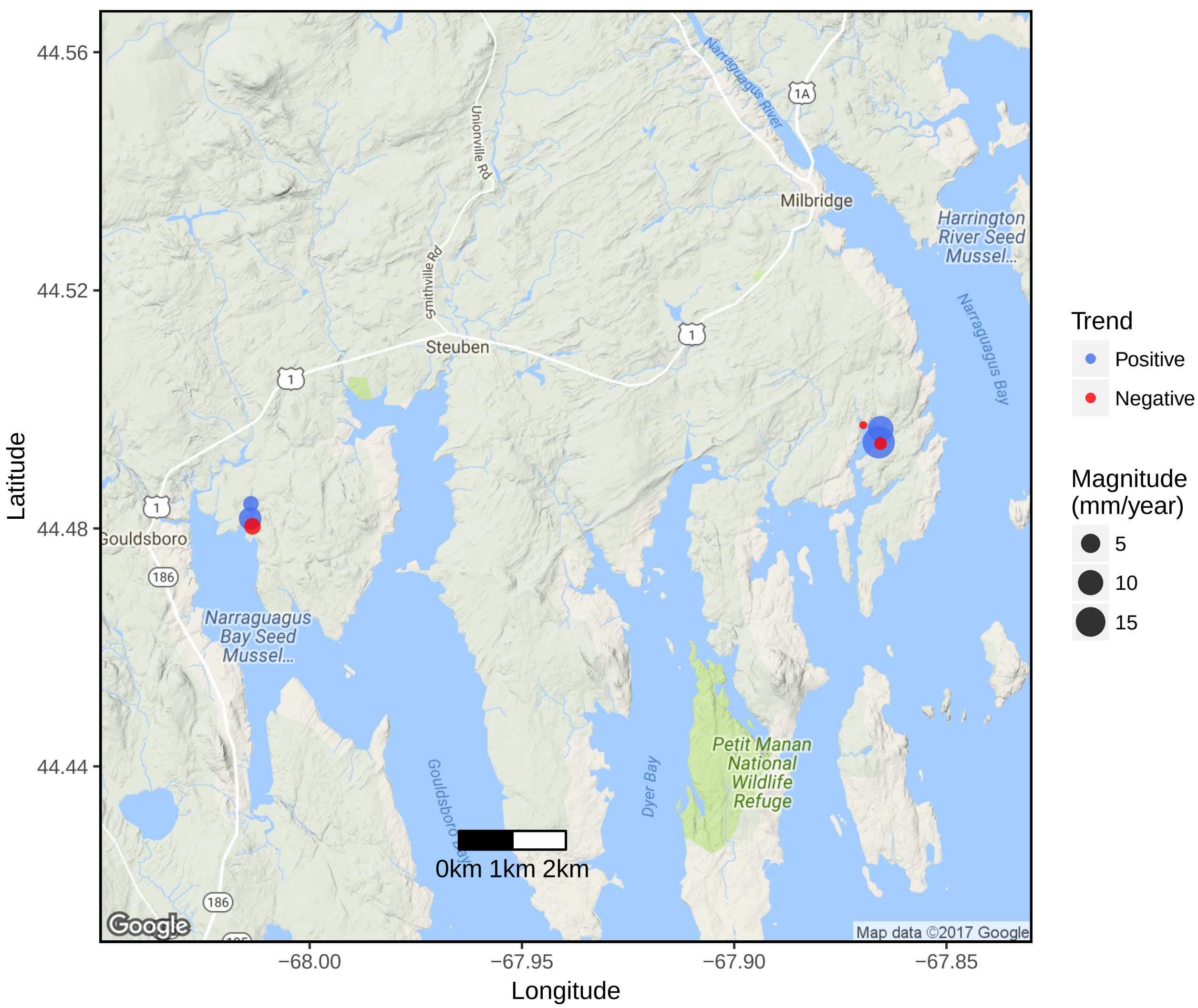


Table 1. Trends of surface elevation table (SET) stations within Maine Coastal Islands. Means and SEs for trends are shown for both linear models with and without observers.

	SET_Name	Mean	SE	CV	Mean.obs	SE.obs	CV.obs
1	Gouldsboro Marsh 1	2.93	3.91	2.67	2.93	3.91	2.67
2	Gouldsboro Marsh 2	7.62	3.93	1.03	7.62	3.93	1.03
3	Sawyers Marsh 2	10.46	1.46	0.28	10.46	1.46	0.28
4	Sawyers Marsh 3	18.61	4.81	0.52	18.61	4.81	0.52
5	Gouldsboro Marsh 3	-3.42	3.14	-1.84	-3.42	3.14	-1.84
6	Sawyers Marsh 1	-1.31	1.39	-2.13	-1.31	1.39	-2.13
7	Sawyers Marsh 4	-1.96	1.92	-1.96	-1.96	1.92	-1.96

Summary of Raw Data − Surface elevation change (mm)

Figure 2. Elevation change (mm) within Maine Coastal Islands NWR. Means and SEs for each year (and within year visits) are shown along with overall linear trend.

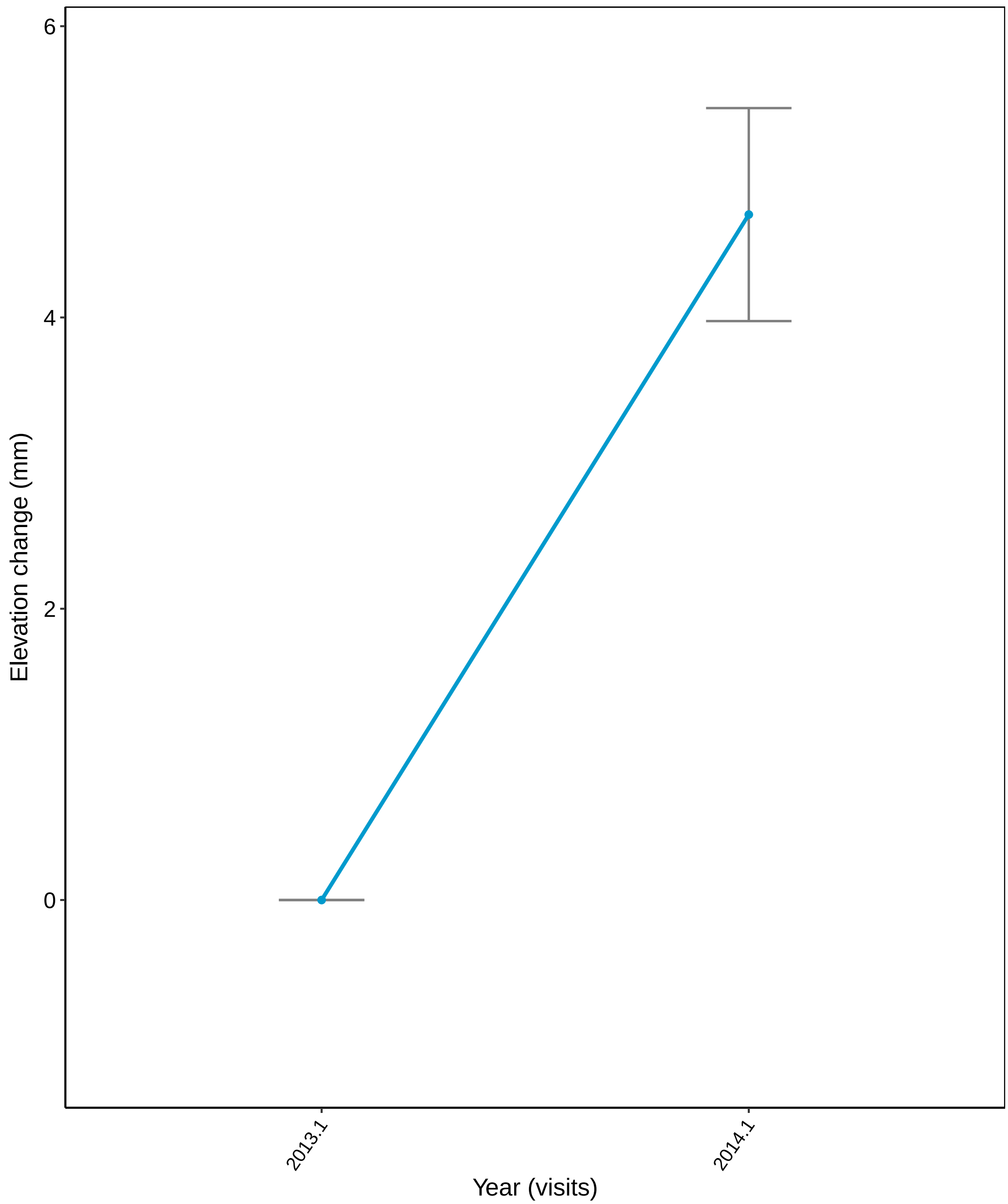


Figure 3. Summary of Site-level elevation change (mm) data within Maine Coastal Islands NWR. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes.

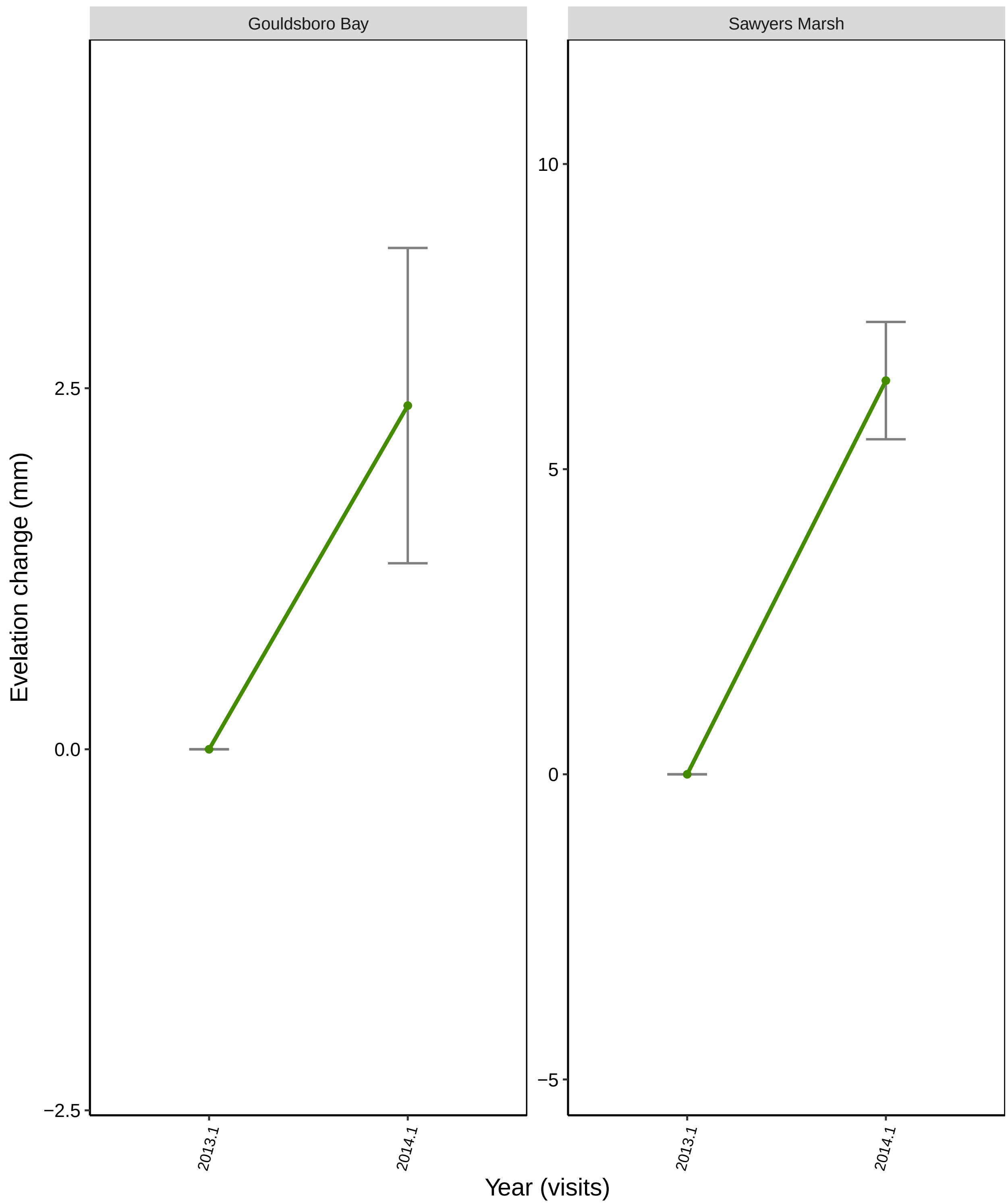
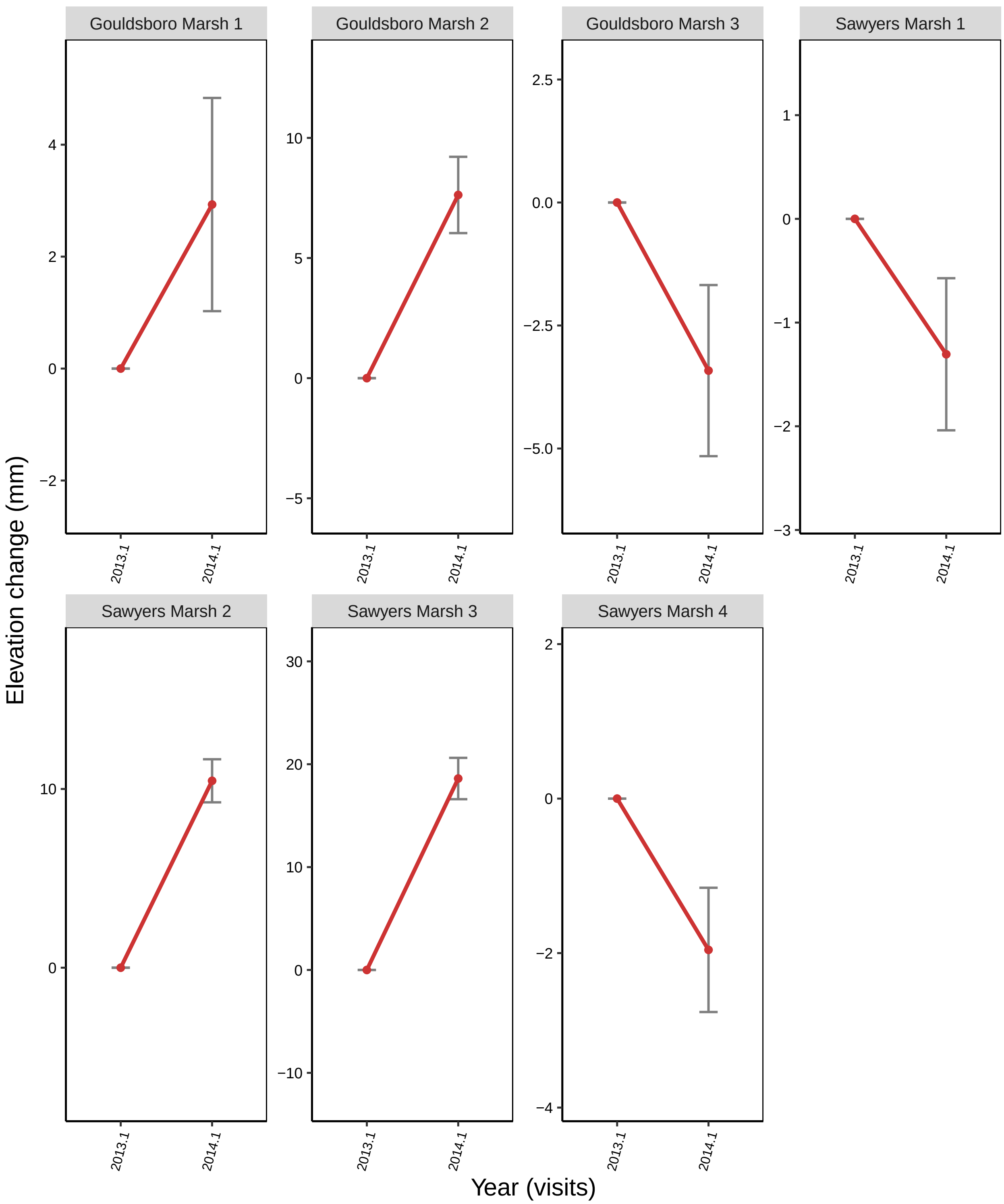


Figure 4. Summary of SET station-level elevation change (mm) data within Maine Coastal Islands NWR. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes.



Rachel Carson NWR

Surface elevation table (SET) data was collected within Rachel Carson NWR at the following 22 SET stations (Bourne 1, Bourne 2, Bourne 3, Control 02, Drakes 02, Drakes 03, Furbish 01, Furbish 02, Furbish 03, Granite Point Control 02, Granite Point Control 03, Harbor 02, ME1, ME2, Mile North 01, Mile North 03, Mile South 01, Mile South 02, Mile South 03, Moody 1, Moody 2, Moody 3) between 2001 and 2015. Trends ranged from -16.12 to 11.47. Overall, the average refuge-level trend was 1.2 ± 1.17 (mean ± SE).

Trends of changes in Salt marsh Elevation (mm)

Figure 1. Map showing locations, trend directionality, and trend magnitude of SET stations within Rachel Carson. Radii of positve (blue) and negative (red) points show the magnitude of linear trends.

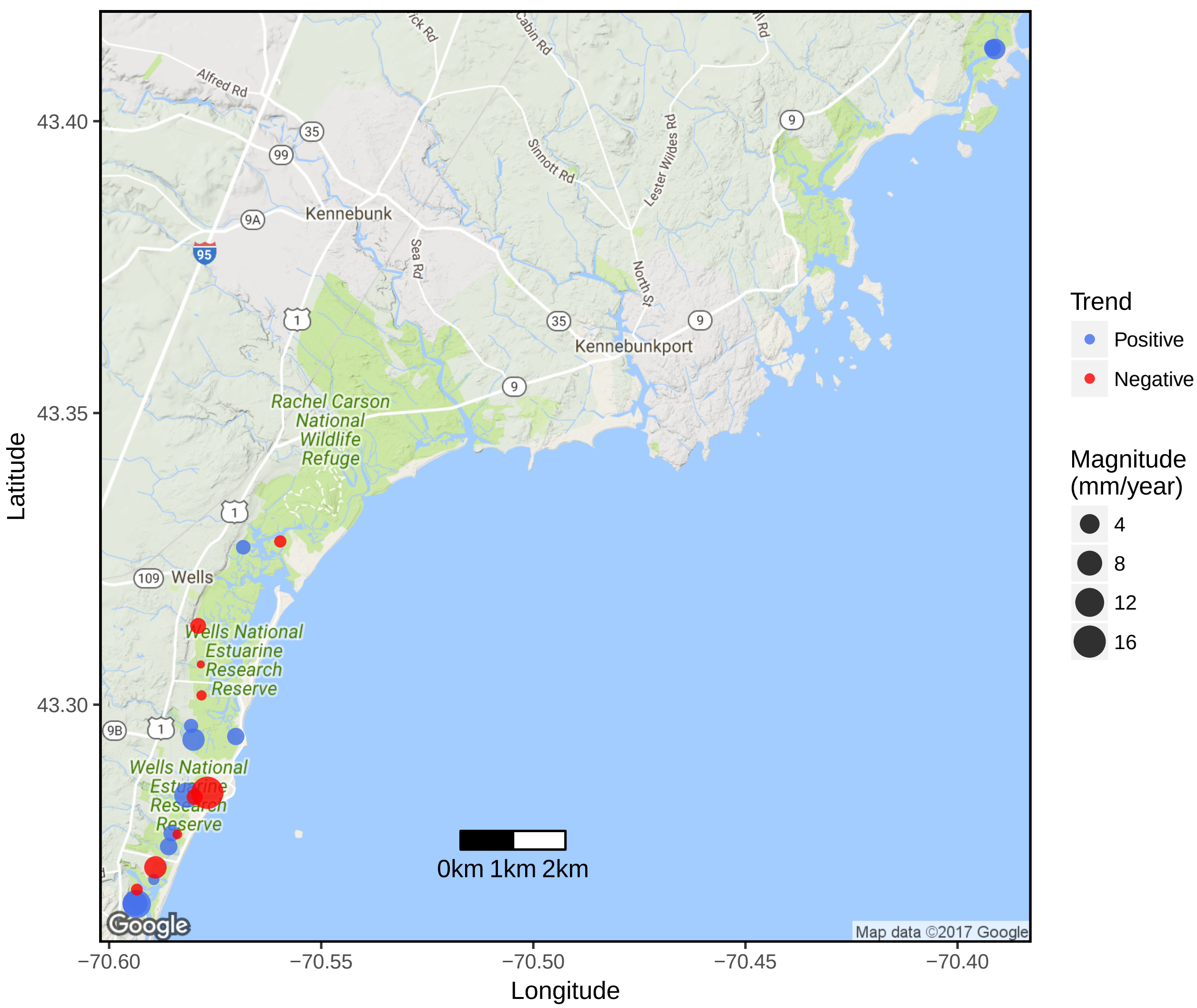


Table 1. Trends of surface elevation table (SET) stations within Rachel Carson. Means and SEs for trends are shown for both linear models with and without observers.

	SET_Name	Mean	SE	CV	Mean.obs	SE.obs	CV.obs
1	Bourne 1	2.25	0.28	0.25	2.25	0.28	0.25
2	Drakes 03	1.51	0.67	0.88	1.51	0.67	0.88
3	Bourne 3	2.72	0.51	0.38	2.72	0.51	0.38
4	Control 02	3.45	0.12	0.07	3.40	0.14	0.08
5	ME1	11.47	0.36	0.06	11.47	0.36	0.06
6	Granite Point Control 02	4.64	1.73	0.75	4.66	1.73	0.74
7	Granite Point Control 03	2.37	0.16	0.13	2.49	0.19	0.15
8	Furbish 02	8.28	0.72	0.17	8.28	0.72	0.17
9	Mile South 01	1.38	0.65	0.95	1.38	0.65	0.95
10	ME2	7.99	0.14	0.03	7.91	0.15	0.04
11	Mile South 03	5.88	2.66	0.91	5.88	2.66	0.91
12	Moody 2	0.64	1.06	3.33	0.64	1.06	3.33
13	Mile South 02	2.67	0.63	0.47	2.67	0.63	0.47
14	Harbor 02	-1.99	0.68	-0.68	-1.99	0.68	-0.68
15	Furbish 01	-16.12	20.64	-2.56	-16.12	20.64	-2.56
16	Mile North 03	-0.49	1.01	-4.17	-0.49	1.01	-4.17
17	Drakes 02	-0.83	1.93	-4.64	-0.83	1.93	-4.64
18	Bourne 2	-0.43	1.31	-6.07	-0.43	1.31	-6.07
19	Mile North 01	-0.36	0.87	-4.84	-0.36	0.87	-4.84
20	Moody 1	-5.89	0.71	-0.24	-5.89	0.71	-0.24
21	Furbish 03	-2.10	0.77	-0.74	-2.10	0.77	-0.74
22	Moody 3	-0.74	1.30	-3.54	-0.74	1.30	-3.54

Summary of Raw Data − Surface elevation change (mm)

Figure 2. Elevation change (mm) within Rachel Carson NWR. Means and SEs for each year (and within year visits) are shown along with overall linear trend. Figure 2. Elevation change (mm) within NA. Means and SEs for each year (and within year visits) are shown along with overall linear trend.

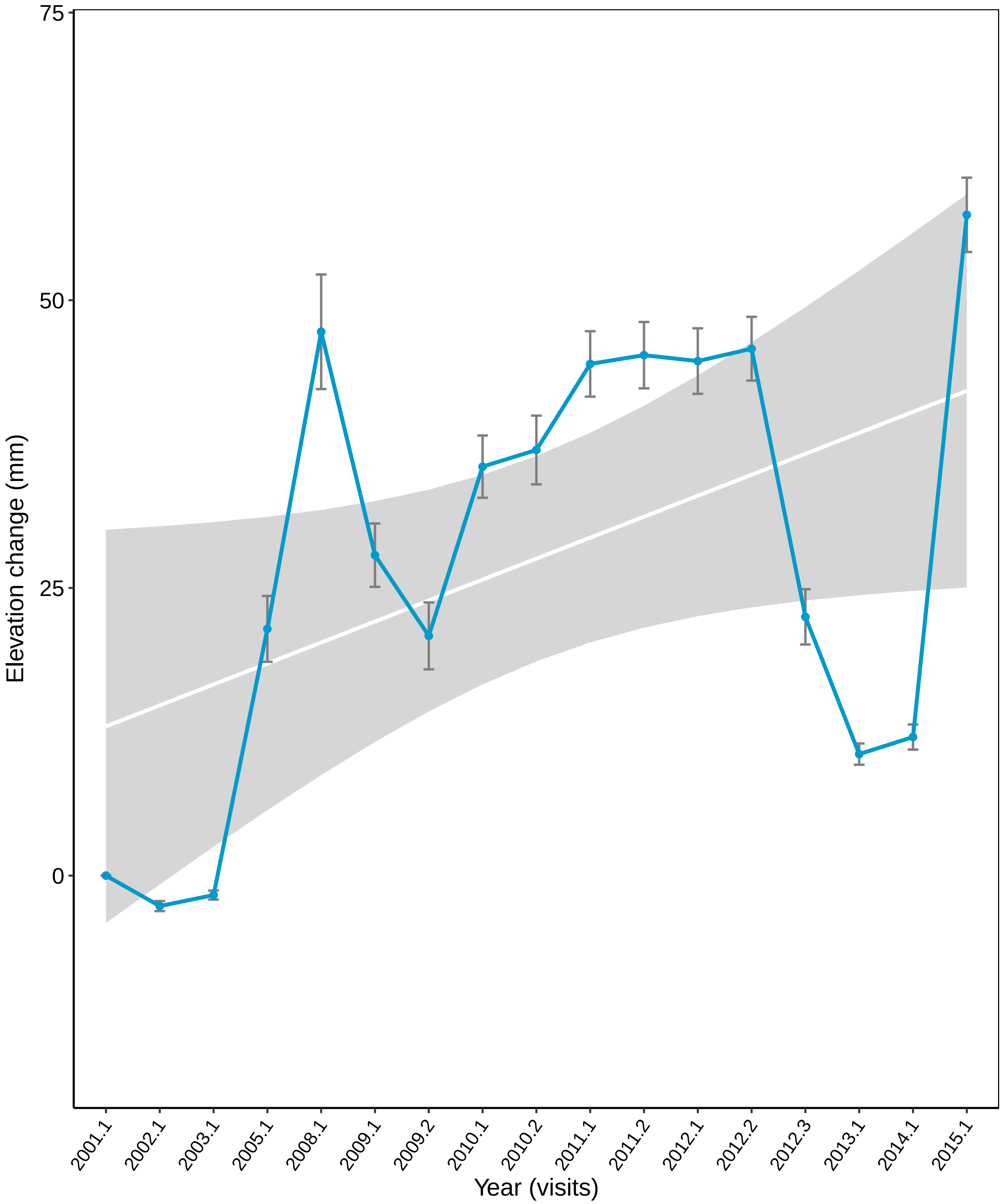


Figure 3. Summary of Site-level elevation change (mm) data within Rachel Carson NWR. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes. Figure 3. Summary of Site-level elevation change (mm) data within NA. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes.

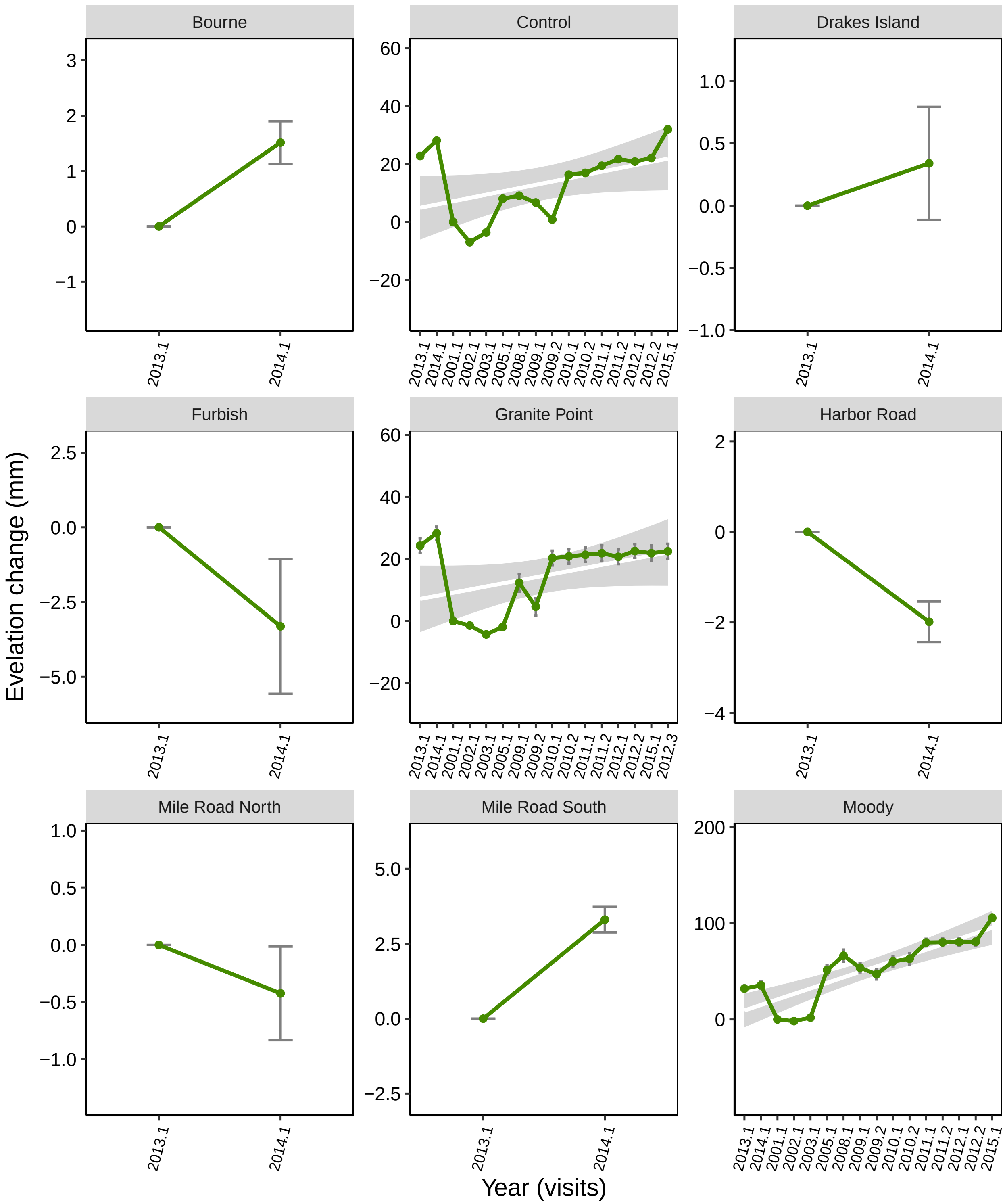
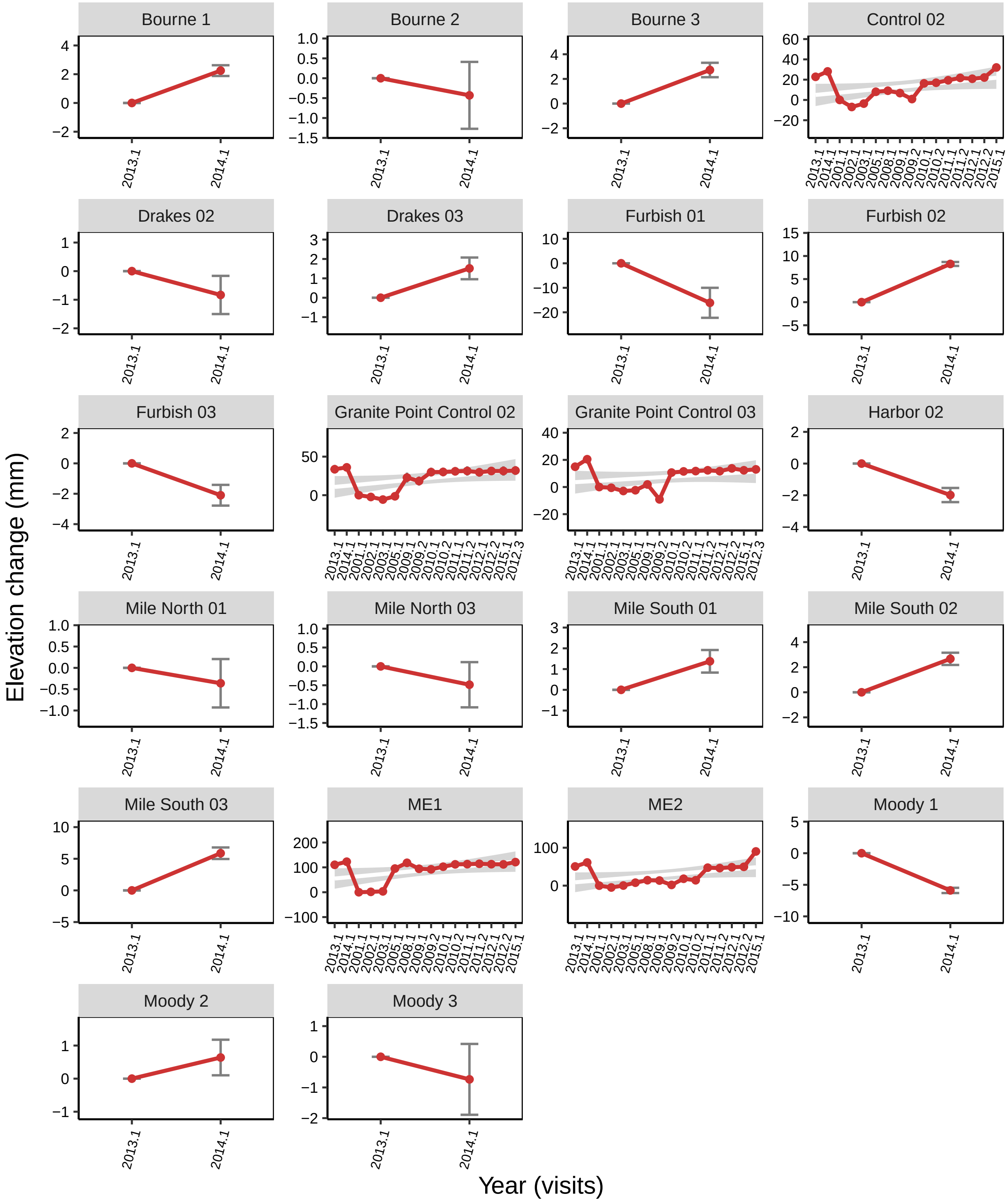


Figure 4. Summary of SET station-level elevation change (mm) data within Rachel Carson NWR. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes.



Parker River NWR

Surface elevation table (SET) data was collected within Parker River NWR at the following 9 SET stations (B2 1-80, B2 4-120, B2 5-40, Control 3-120, Control 3-40, Control 4-120, Knobb 01, SP01, SP02) between 2008 and 2014. Trends ranged from -1.9 to 10.48. Overall, the average refuge-level trend was 4.05 ± 1.2 (mean ± SE).

Trends of changes in Salt marsh Elevation (mm)

Figure 1. Map showing locations, trend directionality, and trend magnitude of SET stations within Parker River. Radii of positve (blue) and negative (red) points show the magnitude of linear trends.

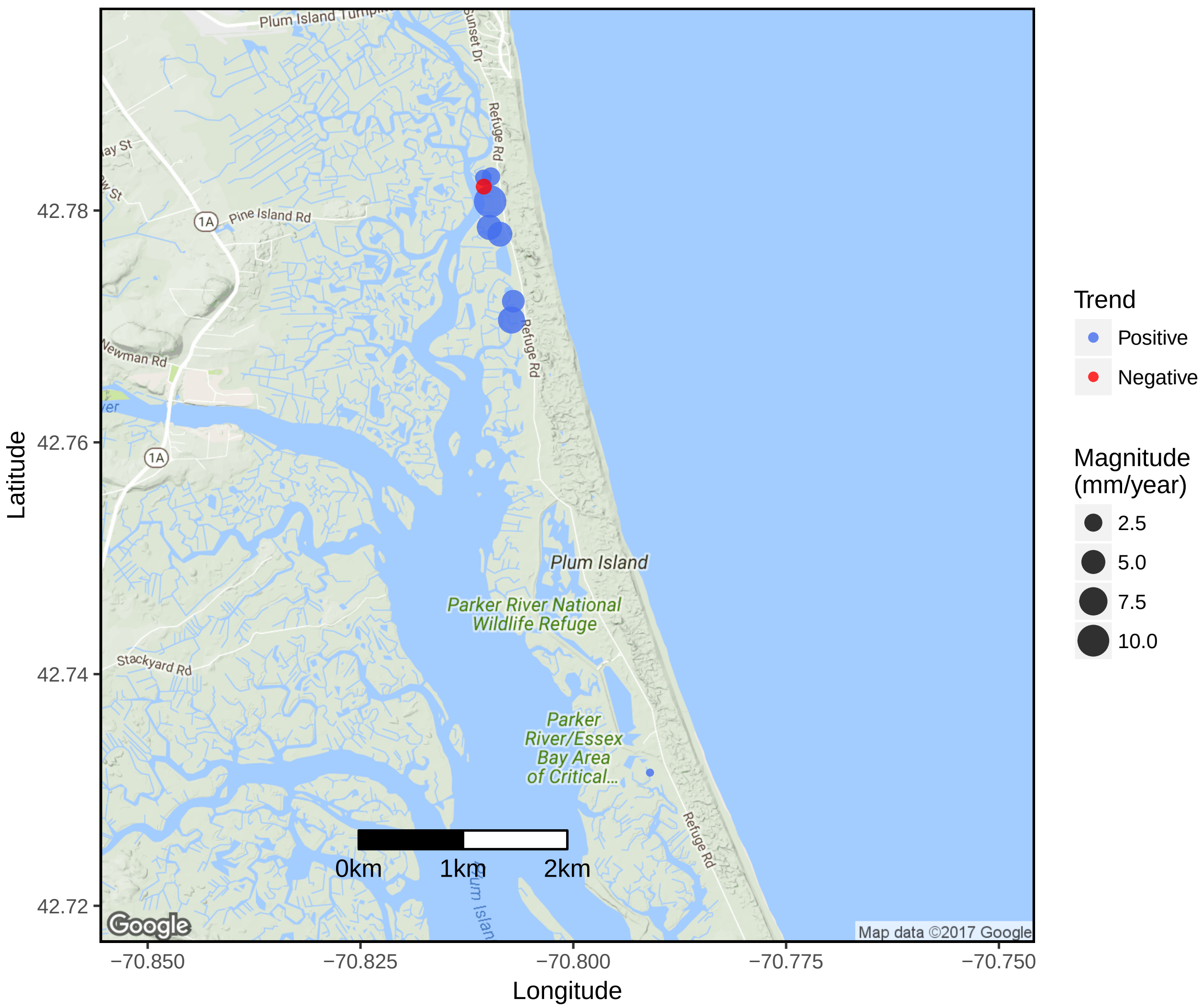


Table 1. Trends of surface elevation table (SET) stations within Parker River. Means and SEs for trends are shown for both linear models with and without observers.

	SET_Name	Mean	SE	CV	Mean.obs	SE.obs	CV.obs
1	B2 1-80	13.01	1.46	0.22	10.48	1.72	0.33
2	B2 4-120	7.67	0.20	0.05	5.69	0.71	0.25
3	B2 5-40	8.25	1.46	0.35	5.47	1.11	0.41
4	Control 3-120	2.06	0.26	0.26	2.06	0.26	0.25
5	Control 3-40	2.64	0.87	0.66	2.65	0.92	0.69
6	Knobb 01	0.90	1.62	3.58	0.90	1.62	3.58
7	SP01	4.38	1.08	0.50	4.38	1.08	0.50
8	SP02	6.72	2.95	0.88	6.72	2.95	0.88
9	Control 4-120	-1.90	0.23	-0.25	-1.90	0.23	-0.25

Summary of Raw Data − Surface elevation change (mm)

Figure 2. Elevation change (mm) within Parker River NWR. Means and SEs for each year (and within year visits) are shown along with overall linear trend.

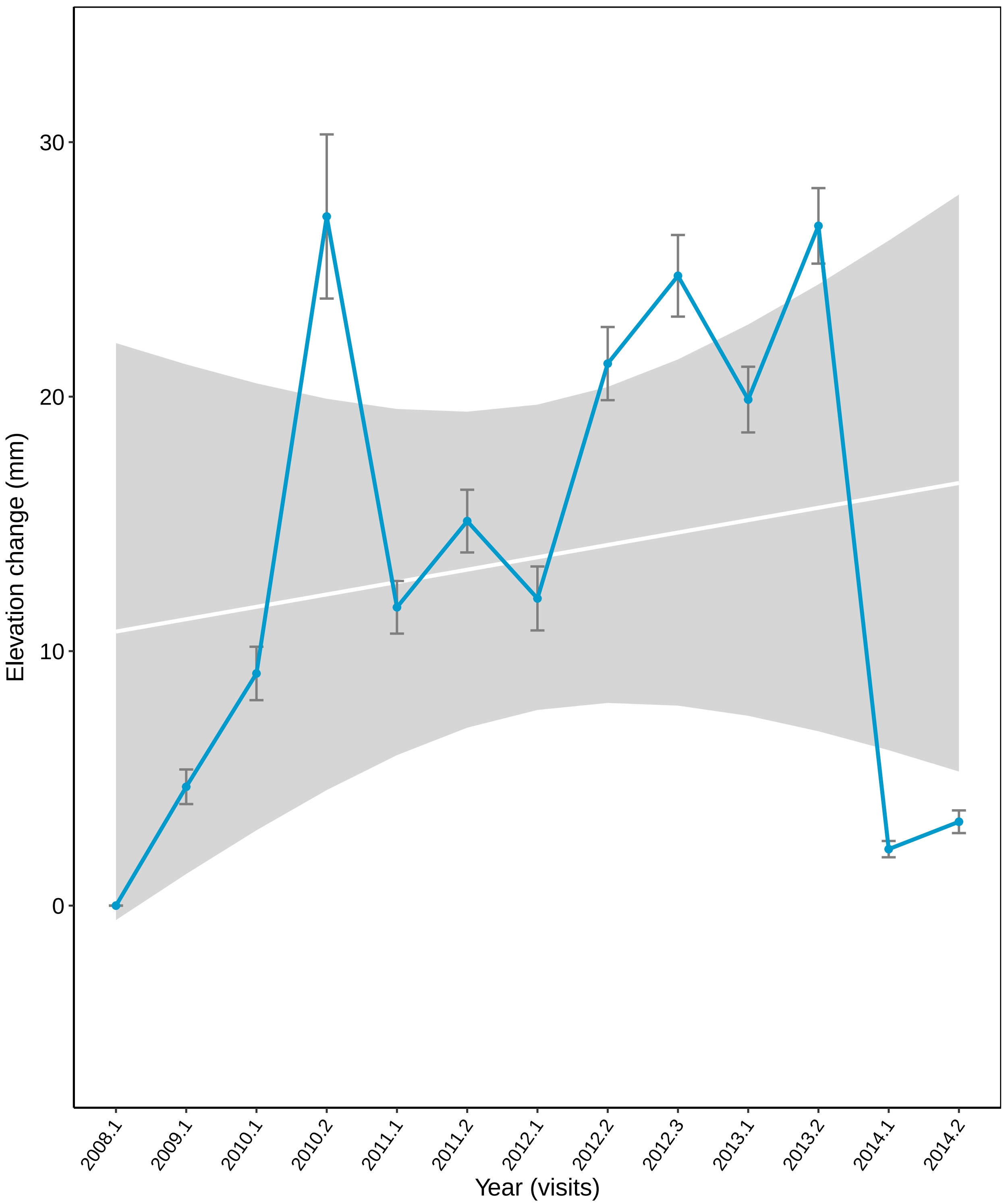


Figure 3. Summary of Site-level elevation change (mm) data within Parker River NWR. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes.

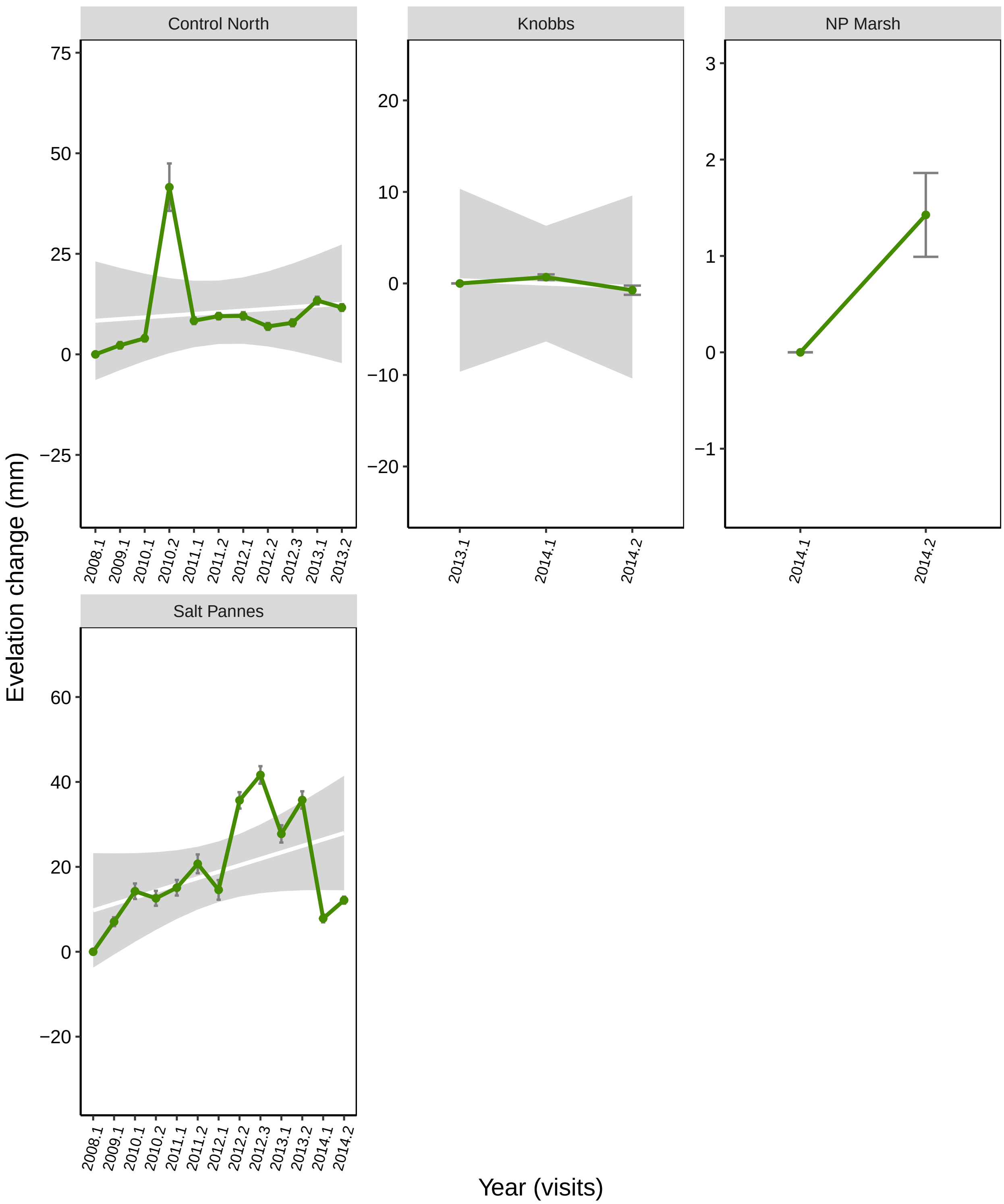
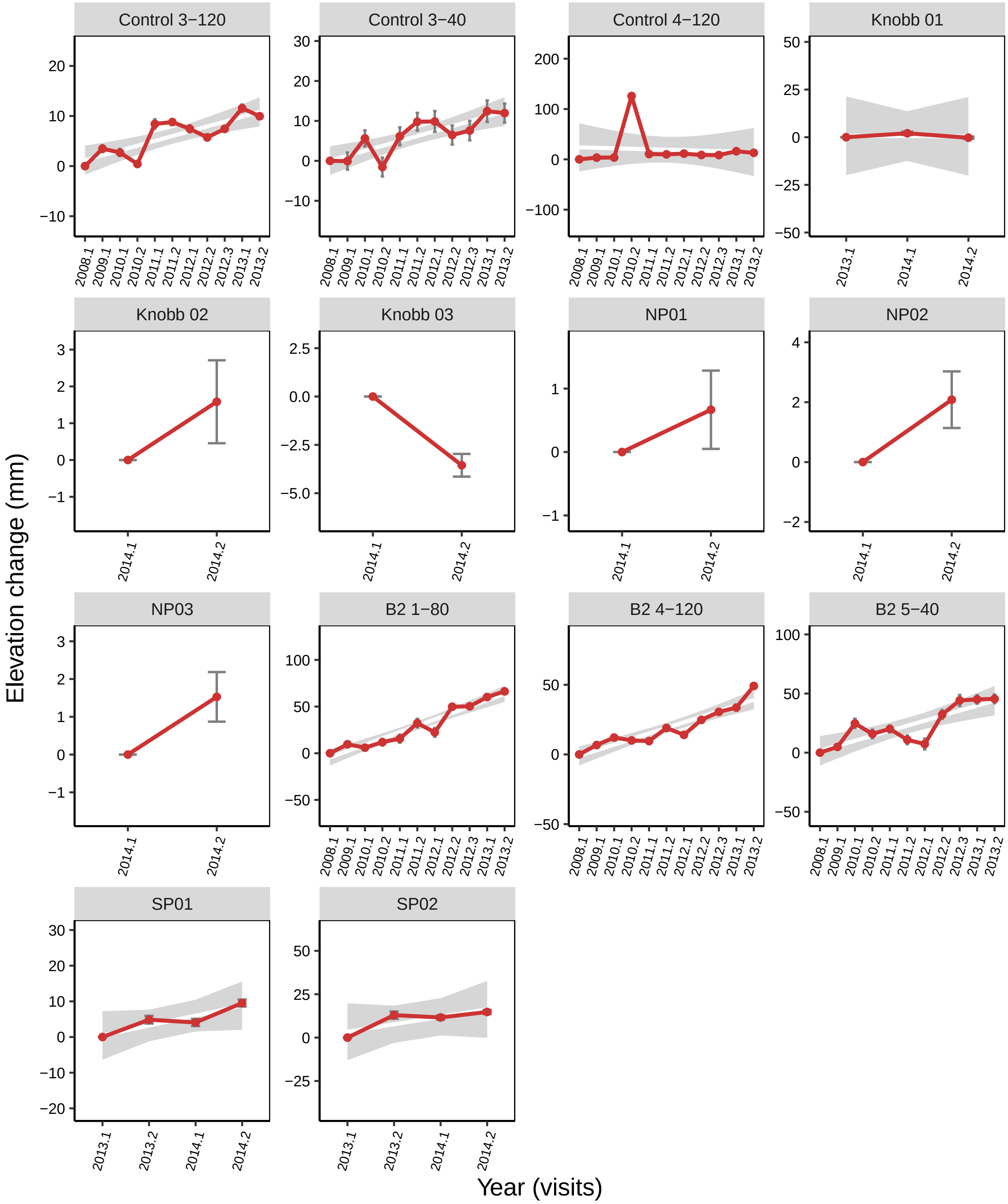


Figure 4. Summary of SET station-level elevation change (mm) data within Parker River NWR. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes.



Sachuest Point NWR

Surface elevation table (SET) data was collected within Sachuest Point NWR at the following 6 SET stations (SPT01, SPT02, SPT03, SPT04, SPT05, SPT06) between 2004 and 2015. Trends ranged from 0.85 to 6.47. Overall, the average refuge-level trend was 2.75 ± 0.92 (mean ± SE).

Trends of changes in Salt marsh Elevation (mm)

Figure 1. Map showing locations, trend directionality, and trend magnitude of SET stations within Sachuest Point. Radii of positve (blue) and negative (red) points show the magnitude of linear trends.

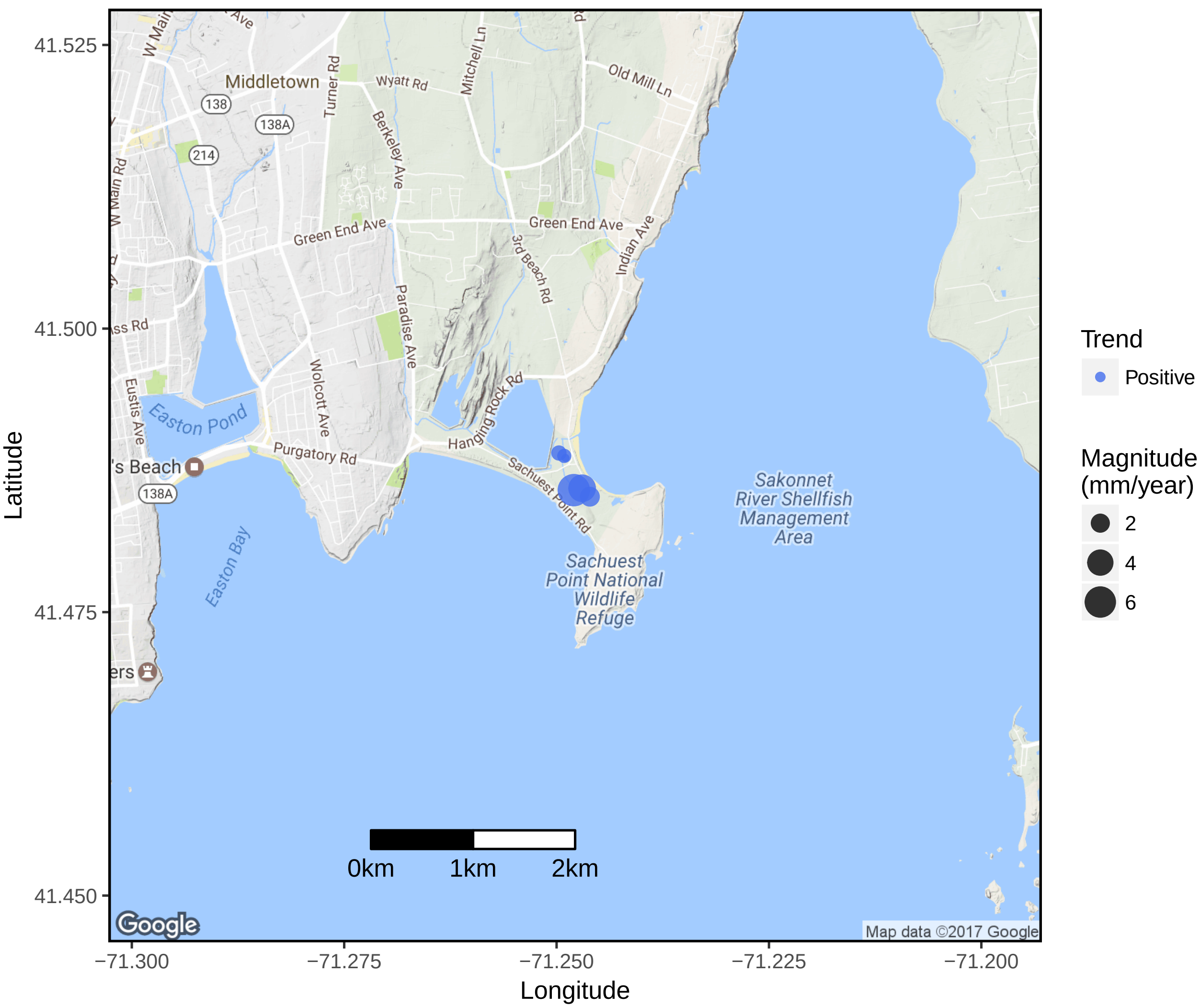


Table 1. Trends of surface elevation table (SET) stations within Sachuest Point. Means and SEs for trends are shown for both linear models with and without observers.

	SET_Name	Mean	SE	CV	Mean.obs	SE.obs	CV.obs
1	SPT01	6.00	0.21	0.07	6.47	0.14	0.04
2	SPT02	5.26	1.31	0.50	4.47	1.02	0.46
3	SPT03	2.21	0.45	0.41	2.16	0.42	0.39
4	SPT04	2.63	0.81	0.61	0.85	0.08	0.19
5	SPT05	2.27	0.67	0.59	1.20	0.36	0.60
6	SPT06	3.55	0.19	0.11	1.33	0.19	0.29

Summary of Raw Data − Surface elevation change (mm)

Figure 2. Elevation change (mm) within Sachuest Point NWR. Means and SEs for each year (and within year visits) are shown along with overall linear trend.

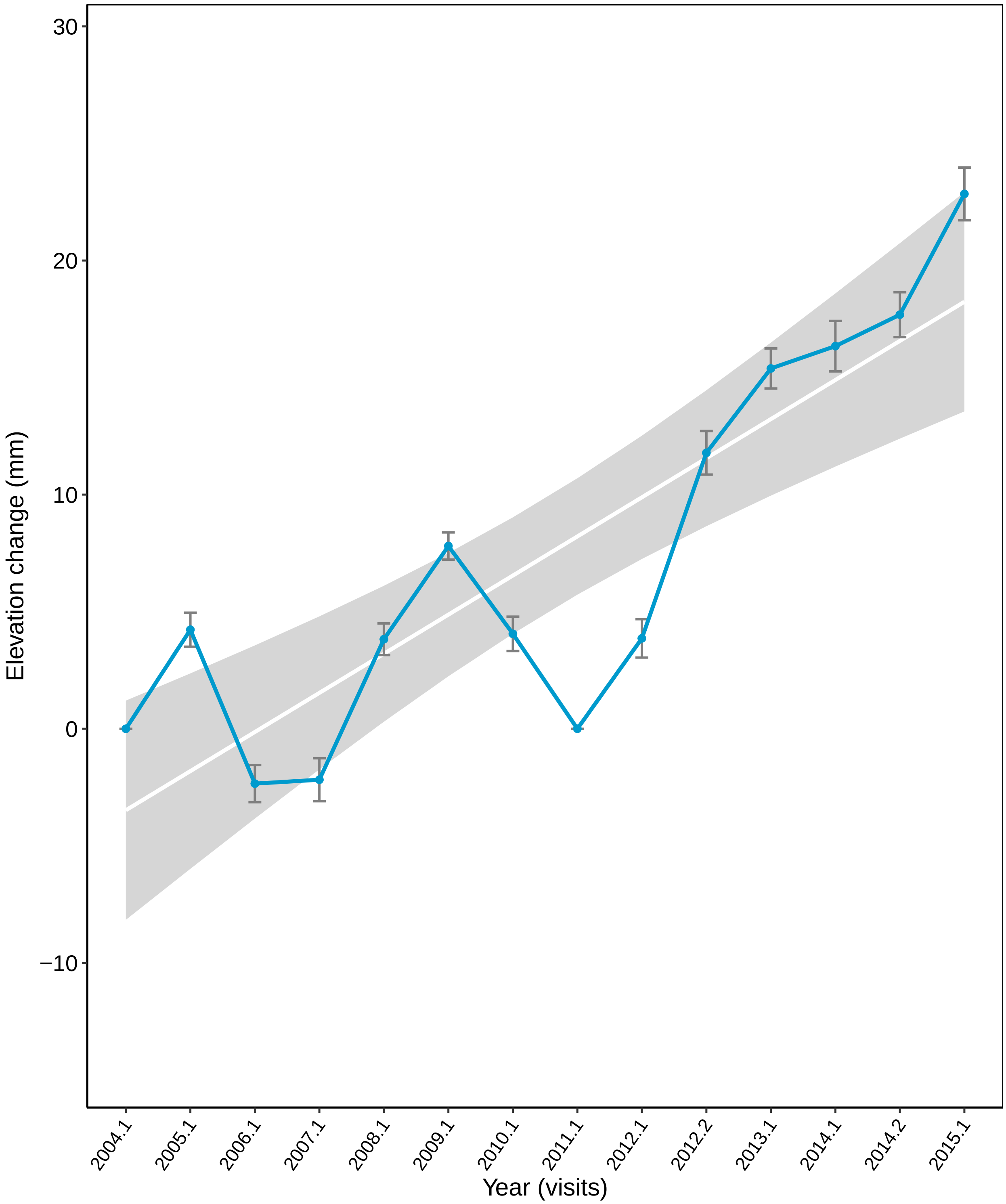


Figure 3. Summary of Site-level elevation change (mm) data within Sachuest Point NWR. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes.

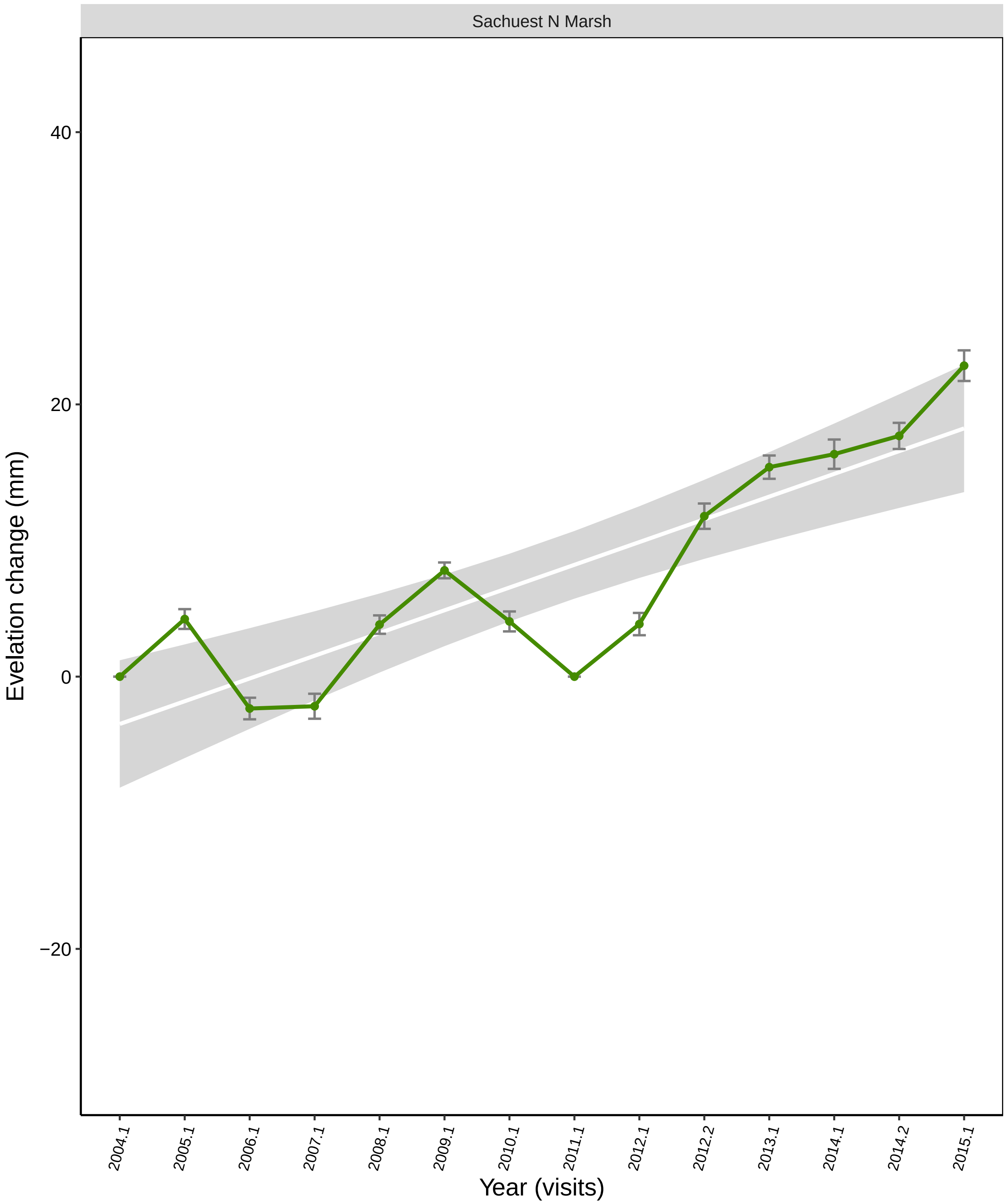
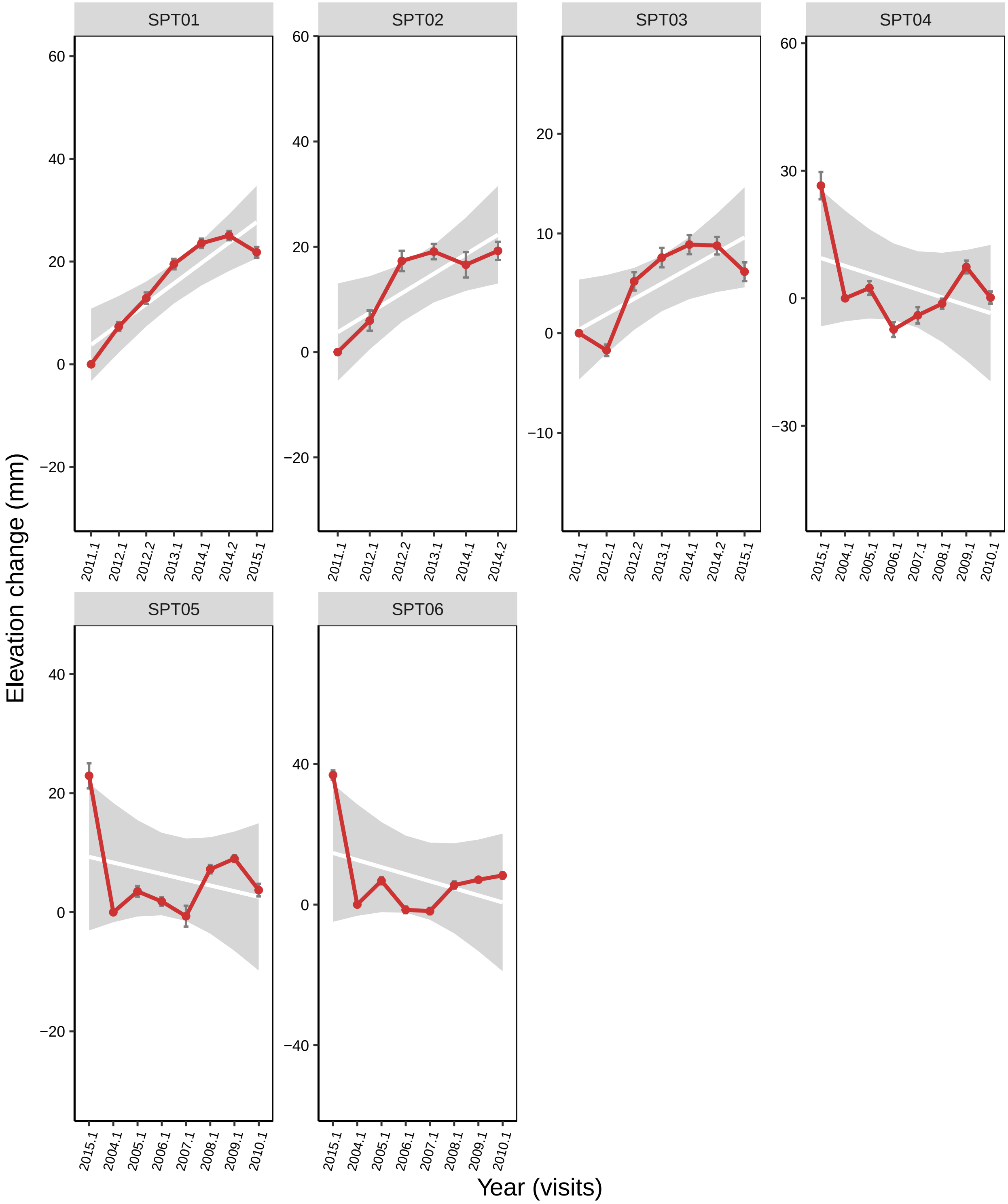


Figure 4. Summary of SET station-level elevation change (mm) data within Sachuest Point NWR. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes.



John H Chaffee NWR

Surface elevation table (SET) data was collected within John H Chaffee NWR at the following 7 SET stations (JHC01, JHC02, JHC03, JHC04, JHC05, JHC06, JHC07) between 2011 and 2015. Trends ranged from 0.11 to 3.77. Overall, the average refuge-level trend was 1.59 $\pm$ 0.6 (mean $\pm$ SE).

Trends of changes in Salt marsh Elevation (mm)

Figure 1. Map showing locations, trend directionality, and trend magnitude of SET stations within John H Chaffee. Radii of positve (blue) and negative (red) points show the magnitude of linear trends.

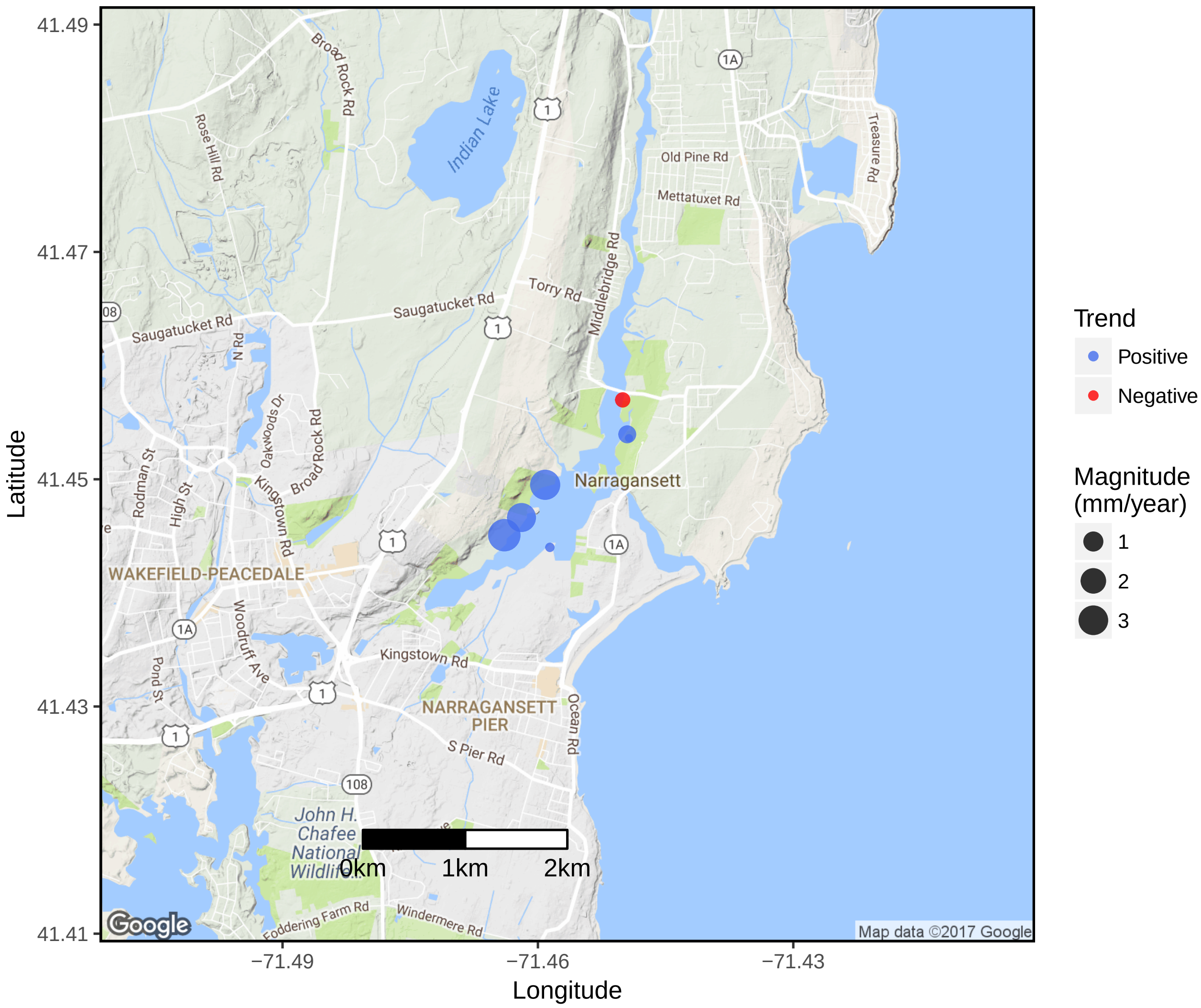


Table 1. Trends of surface elevation table (SET) stations within John H Chaffee. Means and SEs for trends are shown for both linear models with and without observers.

	SET_Name	Mean	SE	CV	Mean.obs	SE.obs	CV.obs
1	JHC01	0.48	0.33	1.39	0.12	0.08	1.41
2	JHC02	3.87	0.67	0.35	3.77	0.59	0.31
3	JHC03	3.02	0.63	0.42	2.83	0.68	0.48
4	JHC04	3.27	0.52	0.32	3.14	0.47	0.30
5	JHC05	0.71	0.25	0.70	0.11	0.48	8.76
6	JHC06	1.33	0.09	0.13	0.71	0.41	1.15
7	JHC07	-0.61	0.55	-1.80	0.43	0.93	4.31

Summary of Raw Data − Surface elevation change (mm)

Figure 2. Elevation change (mm) within John H Chaffee NWR. Means and SEs for each year (and within year visits) are shown along with overall linear trend.

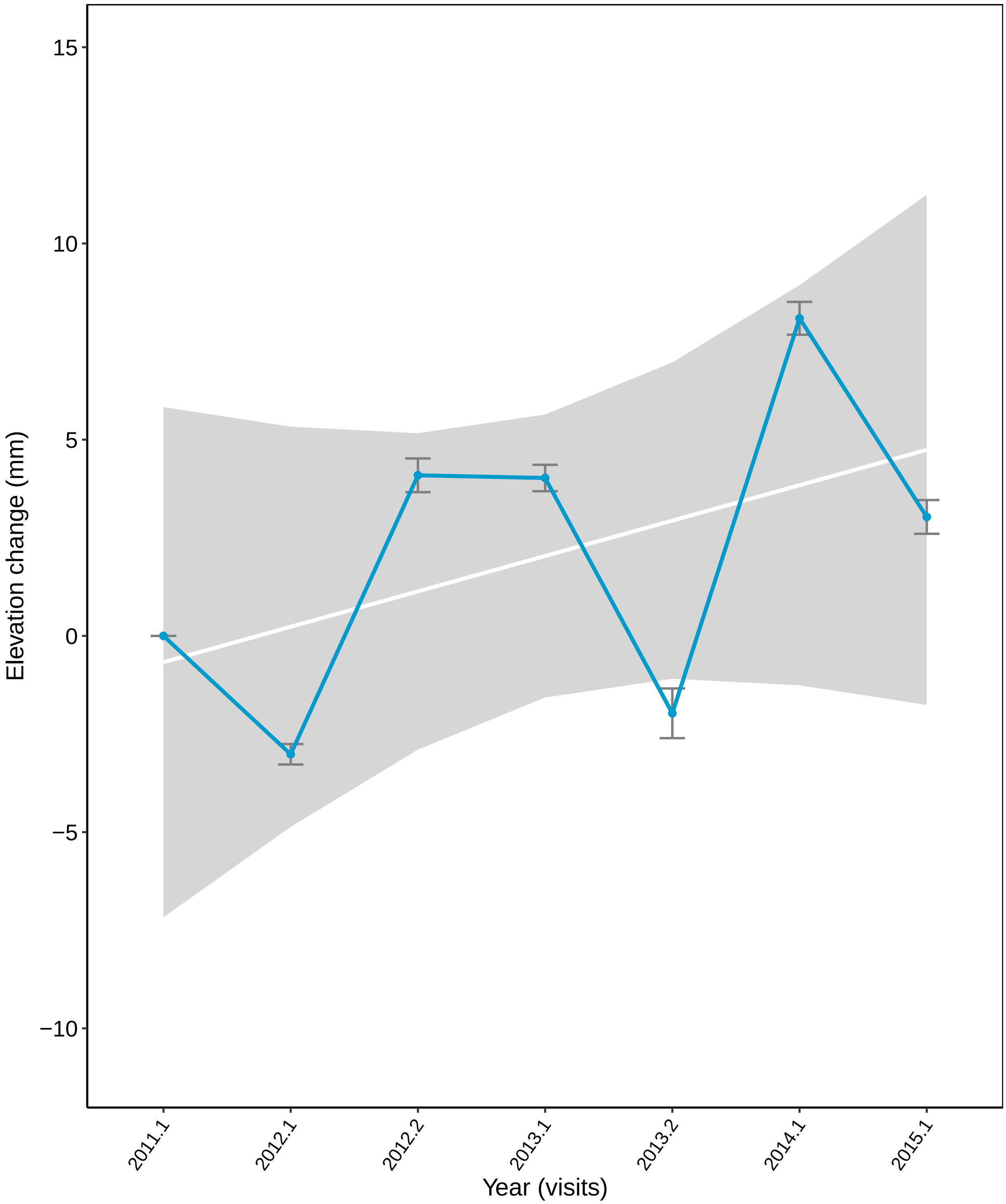


Figure 3. Summary of Site-level elevation change (mm) data within John H Chaffee NWR. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes.

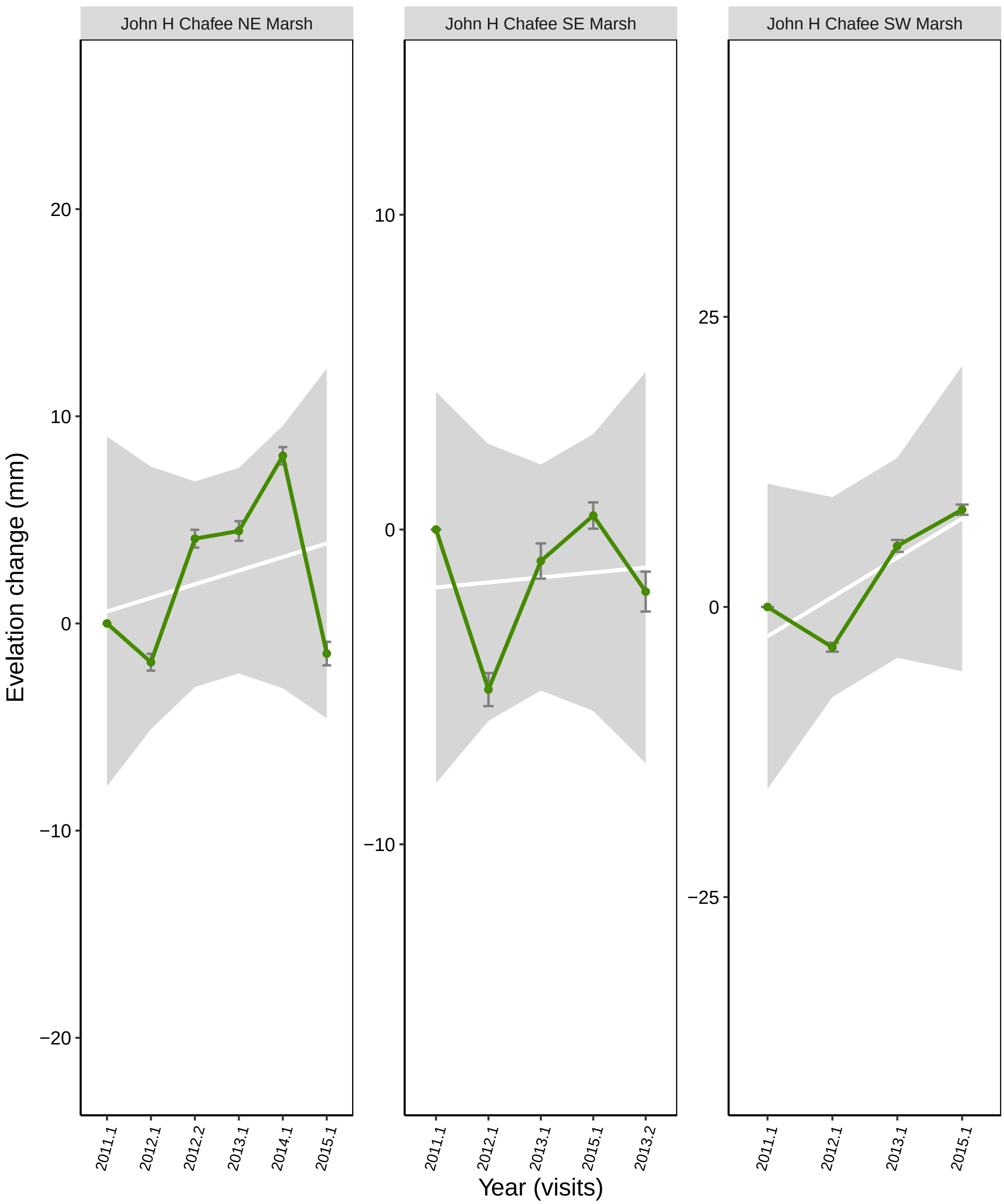
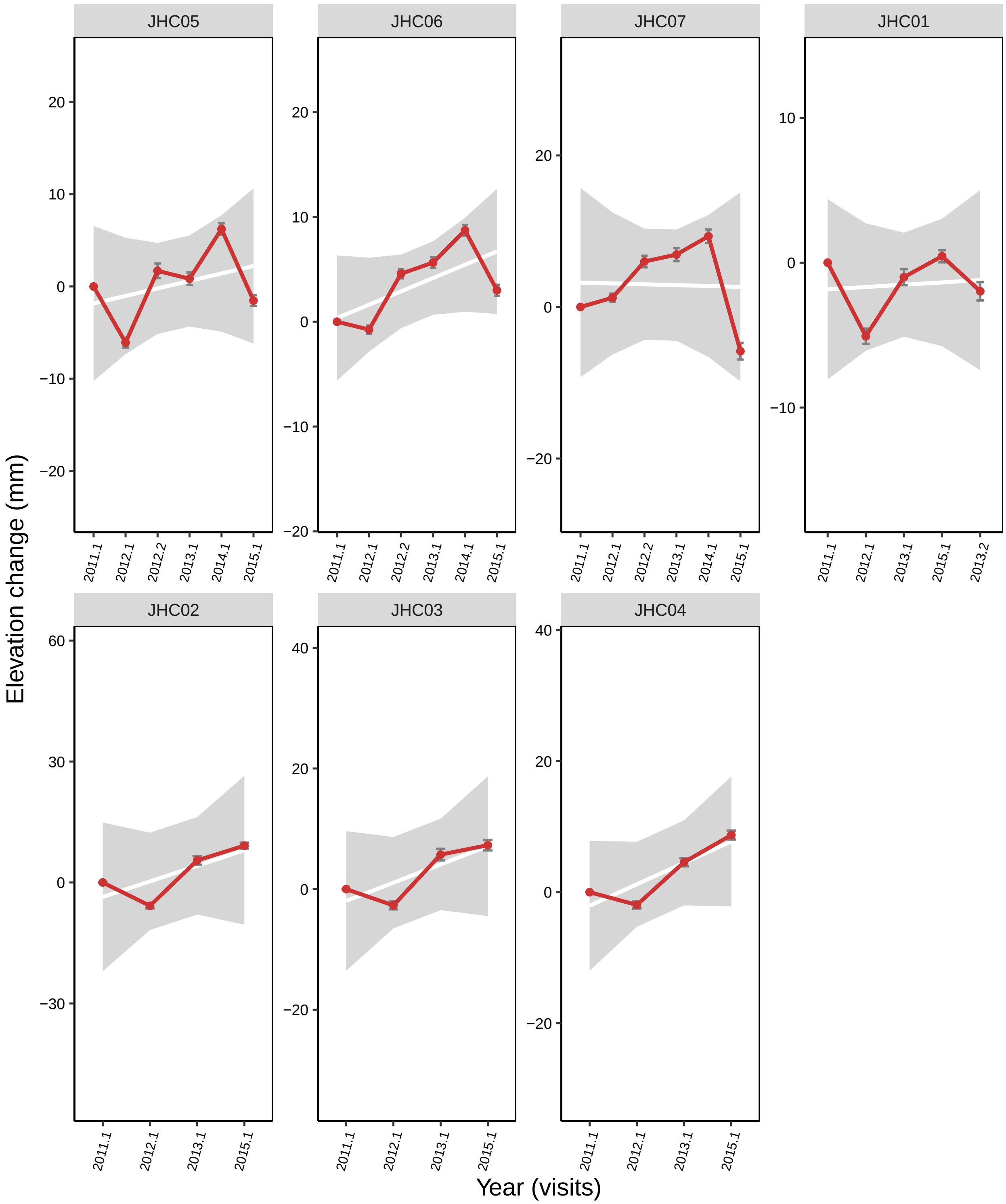


Figure 4. Summary of SET station-level elevation change (mm) data within John H Chaffee NWR. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes.



Oyster Bay NWR

Surface elevation table (SET) data was collected within Oyster Bay NWR at the following 2 SET stations (FC01, FC03) between 2012 and 2014. Trends ranged from -0.03 to 4.78. Overall, the average refuge-level trend was 2.37 ± 2.4 (mean ± SE).

Trends of changes in Salt marsh Elevation (mm)

Figure 1. Map showing locations, trend directionality, and trend magnitude of SET stations within Oyster Bay. Radii of positve (blue) and negative (red) points show the magnitude of linear trends.

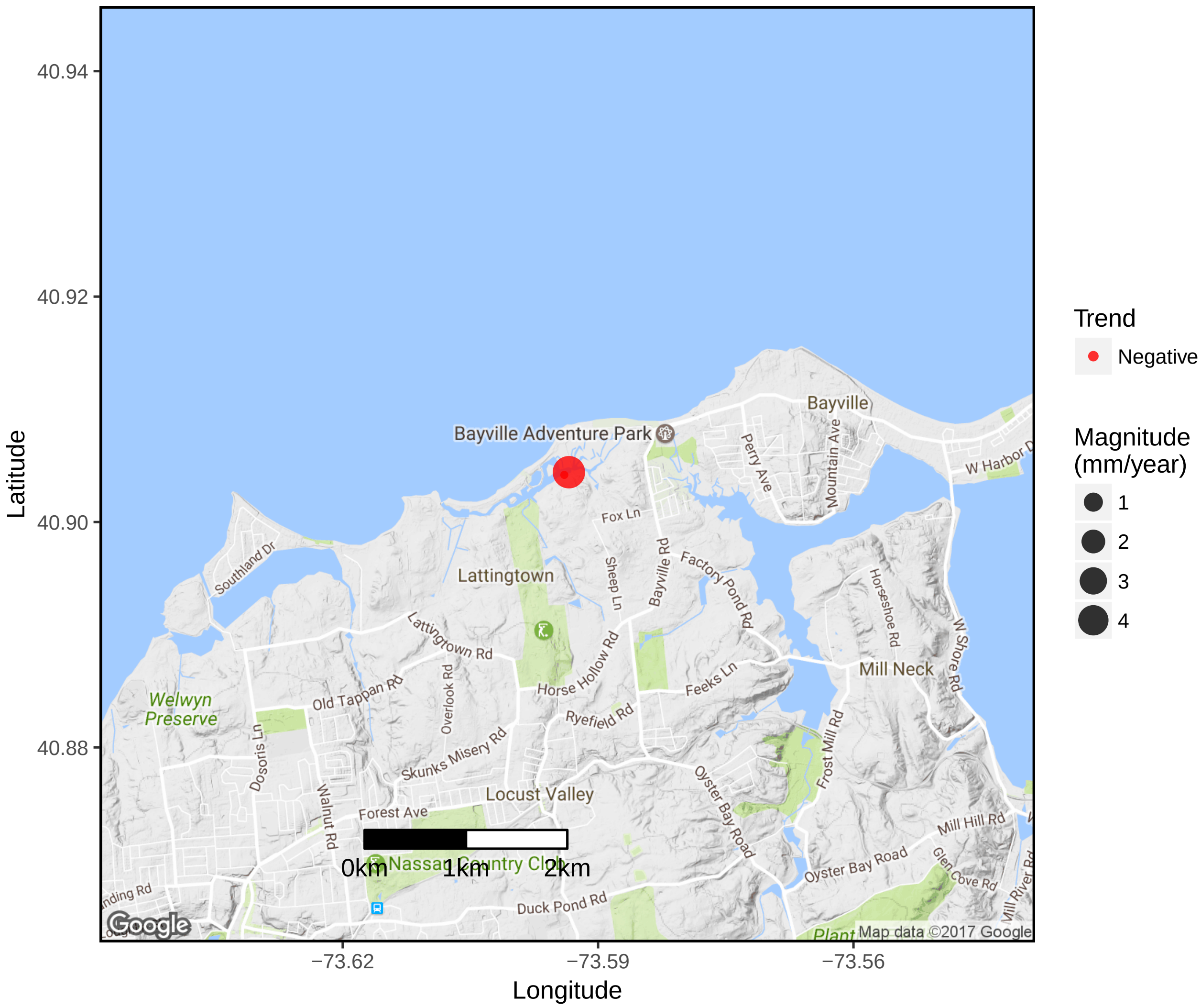


Table 1. Trends of surface elevation table (SET) stations within Oyster Bay. Means and SEs for trends are shown for both linear models with and without observers.

	SET_Name	Mean	SE	CV	Mean.obs	SE.obs	CV.obs
1	FC01	-0.90	0.82	-1.83	4.78	3.16	1.32
2	FC03	-2.81	1.98	-1.41	-0.03	2.20	-154.00

Summary of Raw Data − Surface elevation change (mm)

Figure 2. Elevation change (mm) within Oyster Bay NWR. Means and SEs for each year (and within year visits) are shown along with overall linear trend.

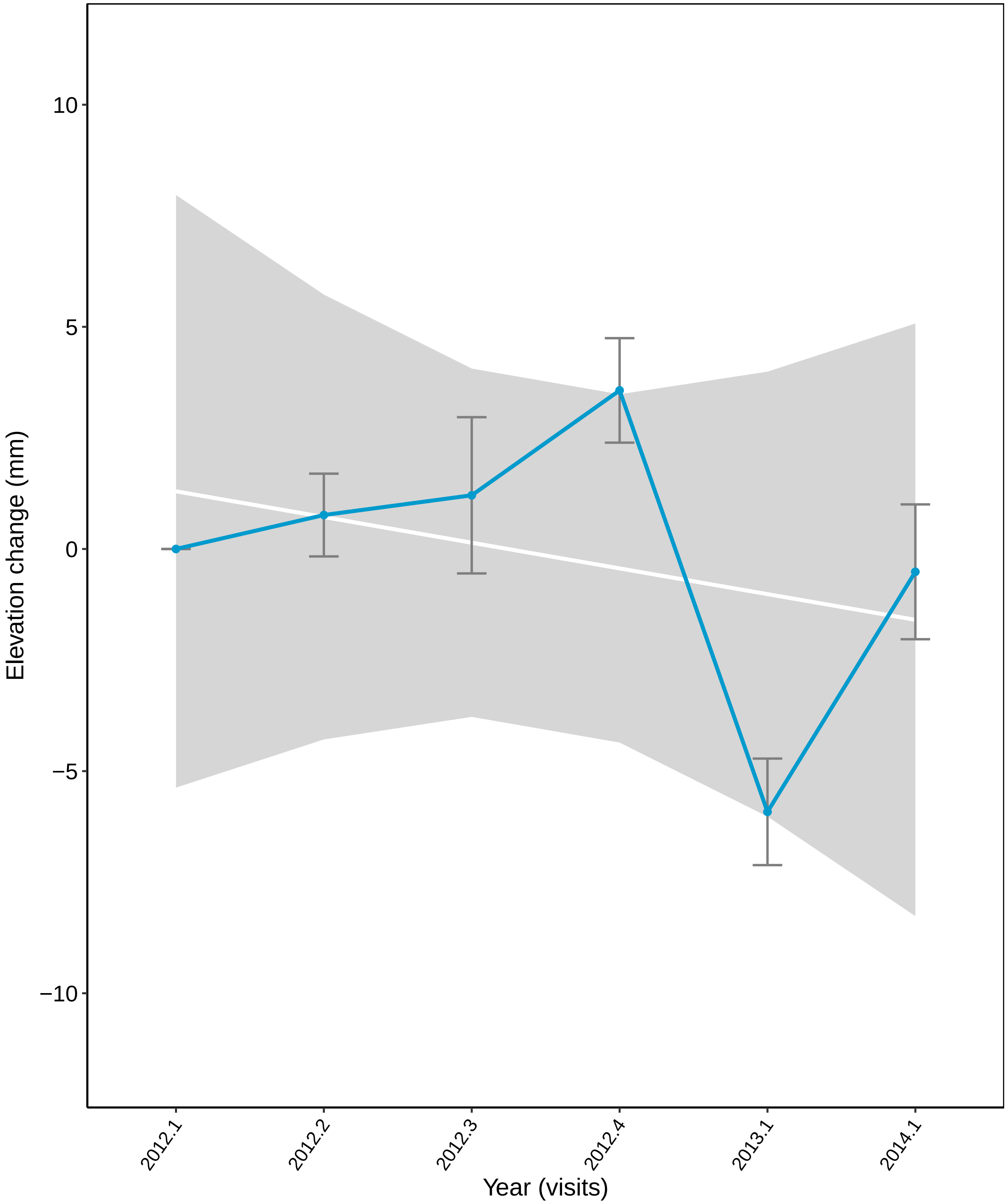


Figure 3. Summary of Site-level elevation change (mm) data within Oyster Bay NWR. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes.

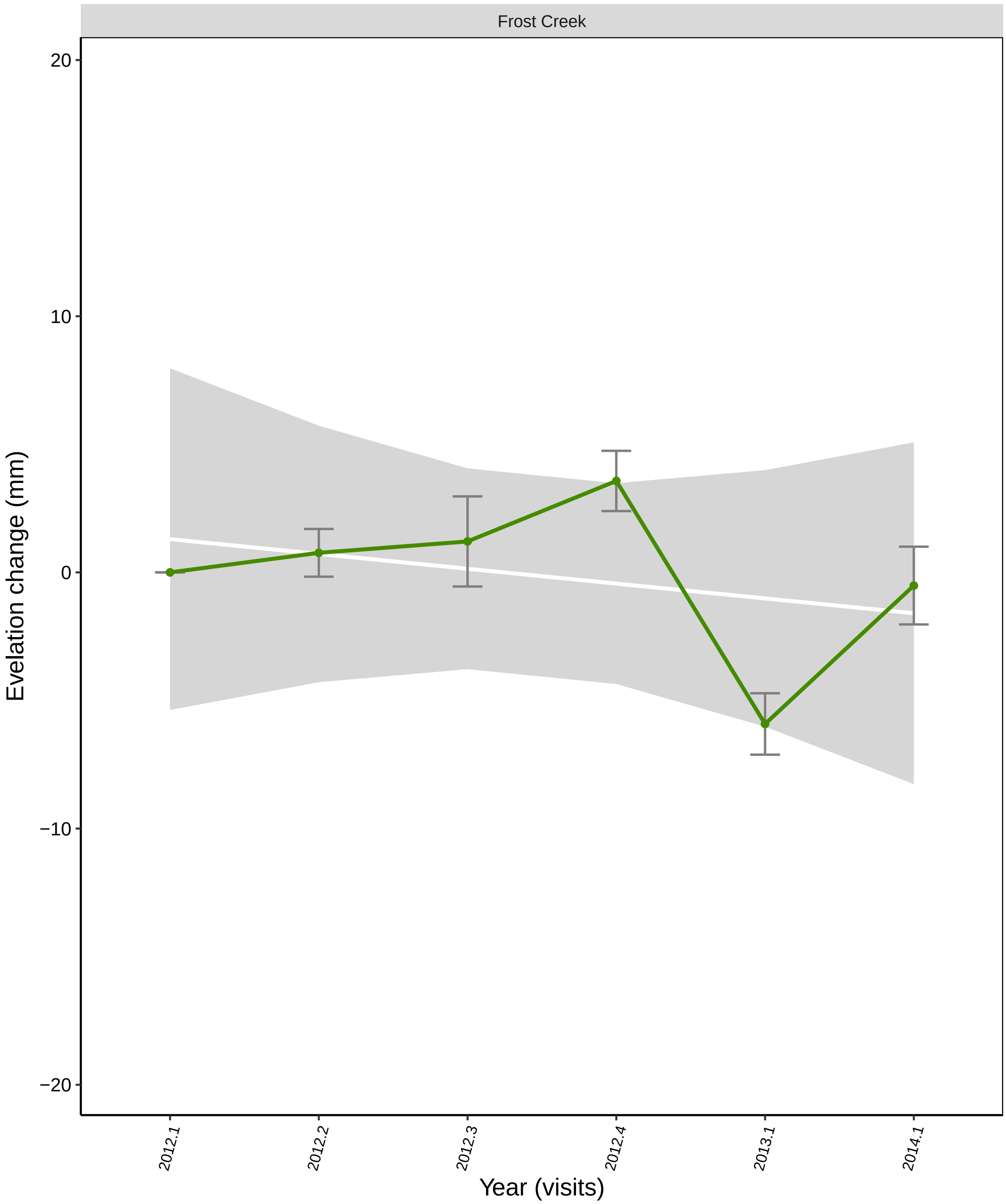
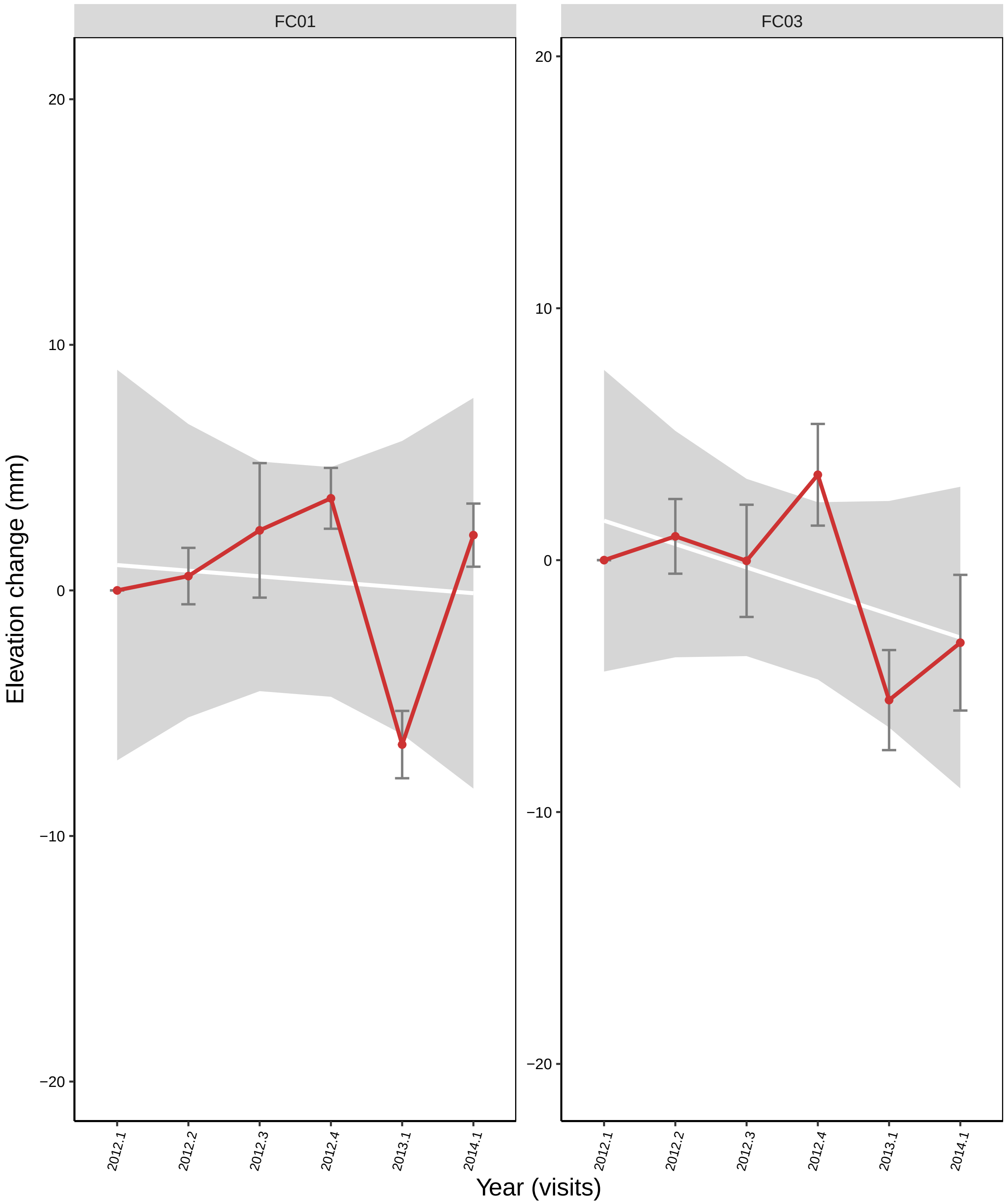


Figure 4. Summary of SET station-level elevation change (mm) data within Oyster Bay NWR. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes.



Wertheim NWR

Surface elevation table (SET) data was collected within Wertheim NWR at the following 12 SET stations (SP1, SP2, SP3, WEU1, WEU2, WEU3, WNU1, WNU2, WNU3, WWU1, WWU2, WWU3) between 2009 and 2014. Trends ranged from -3.08 to 12.09. Overall, the average refuge-level trend was 4.1 ± 1.14 (mean ± SE).

Trends of changes in Salt marsh Elevation (mm)

Figure 1. Map showing locations, trend directionality, and trend magnitude of SET stations within Wertheim. Radii of positve (blue) and negative (red) points show the magnitude of linear trends.

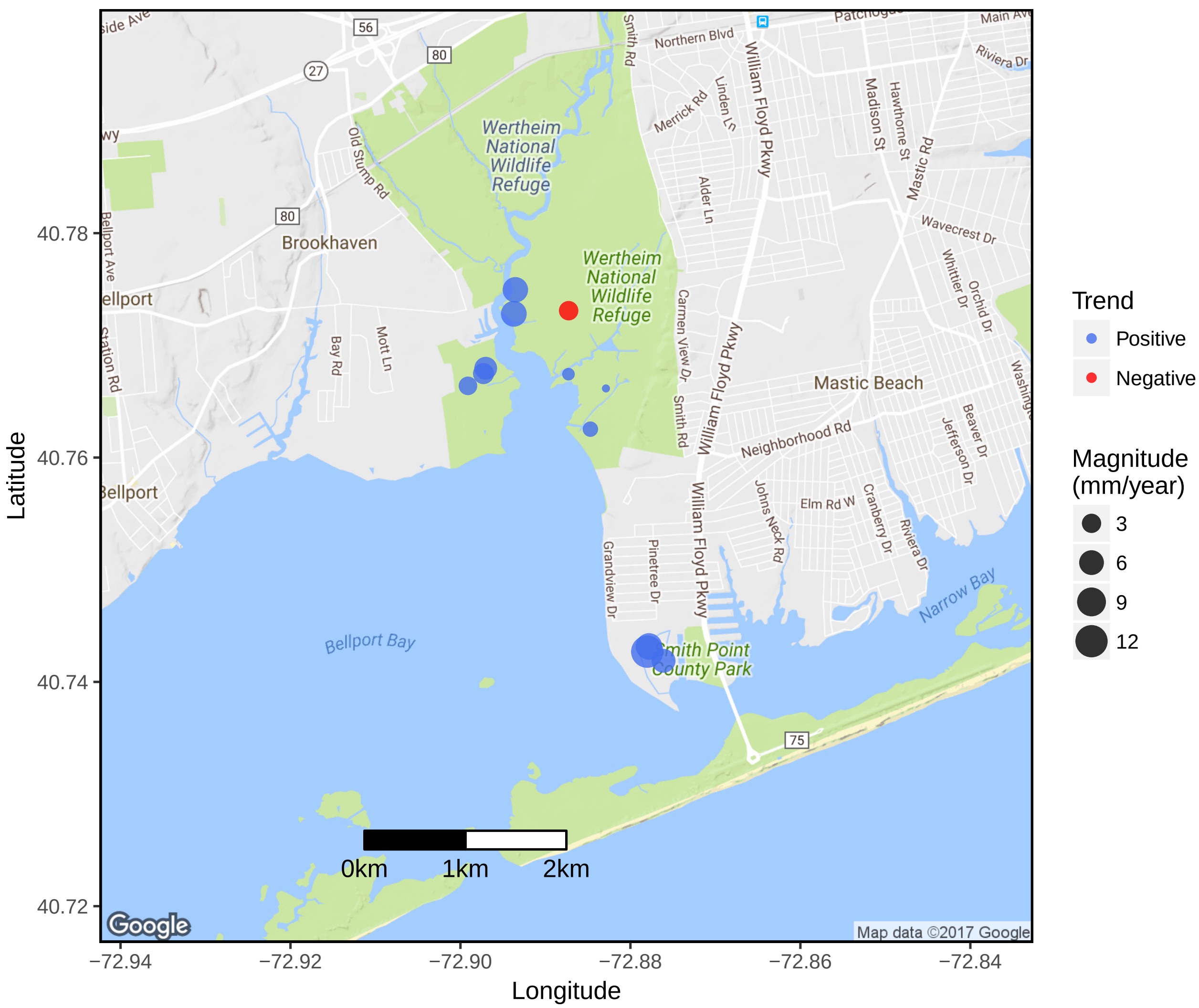


Table 1. Trends of surface elevation table (SET) stations within Wertheim. Means and SEs for trends are shown for both linear models with and without observers.

	SET_Name	Mean	SE	CV	Mean.obs	SE.obs	CV.obs
1	SP1	7.54	0.84	0.22	7.26	0.77	0.21
2	SP2	11.90	1.59	0.27	12.09	1.44	0.24
3	SP3	5.38	0.53	0.20	5.43	0.51	0.19
4	WEU1	2.24	2.32	2.07	1.59	2.23	2.80
5	WEU2	3.72	0.73	0.39	0.54	0.67	2.51
6	WEU3	1.88	2.26	2.41	0.94	1.85	3.92
7	WNU1	6.78	1.04	0.31	6.68	1.48	0.44
8	WNU2	7.10	2.76	0.78	6.47	3.15	0.97
9	WWU1	4.74	0.50	0.21	4.79	0.46	0.19
10	WWU2	3.75	0.26	0.14	3.83	0.26	0.14
11	WWU3	2.61	0.40	0.31	2.70	0.35	0.26
12	WNU3	-1.60	1.78	-2.23	-3.08	3.72	-2.41

Summary of Raw Data − Surface elevation change (mm)

Figure 2. Elevation change (mm) within Wertheim NWR. Means and SEs for each year (and within year visits) are shown along with overall linear trend.

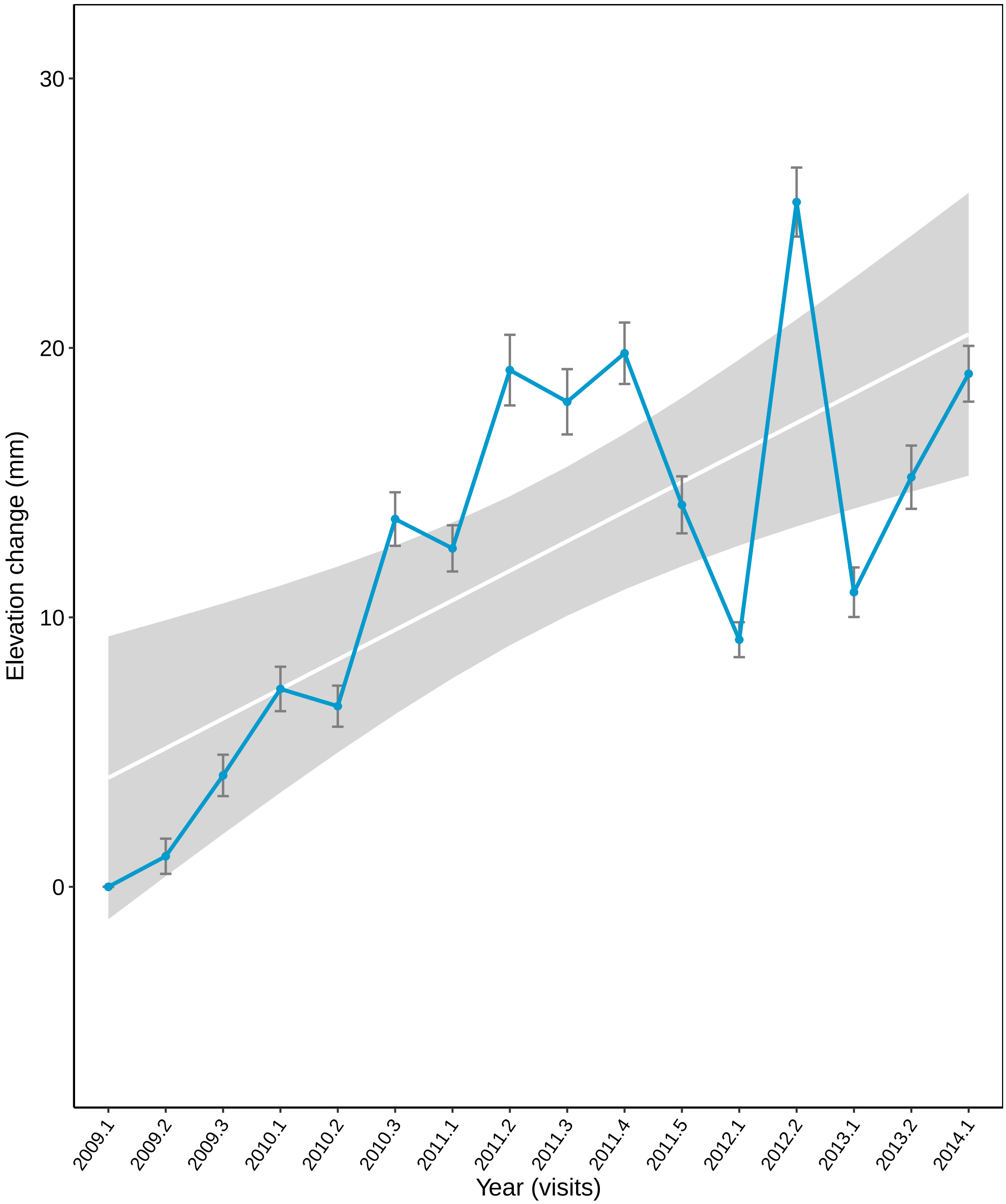


Figure 3. Summary of Site-level elevation change (mm) data within Wertheim NWR. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes.

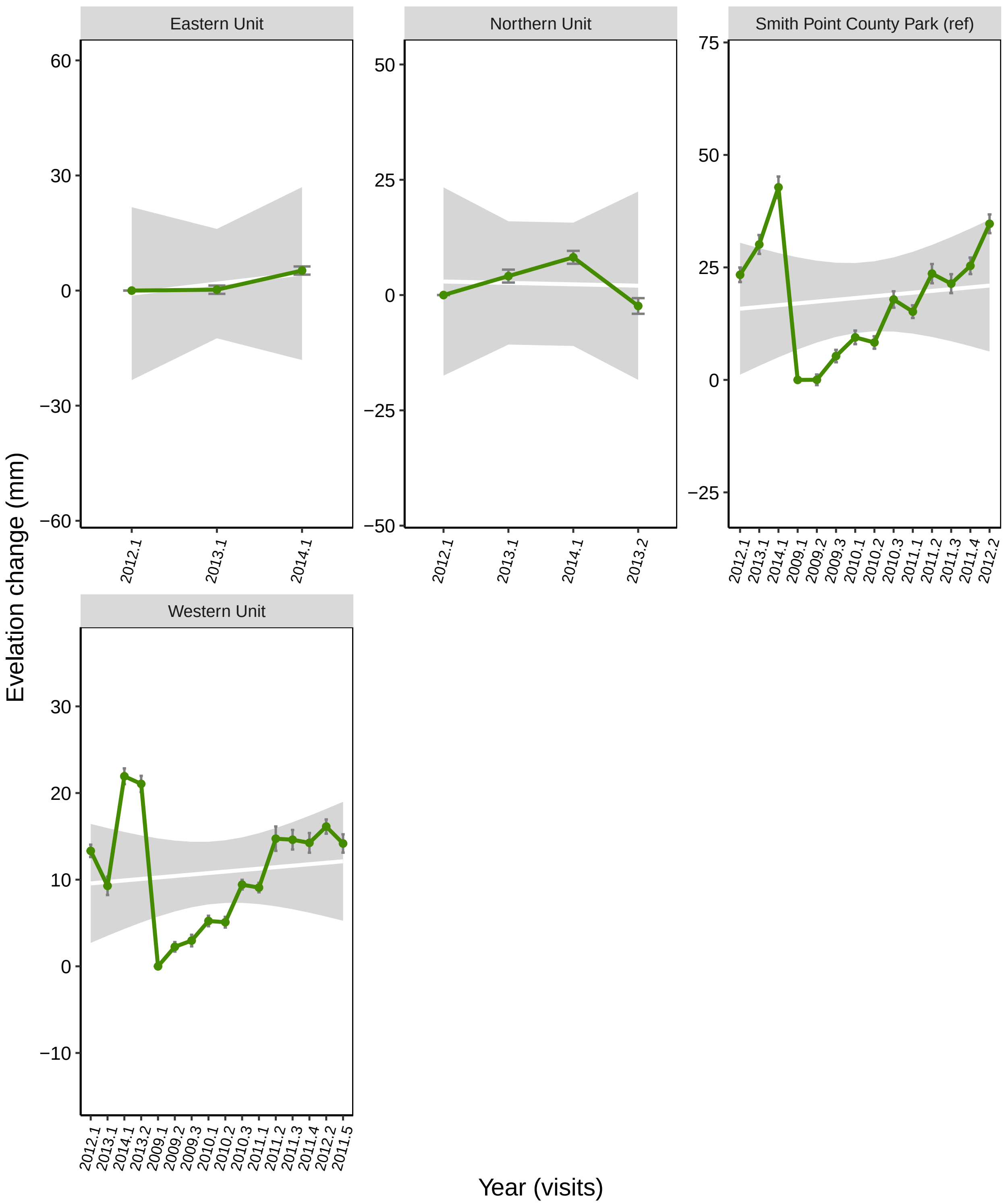
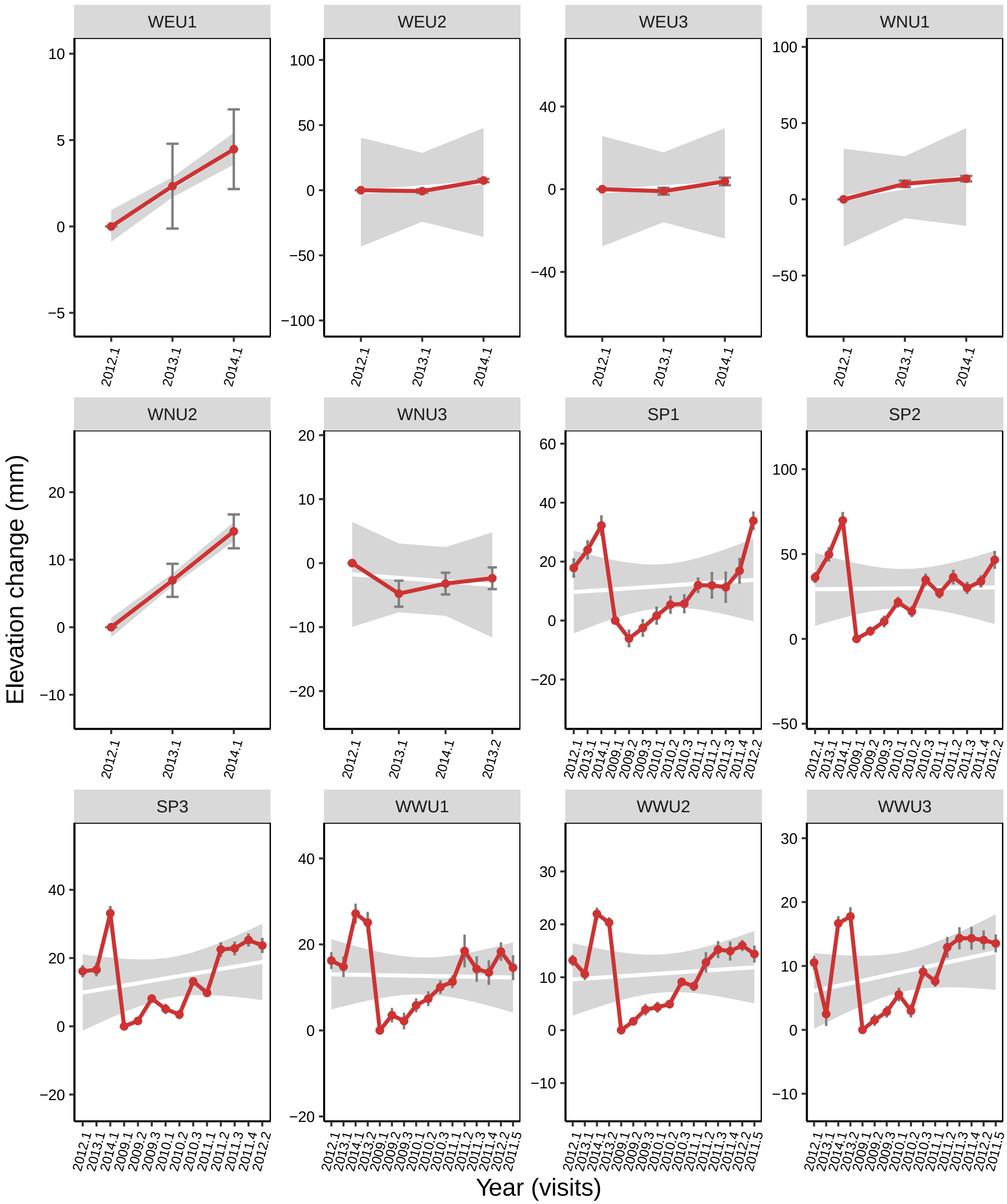


Figure 4. Summary of SET station-level elevation change (mm) data within Wertheim NWR. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes.



Edwin B. Forsythe NWR

Surface elevation table (SET) data was collected within Edwin B. Forsythe NWR at the following 19 SET stations (AT&T Control SET 01, AT&T Control SET 02, AT&T Control SET 03, AT&T SMI 07, AT&T SMI 08, AT&T SMI 09, AT&T Treatment SET 04, AT&T Treatment SET 05, AT&T Treatment SET 06, LB-surf 1, LB-surf 2, Mill Crk-Cedar Run SET Purple 01, Mill Crk-Cedar Run SET Purple 02, Mill Crk-Cedar Run SET Purple 03, Motts-Mull. Wild SET 02, Simpkins, West Creek SET 01, West Creek SET 02, West Creek SET 03) between 2002 and 2014. Trends ranged from -19.69 to 154.85. Overall, the average refuge-level trend was 24.12 ± 10.45 (mean ± SE).

Trends of changes in Salt marsh Elevation (mm)

Figure 1. Map showing locations, trend directionality, and trend magnitude of SET stations within Edwin B. Forsythe. Radii of positve (blue) and negative (red) points show the magnitude of linear trends.

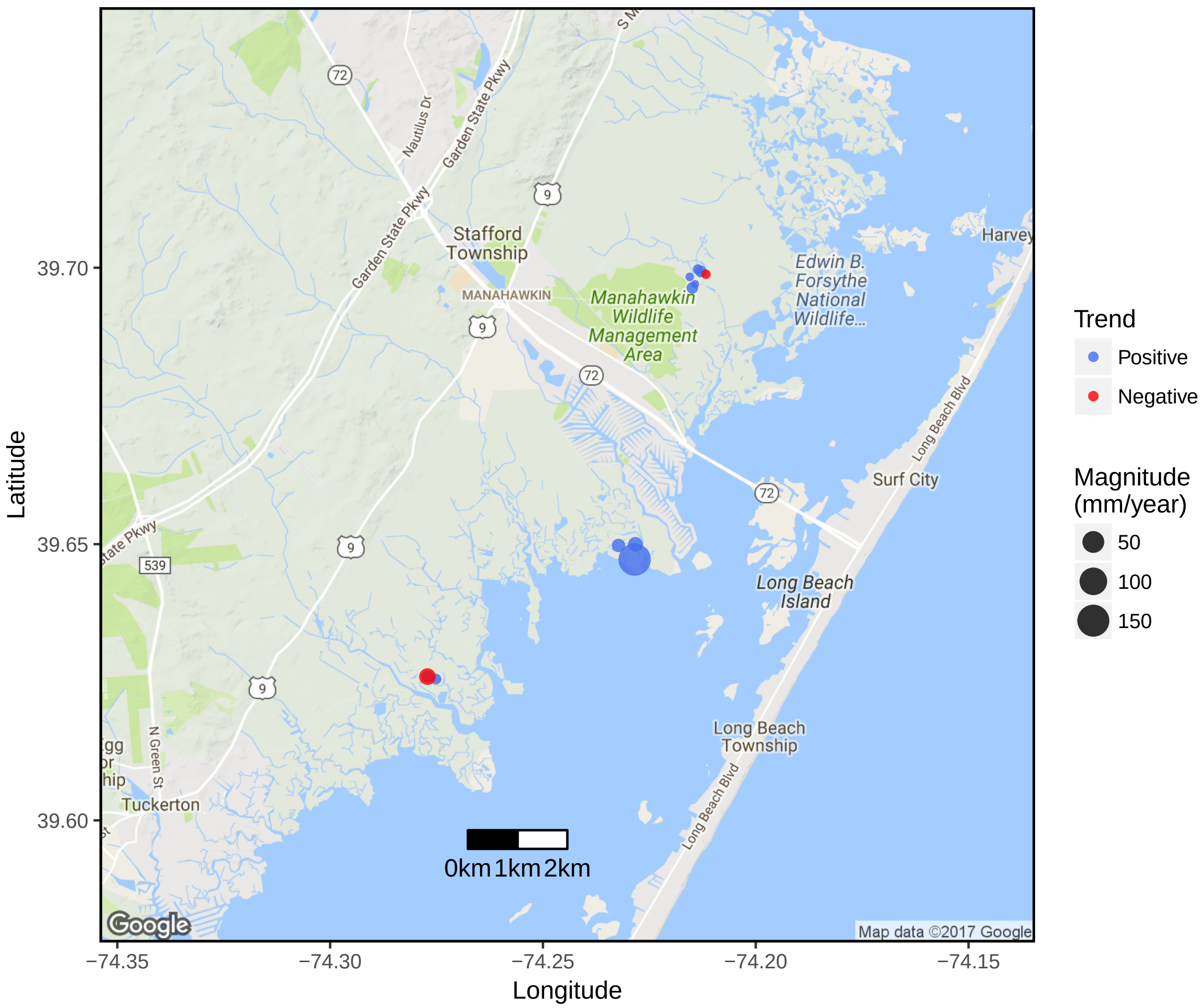


Table 1. Trends of surface elevation table (SET) stations within Edwin B. Forsythe. Means and SEs for trends are shown for both linear models with and without observers.

	SET_Name	Mean	SE	CV	Mean.obs	SE.obs	CV.obs
1	AT&T Control SET 01	1.67	0.90	1.08	1.67	0.90	1.08
2	AT&T Control SET 02	3.98	2.62	1.32	3.98	2.62	1.32
3	AT&T Treatment SET 04	0.64	0.39	1.20	0.64	0.39	1.20
4	AT&T SMI 07	75.79	3.75	0.10	75.79	3.75	0.10
5	AT&T SMI 08	99.50	5.57	0.11	99.50	5.57	0.11
6	AT&T SMI 09	88.77	7.00	0.16	88.77	7.00	0.16
7	AT&T Treatment SET 05	0.57	0.44	1.53	0.57	0.44	1.53
8	AT&T Treatment SET 06	3.68	0.73	0.40	3.68	0.73	0.40
9	Mill Crk-Cedar Run SET Purple 03	8.03	2.35	0.59	8.03	2.35	0.59
10	Mill Crk-Cedar Run SET Purple 01	154.85	9.23	0.12	154.85	9.23	0.12
11	Mill Crk-Cedar Run SET Purple 02	12.31	0.50	0.08	12.31	0.50	0.08
12	West Creek SET 02	5.31	3.40	1.28	5.31	3.40	1.28
13	West Creek SET 01	2.31	5.76	5.00	2.31	5.76	5.00
14	AT&T Control SET 03	-1.06	0.38	-0.71	-1.06	0.38	-0.71
15	LB-surf 2	-11.64	0.70	-0.12	7.89	1.23	0.31
16	Motts-Mull. Wild SET 02	-0.86	1.85	-4.30	-0.86	1.85	-4.30
17	Simpkins	-6.36	2.76	-0.87	13.05	0.67	0.10
18	LB-surf 1	-18.34	1.60	-0.18	1.61	1.02	1.27
19	West Creek SET 03	-19.69	0.90	-0.09	-19.69	0.90	-0.09

Summary of Raw Data − Surface elevation change (mm)

Figure 2. Elevation change (mm) within Edwin B. Forsythe NWR. Means and SEs for each year (and within year visits) are shown along with overall linear trend. Figure 2. Elevation change (mm) within NA. Means and SEs for each year (and within year visits) are shown along with overall linear trend.

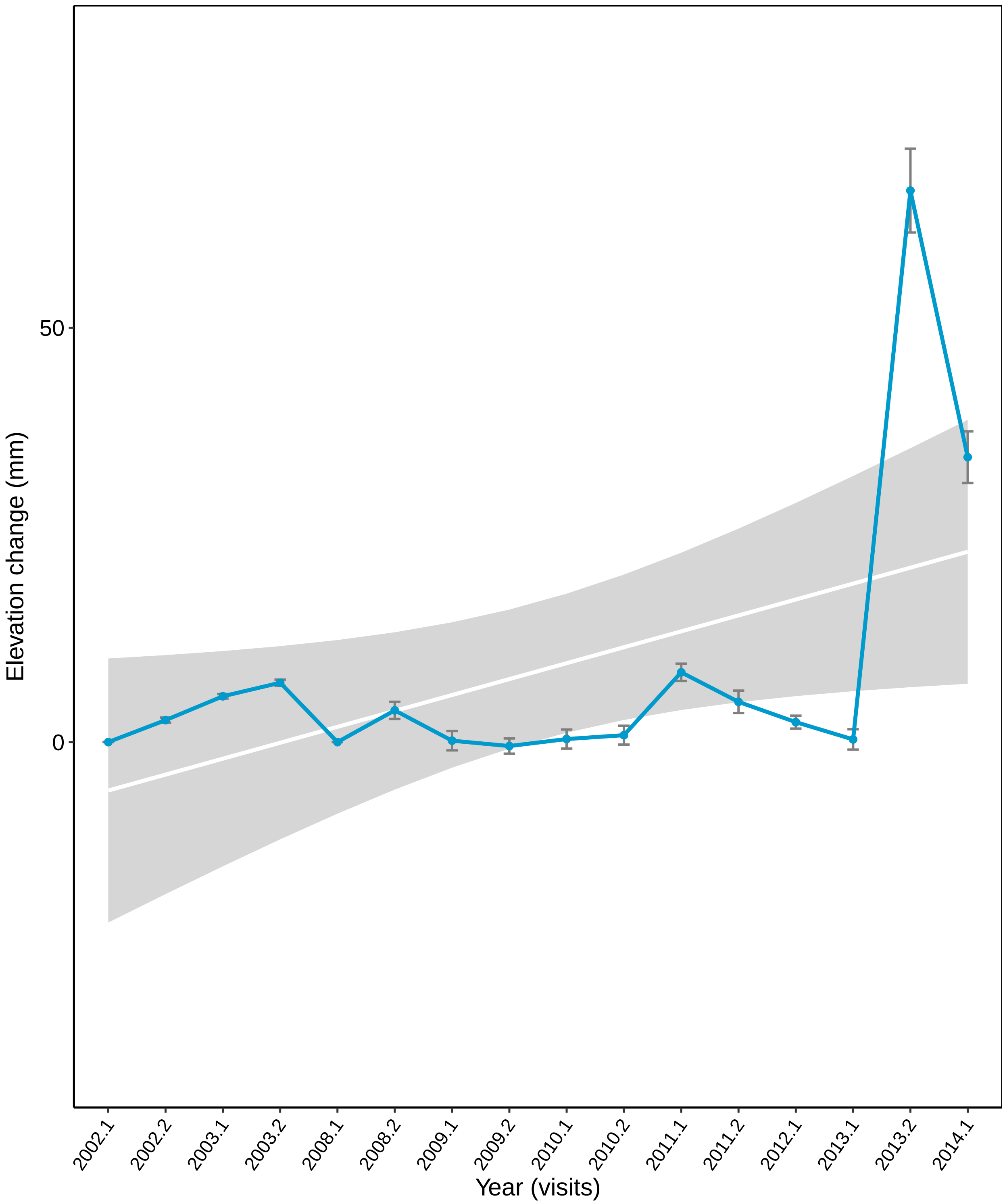


Figure 3. Summary of Site-level elevation change (mm) data within Edwin B. Forsythe NWR. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes. Figure 3. Summary of Site-level elevation change (mm) data within NA. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes.

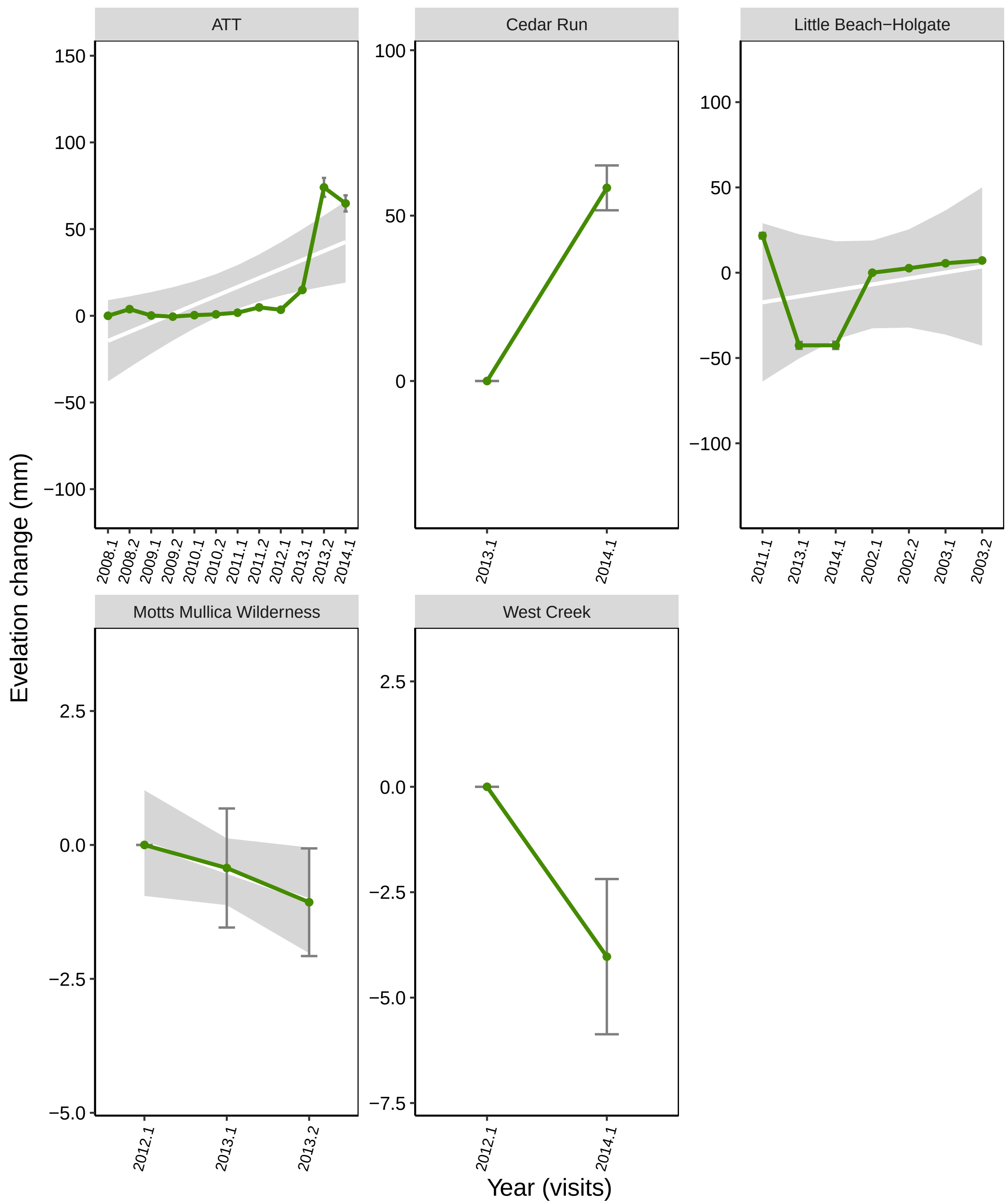
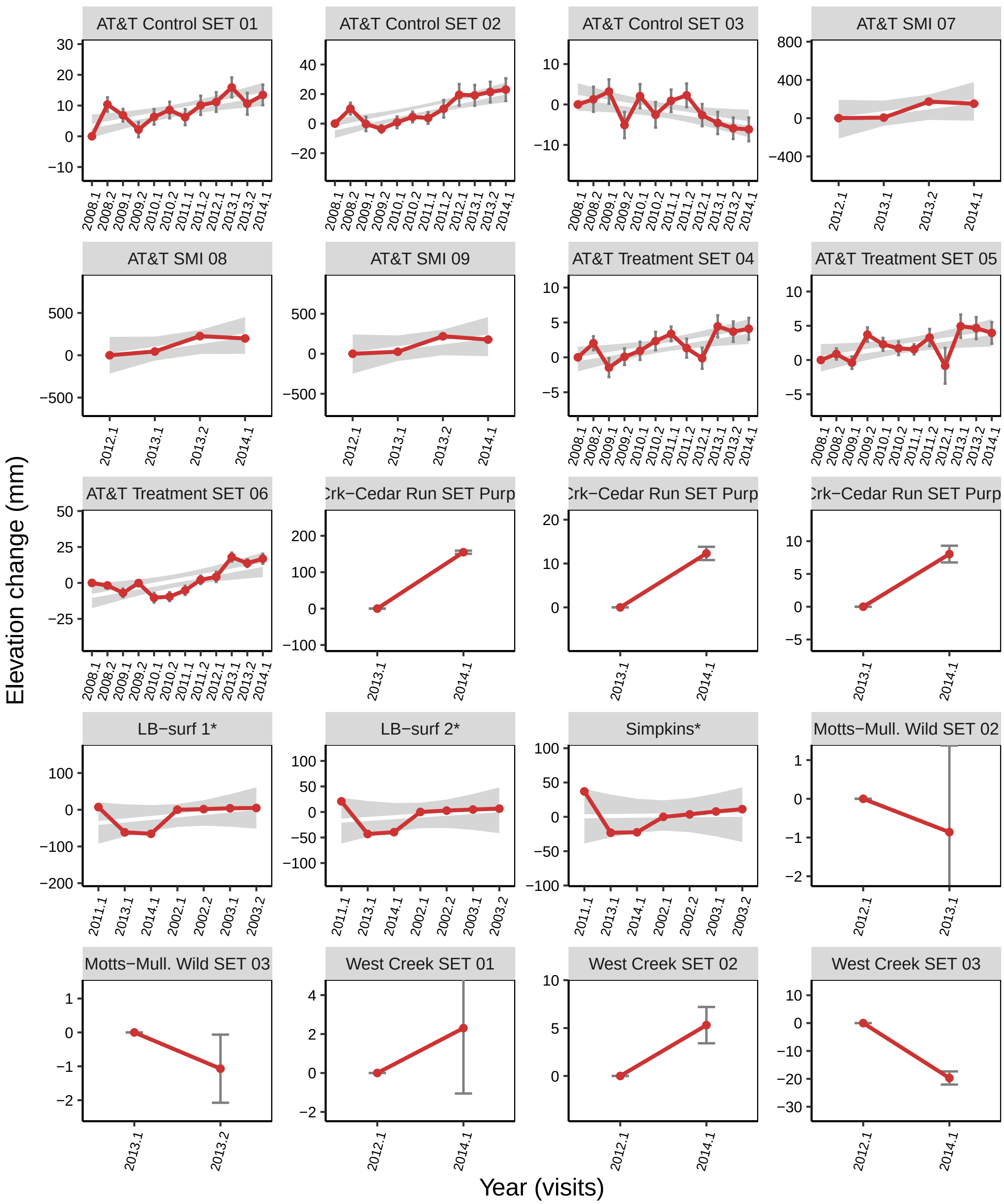


Figure 4. Summary of SET station-level elevation change (mm) data within Edwin B. Forsythe NWR. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes.



Bombay Hook NWR

Surface elevation table (SET) data was collected within Bombay Hook NWR at the following 17 SET stations (SB01, SB02, SB03, SET01_AF, SET01_BHIN, SET01_GI, SET01_Kent, Set01-BHIS, SET02_GI, SET02_Kent, SET03_AF, SET03_GI, SET03_Kent, USGS_1_fertilized, USGS_2_control, USGS_3_control, USGS_4_fertilized) between 2005 and 2016. Trends ranged from -24 to 25.14. Overall, the average refuge-level trend was -2.46 ± 2.81 (mean ± SE).

Trends of changes in Salt marsh Elevation (mm)

Figure 1. Map showing locations, trend directionality, and trend magnitude of SET stations within Bombay Hook. Radii of positve (blue) and negative (red) points show the magnitude of linear trends.

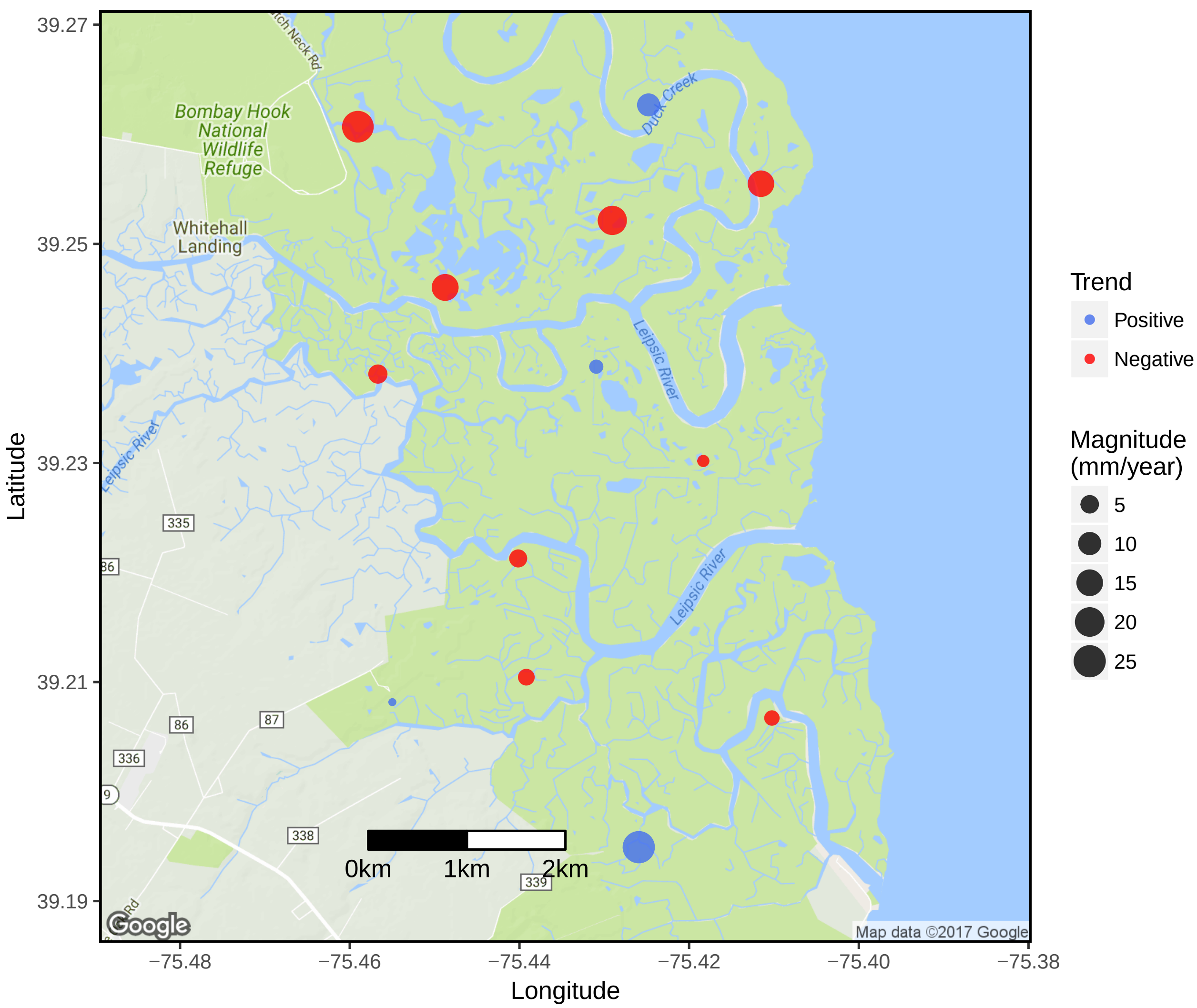


Table 1. Trends of surface elevation table (SET) stations within Bombay Hook. Means and SEs for trends are shown for both linear models with and without observers.

	SET_Name	Mean	SE	CV	Mean.obs	SE.obs	CV.obs
1	SB03	0.40	3.38	17.05	0.40	3.38	17.05
2	SET02_Kent	1.99	2.80	2.82	1.99	2.80	2.82
3	SET03_AF	25.14	13.55	1.08	25.14	13.55	1.08
4	SET01_BHIN	9.85	4.15	0.84	9.85	4.15	0.84
5	USGS_1_fertilized	3.41	0.12	0.07	2.57	0.24	0.18
6	USGS_2_control	4.40	0.35	0.16	3.67	0.49	0.26
7	USGS_3_control	2.40	0.57	0.47	1.55	0.42	0.54
8	USGS_4_fertilized	4.37	0.81	0.37	4.10	0.96	0.47
9	SB01	-4.60	1.11	-0.48	-4.60	1.11	-0.48
10	SB02	-4.70	3.09	-1.31	-3.57	2.98	-1.67
11	SET01_Kent	-5.62	4.99	-1.77	-5.62	4.99	-1.77
12	SET01_AF	-2.68	1.29	-0.96	-2.68	1.29	-0.96
13	SET02_GI	-15.39	4.05	-0.53	-15.39	4.05	-0.53
14	SET01_GI	-19.29	2.19	-0.23	-19.29	2.19	-0.23
15	Set01-BHIS	-14.74	0.80	-0.11	-14.74	0.80	-0.11
16	SET03_Kent	-1.11	3.39	-6.10	-1.11	3.39	-6.10
17	SET03_GI	-24.00	4.61	-0.38	-24.00	4.61	-0.38

Summary of Raw Data − Surface elevation change (mm)

Figure 2. Elevation change (mm) within Bombay Hook NWR. Means and SEs for each year (and within year visits) are shown along with overall linear trend. Figure 2. Elevation change (mm) within NA. Means and SEs for each year (and within year visits) are shown along with overall linear trend.

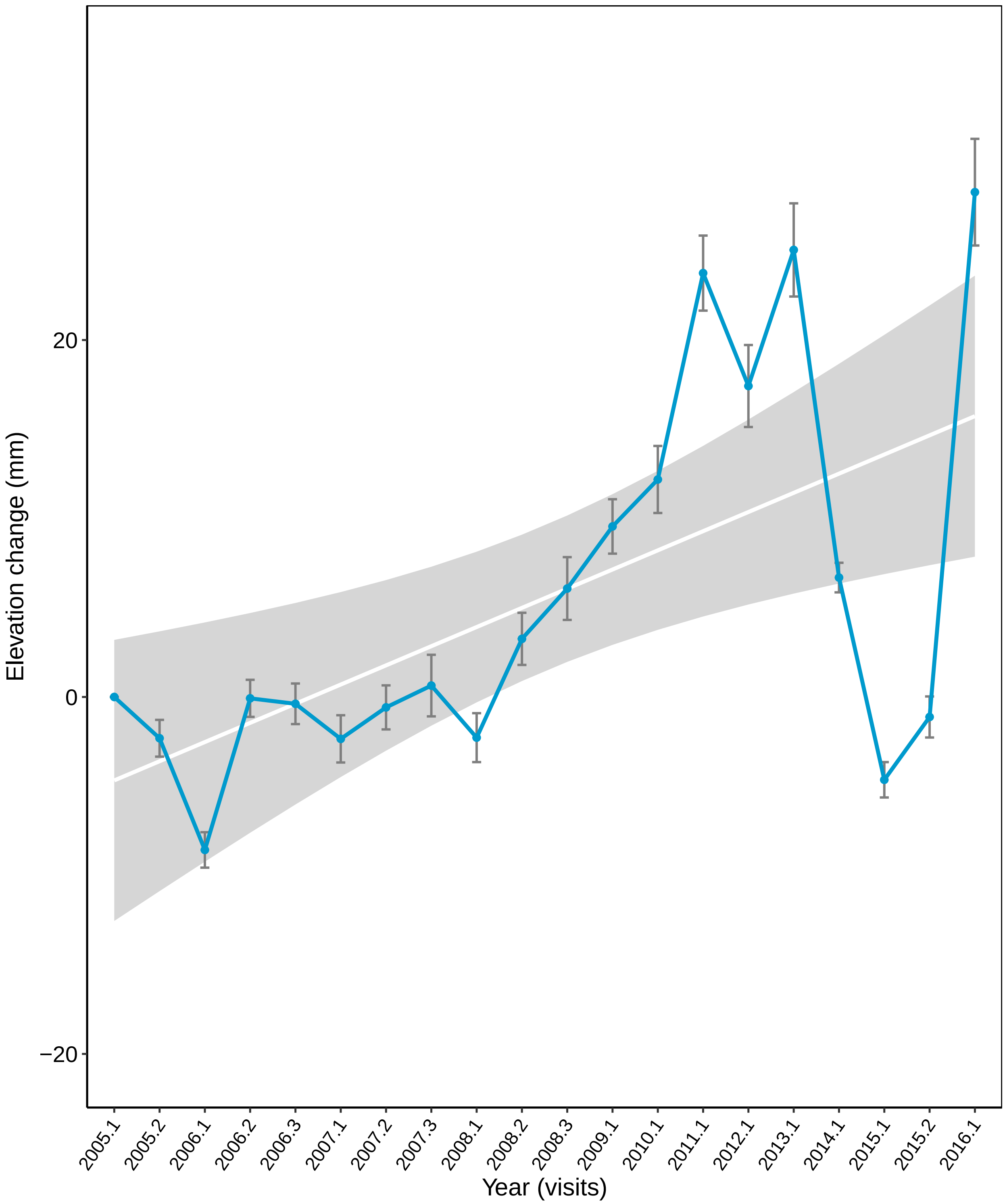


Figure 3. Summary of Site-level elevation change (mm) data within Bombay Hook NWR. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes. Figure 3. Summary of Site-level elevation change (mm) data within NA. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes.

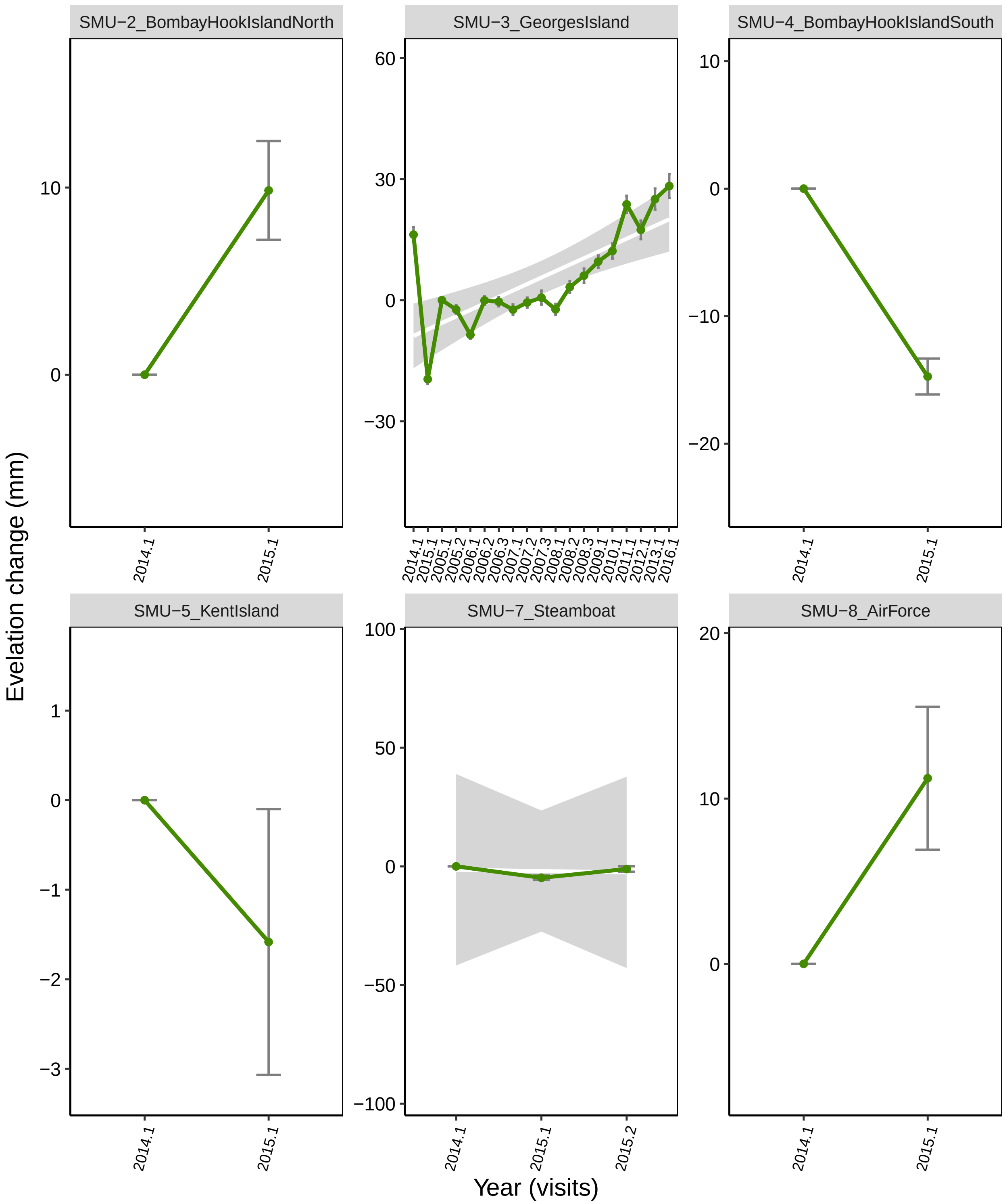
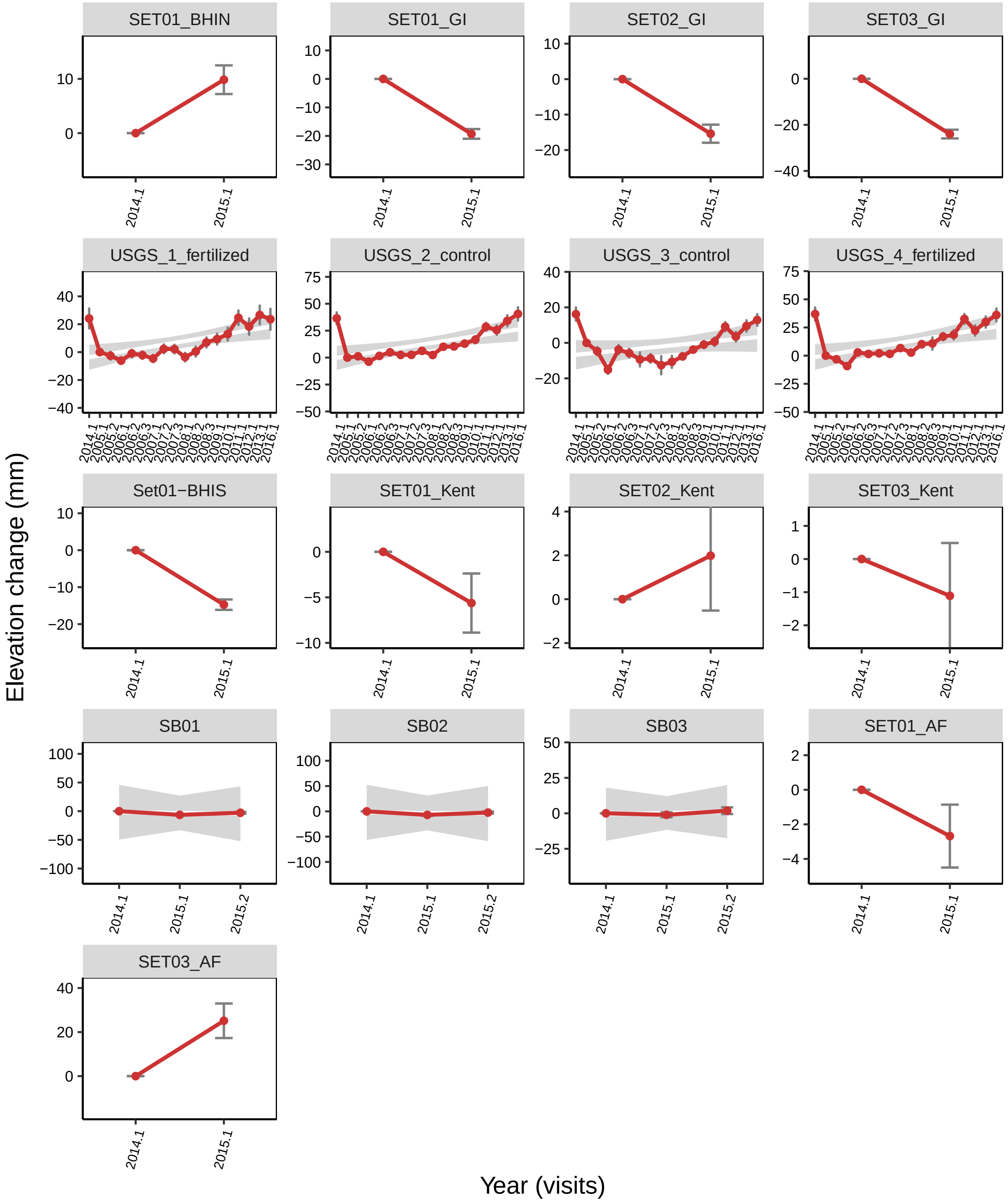


Figure 4. Summary of SET station-level elevation change (mm) data within Bombay Hook NWR. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes.



Prime Hook NWR

Surface elevation table (SET) data was collected within Prime Hook NWR at the following 9 SET stations (PH2-1 (Deep), PH2-2 (Deep), PH2-3 (Deep), PH2-4 (Deep), PH2-5 (Deep), PH2-6 (Deep), Set 1 (Deep), Set 2 (Deep), Set 3 (Deep)) between 2011 and 2015. Trends ranged from -23.77 to 47.99. Overall, the average refuge-level trend was 14.54 ± 6.2 (mean ± SE).

Trends of changes in Salt marsh Elevation (mm)

Figure 1. Map showing locations, trend directionality, and trend magnitude of SET stations within Prime Hook. Radii of positve (blue) and negative (red) points show the magnitude of linear trends.

Table 1. Trends of surface elevation table (SET) stations within Prime Hook. Means and SEs for trends are shown for both linear models with and without observers.

	SET_Name	Mean	SE	CV	Mean.obs	SE.obs	CV.obs
1	PH2-1 (Deep)	23.83	0.65	0.05	23.83	0.65	0.05
2	PH2-6 (Deep)	14.07	1.09	0.16	14.07	1.09	0.16
3	PH2-3 (Deep)	21.88	2.29	0.21	21.88	2.29	0.21
4	PH2-4 (Deep)	13.65	3.31	0.48	13.65	3.31	0.48
5	PH2-5 (Deep)	47.99	3.27	0.14	47.99	3.27	0.14
6	Set 1 (Deep)	12.15	6.53	1.07	12.15	6.53	1.07
7	Set 2 (Deep)	11.98	5.50	0.92	11.98	5.50	0.92
8	Set 3 (Deep)	8.66	1.83	0.42	9.04	1.72	0.38
9	PH2-2 (Deep)	-23.77	3.51	-0.30	-23.77	3.51	-0.30

Summary of Raw Data − Surface elevation change (mm)

Figure 2. Elevation change (mm) within Prime Hook NWR. Means and SEs for each year (and within year visits) are shown along with overall linear trend.

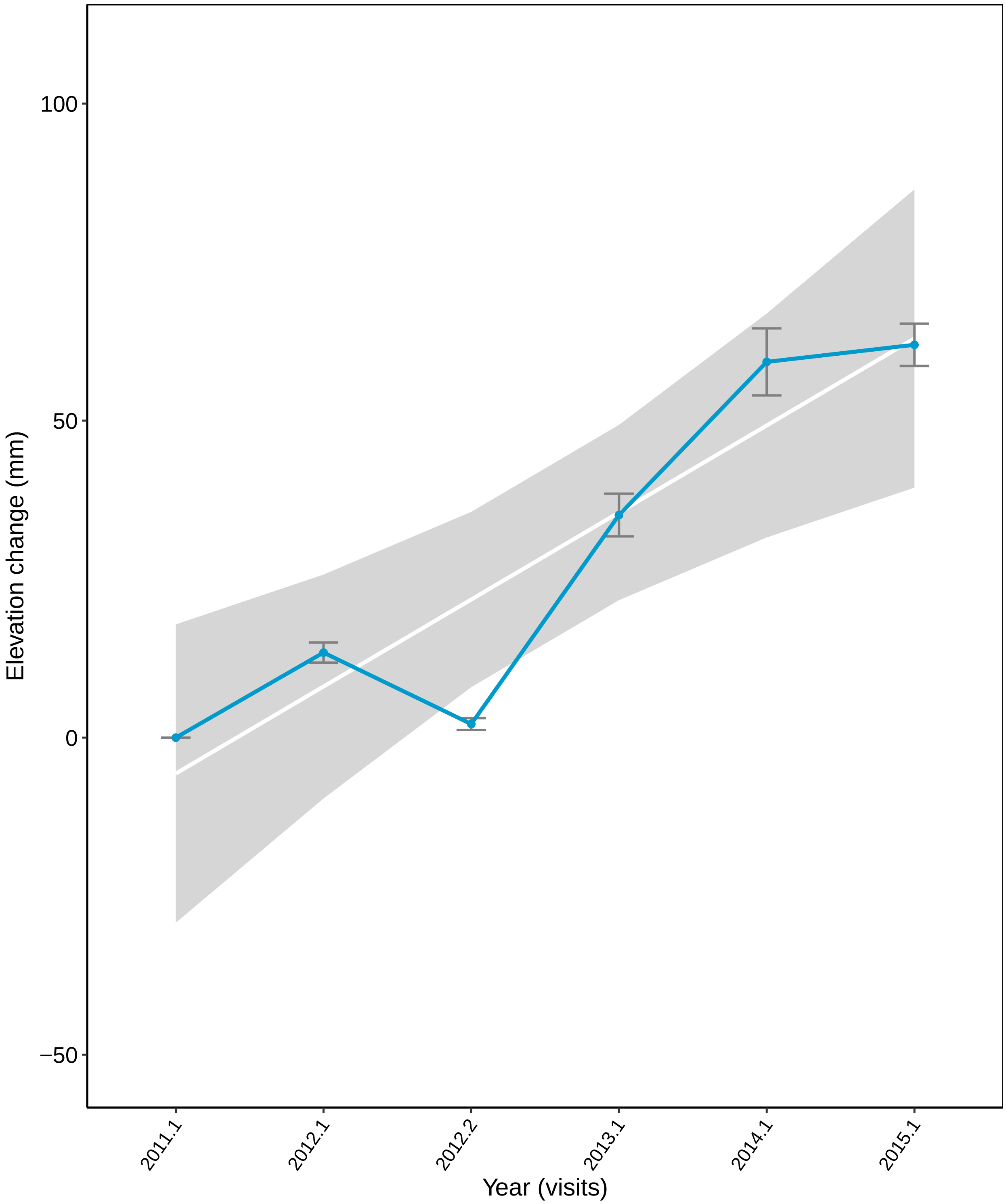


Figure 3. Summary of Site-level elevation change (mm) data within Prime Hook NWR. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes.

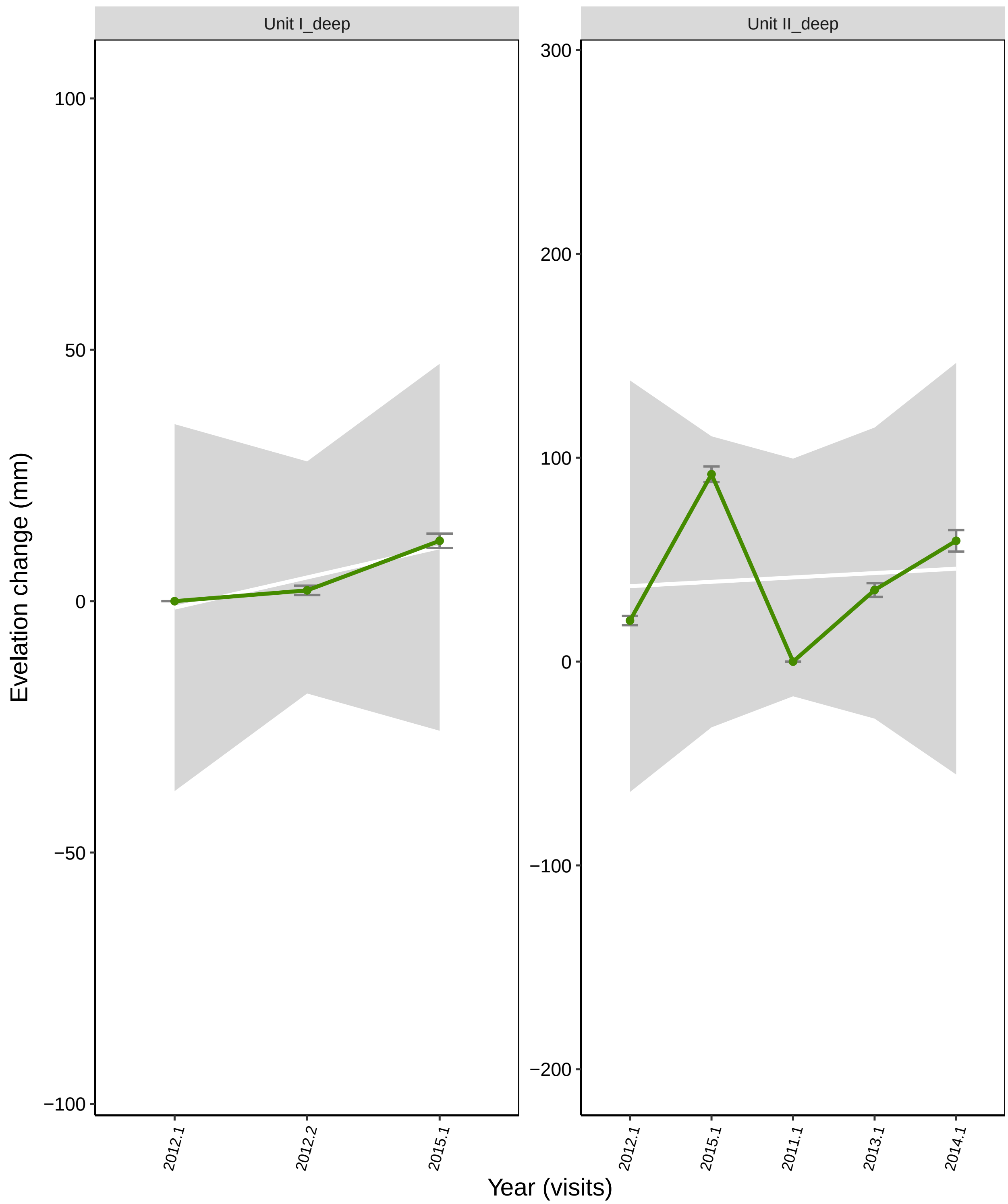
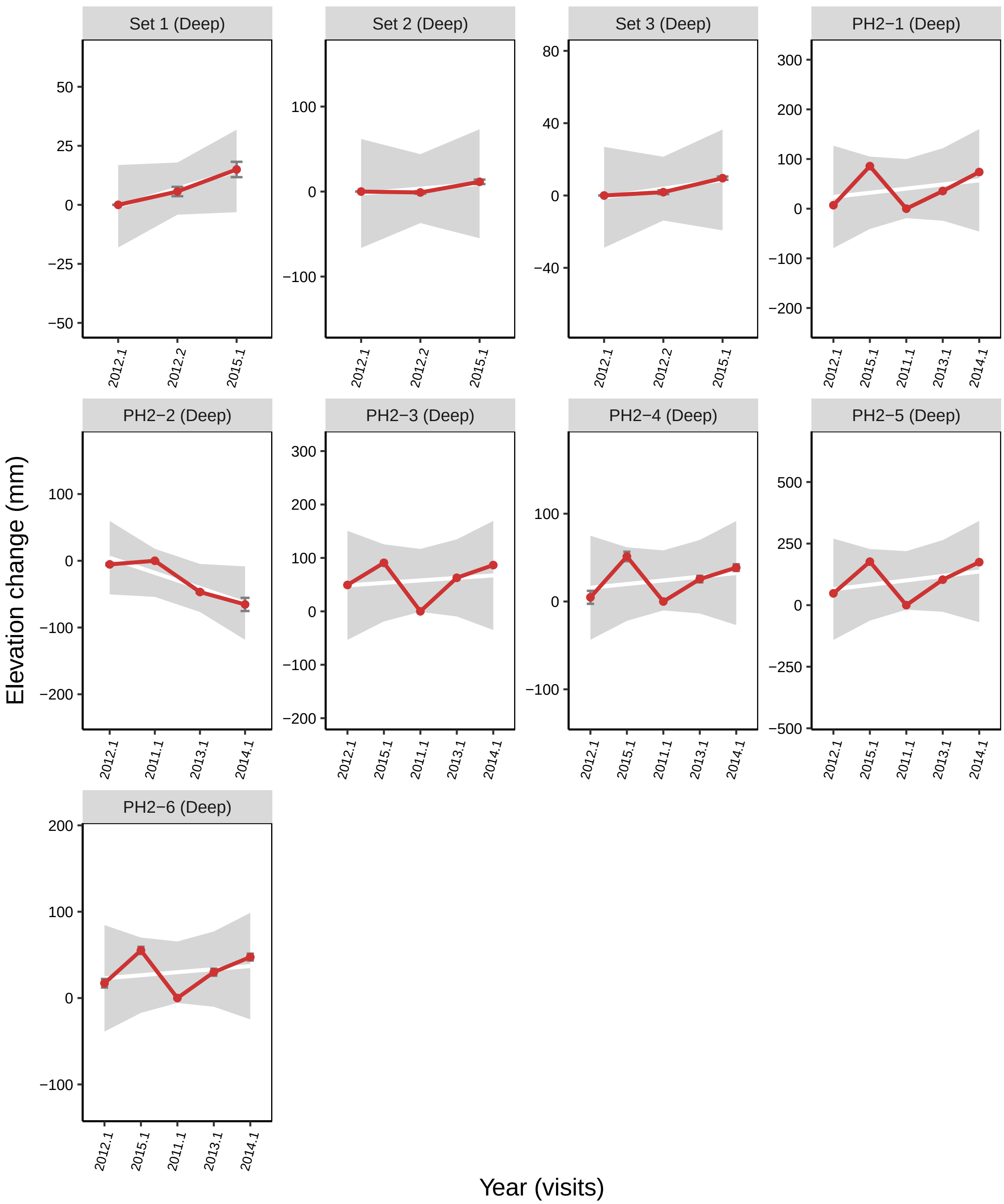


Figure 4. Summary of SET station-level elevation change (mm) data within Prime Hook NWR. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes.



Prime Hook Shallow NWR

Surface elevation table (SET) data was collected within Prime Hook Shallow NWR at the following 9 SET stations (PH2-1 (Shallow), PH2-2 (Shallow), PH2-3 (Shallow), PH2-4 (Shallow), PH2-5 (Shallow), PH2-6 (Shallow), Set 1 (Shallow), Set 2 (Shallow), Set 3 (Shallow)) between 2011 and 2015. Trends ranged from -12.85 to 69.7. Overall, the average refuge-level trend was 20.64 ± 7.24 (mean ± SE).

Trends of changes in Salt marsh Elevation (mm)

Figure 1. Map showing locations, trend directionality, and trend magnitude of SET stations within Prime Hook Shallow. Radii of positve (blue) and negative (red) points show the magnitude of linear trends.

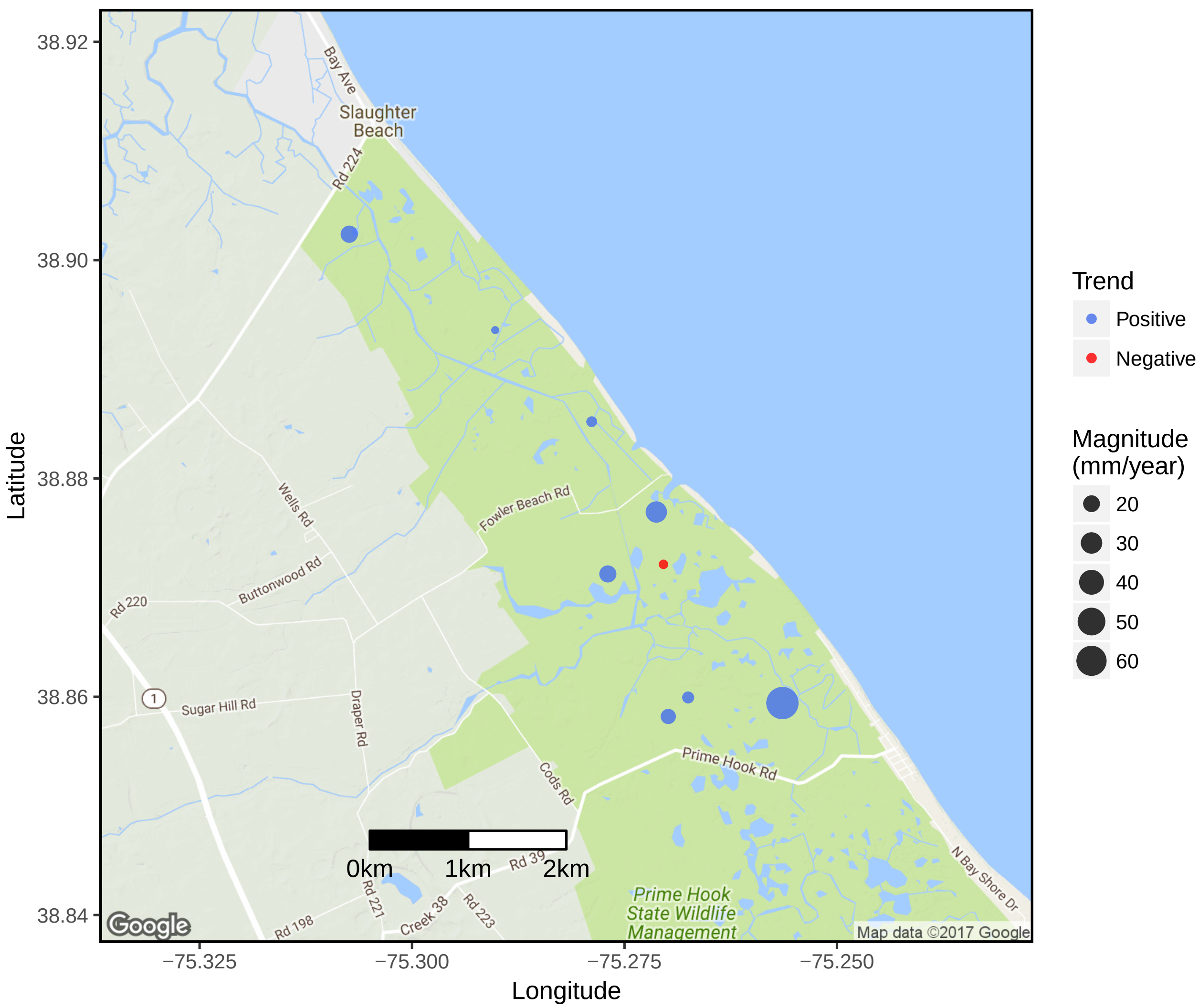


Table 1. Trends of surface elevation table (SET) stations within Prime Hook Shallow. Means and SEs for trends are shown for both linear models with and without observers.

	SET_Name	Mean	SE	CV	Mean.obs	SE.obs	CV.obs
1	PH2-1 (Shallow)	29.72	0.61	0.04	29.72	0.61	0.04
2	PH2-6 (Shallow)	17.59	0.56	0.06	17.59	0.56	0.06
3	PH2-3 (Shallow)	20.62	1.49	0.14	20.62	1.49	0.14
4	PH2-4 (Shallow)	14.16	2.89	0.41	14.16	2.89	0.41
5	PH2-5 (Shallow)	69.70	5.00	0.14	69.70	5.00	0.14
6	Set 1 (Shallow)	20.84	3.28	0.31	20.84	3.28	0.31
7	Set 2 (Shallow)	12.65	3.78	0.60	12.65	3.78	0.60
8	Set 3 (Shallow)	14.22	1.44	0.20	13.37	1.49	0.22
9	PH2-2 (Shallow)	-12.85	1.60	-0.25	-12.85	1.60	-0.25

Summary of Raw Data − Surface elevation change (mm)

Figure 2. Elevation change (mm) within Prime Hook NWR Shallow. Means and SEs for each year (and within year visits) are shown along with overall linear trend.

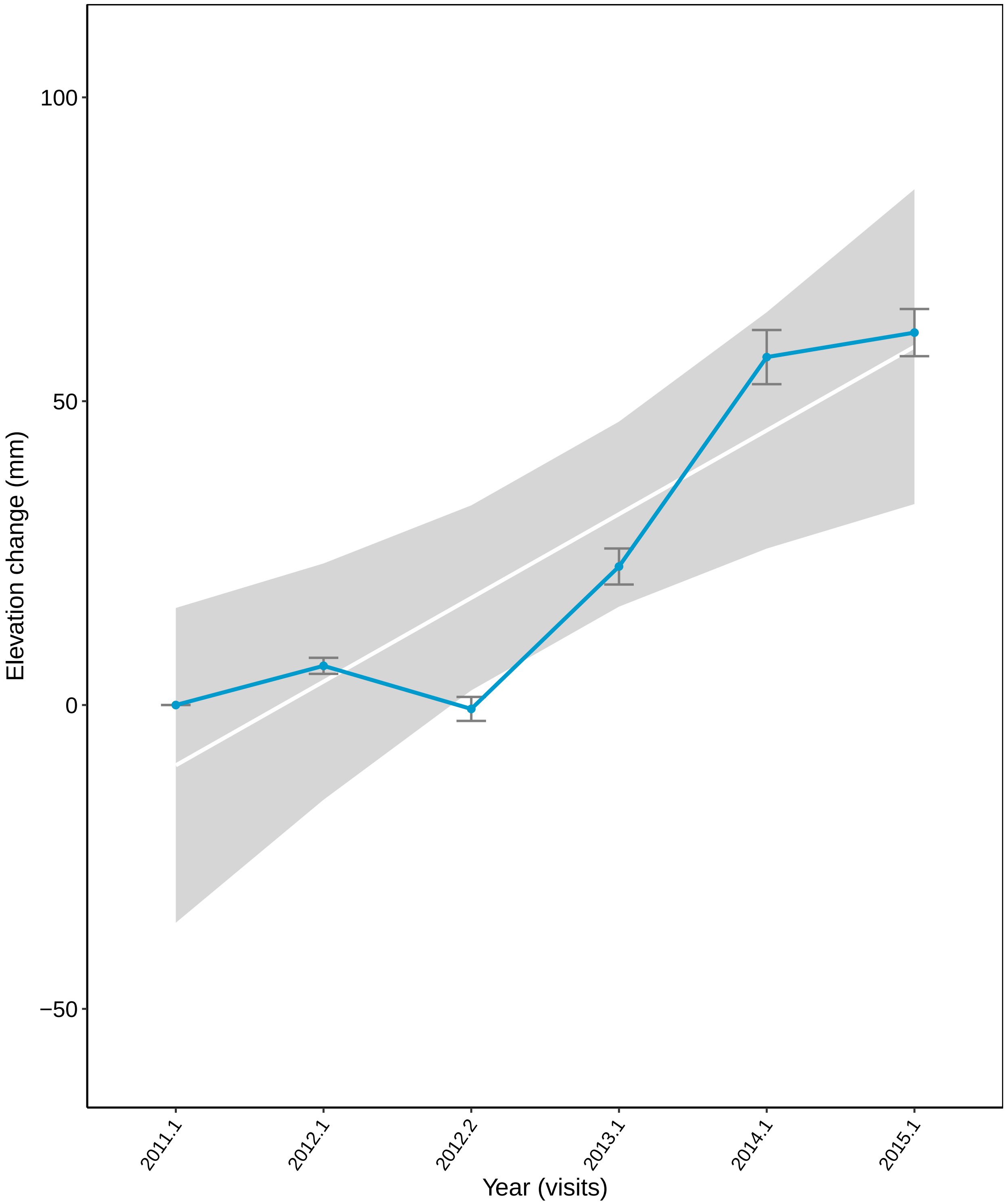


Figure 3. Summary of Site-level elevation change (mm) data within Prime Hook NWR Shallow. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes.

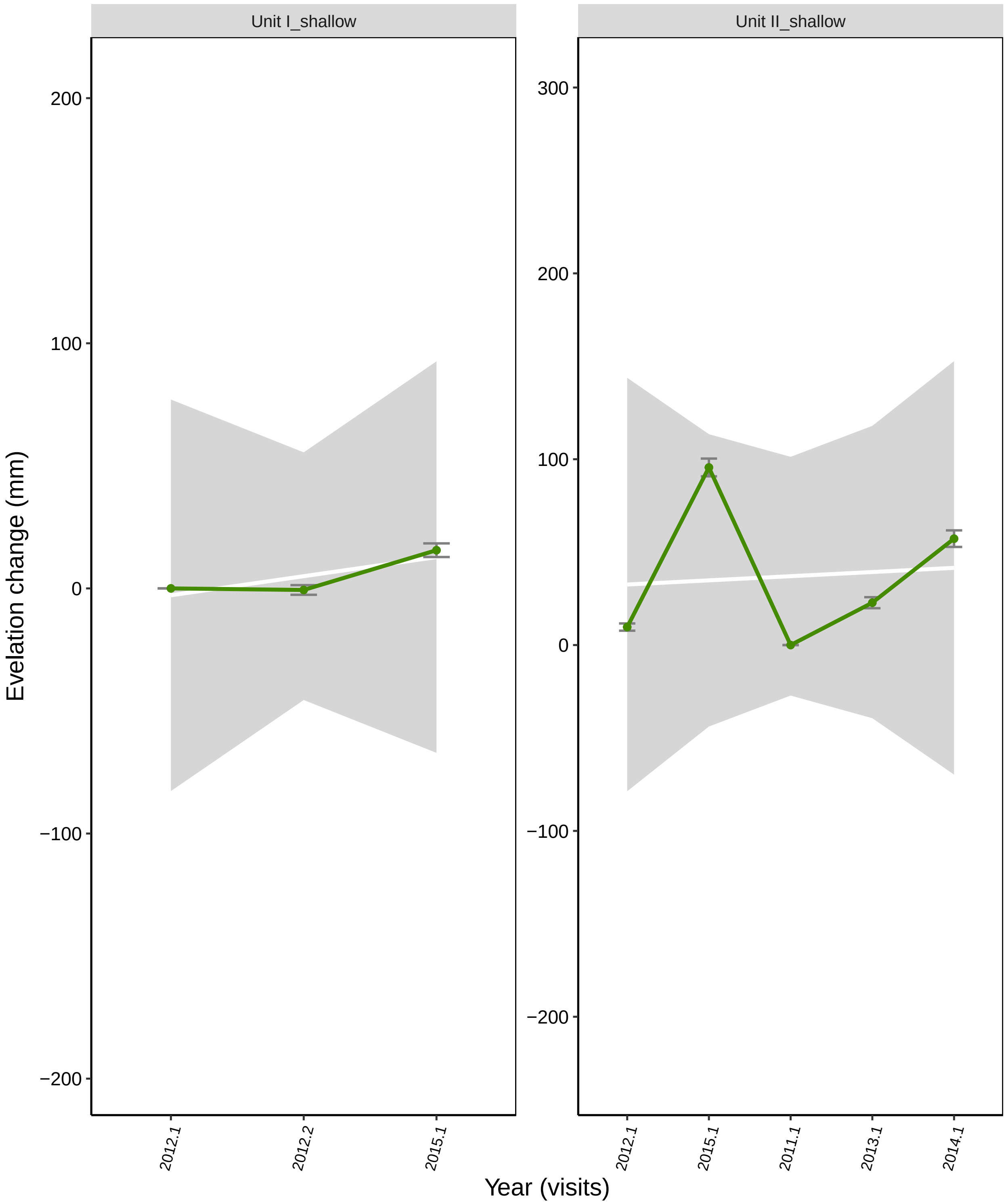
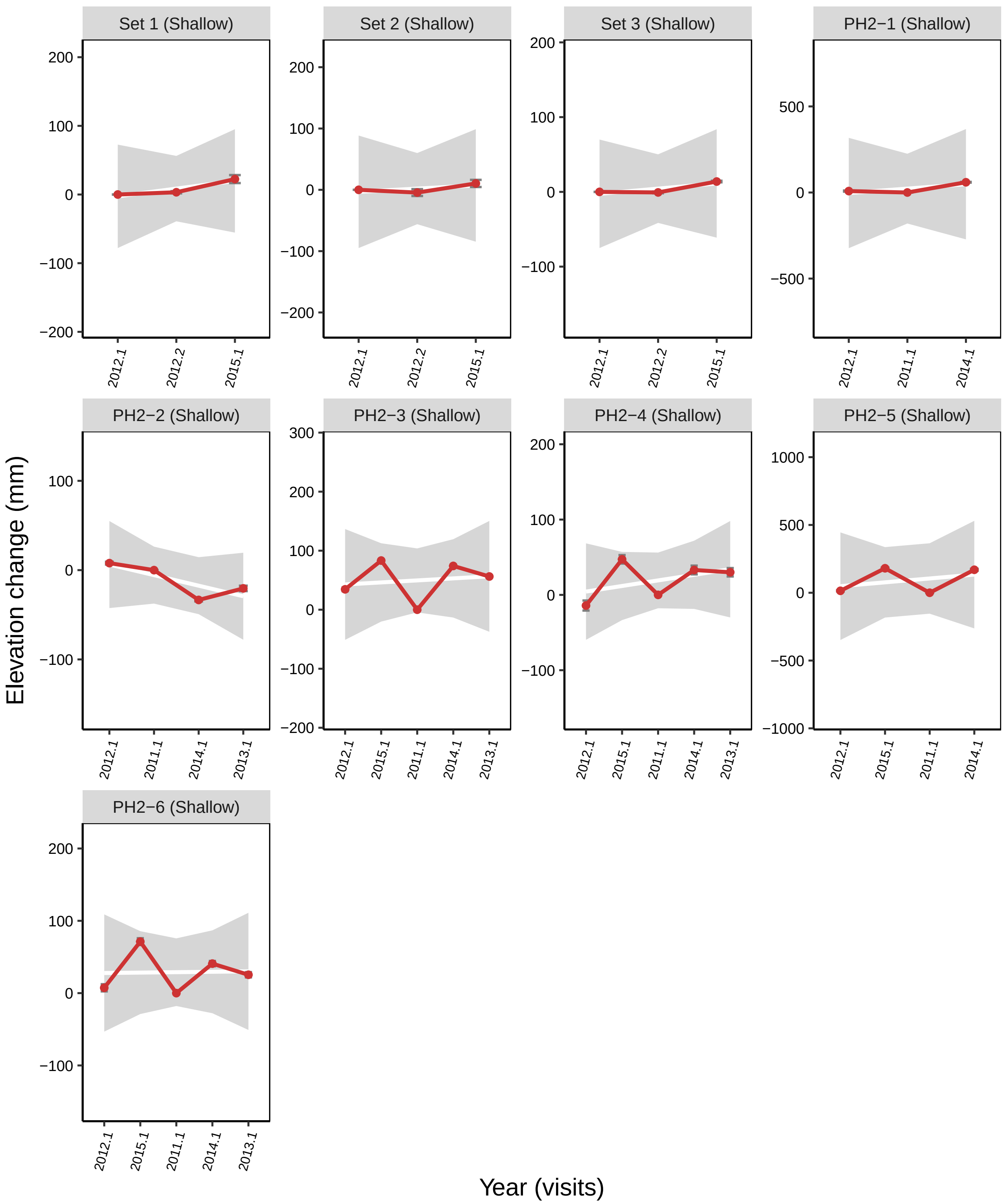


Figure 4. Summary of SET station-level elevation change (mm) data within Prime Hook NWR Shallow. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes.



Eastern Shore of Virginia NWR

Surface elevation table (SET) data was collected within Eastern Shore of Virginia NWR at the following 12 SET stations (Bull Plot 1, Bull Plot 2, Bull Plot 3, ESV Plot 1, ESV Plot 2, ESV Plot 3, FIE Plot 1, FIE Plot 2, FIE Plot 3, FIW Plot 1, FIW Plot 2, FIW Plot 3) between 2012 and 2015. Trends ranged from 1.08 to 7.62. Overall, the average refuge-level trend was 3.75 ± 0.54 (mean ± SE).

Trends of changes in Salt marsh Elevation (mm)

Figure 1. Map showing locations, trend directionality, and trend magnitude of SET stations within Eastern Shore of Virginia. Radii of positve (blue) and negative (red) points show the magnitude of linear trends.

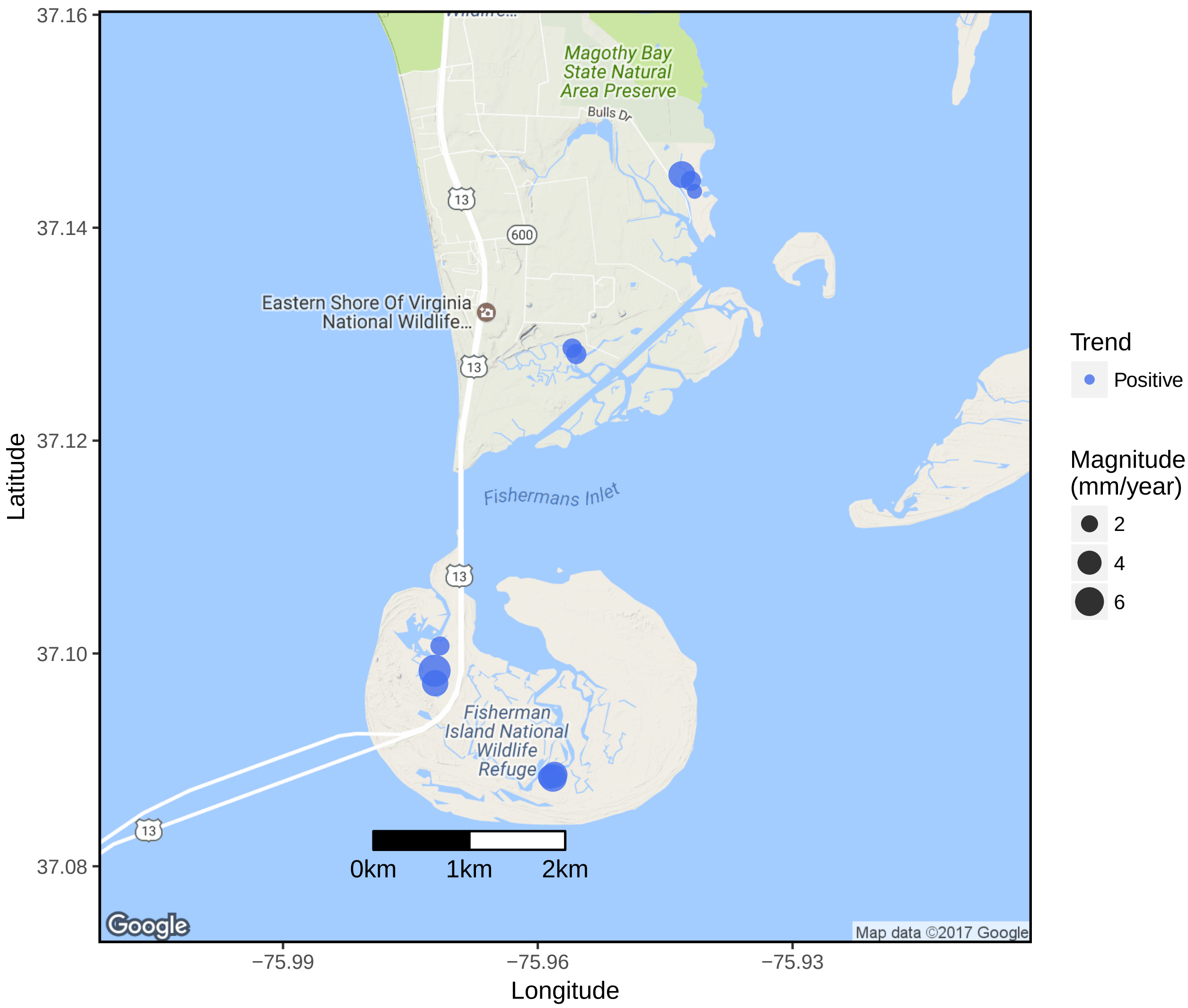


Table 1. Trends of surface elevation table (SET) stations within Eastern Shore of Virginia. Means and SEs for trends are shown for both linear models with and without observers.

	SET_Name	Mean	SE	CV	Mean.obs	SE.obs	CV.obs
1	Bull Plot 1	5.09	1.67	0.65	5.09	1.67	0.65
2	Bull Plot 2	2.76	1.43	1.04	2.76	1.43	1.04
3	Bull Plot 3	1.63	0.50	0.61	1.63	0.50	0.61
4	ESV Plot 1	1.08	0.84	1.56	1.08	0.84	1.56
5	ESV Plot 2	2.58	0.81	0.63	2.58	0.81	0.63
6	ESV Plot 3	2.76	0.43	0.31	2.76	0.43	0.31
7	FIE Plot 1	5.48	0.86	0.31	5.48	0.86	0.31
8	FIE Plot 2	3.87	0.80	0.42	3.87	0.80	0.42
9	FIE Plot 3	4.73	0.88	0.37	4.73	0.88	0.37
10	FIW Plot 1	4.91	0.79	0.32	4.91	0.79	0.32
11	FIW Plot 2	7.62	1.34	0.35	7.62	1.34	0.35
12	FIW Plot 3	2.48	0.79	0.64	2.48	0.79	0.64

Summary of Raw Data − Surface elevation change (mm)

Figure 2. Elevation change (mm) within Eastern Shore of Virginia NWR. Means and SEs for each year (and within year visits) are shown along with overall linear trend.

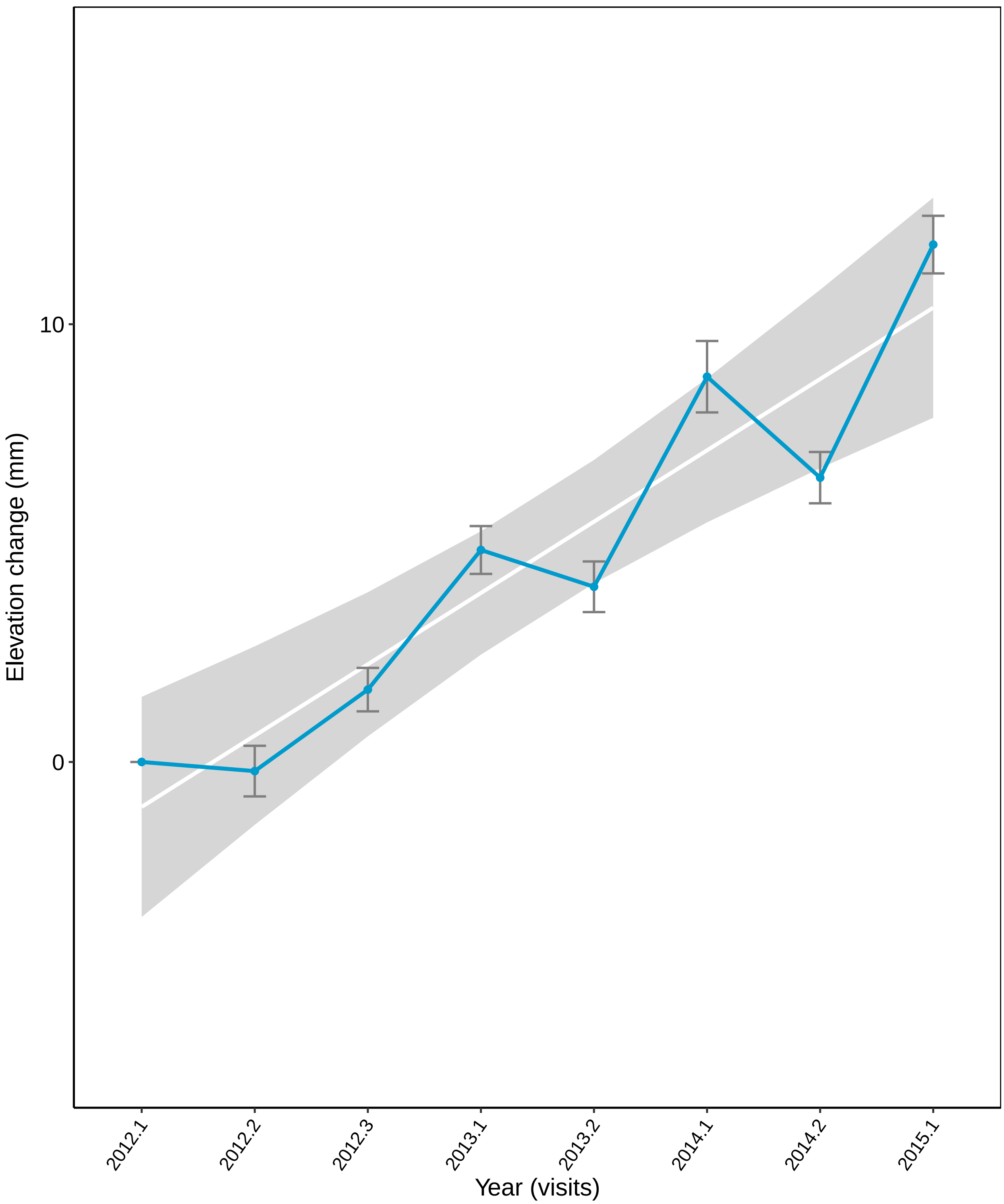


Figure 3. Summary of Site-level elevation change (mm) data within Eastern Shore of Virginia NWR. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes.

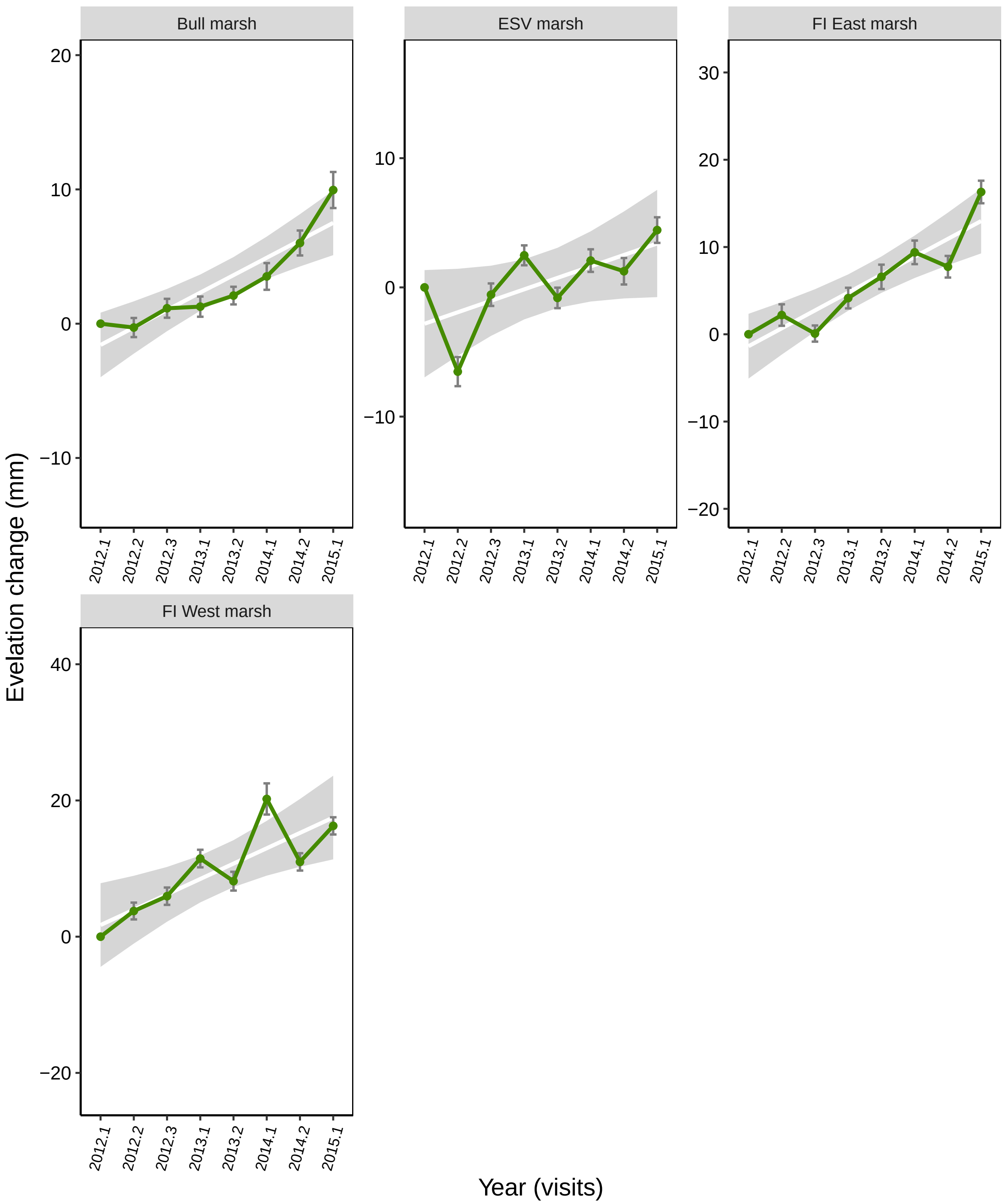
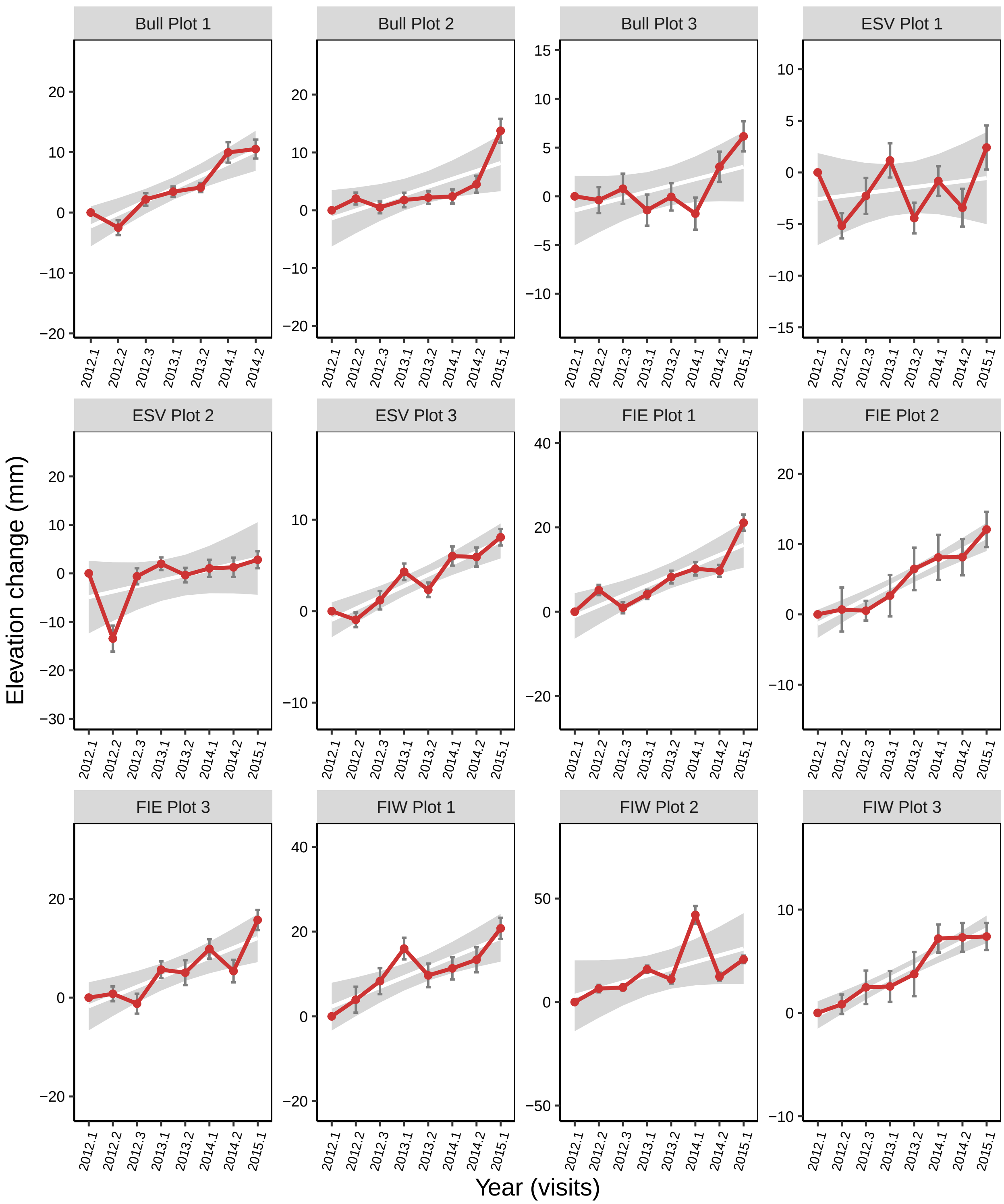


Figure 4. Summary of SET station-level elevation change (mm) data within Eastern Shore of Virginia NWR. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes.



Back Bay NWR

Surface elevation table (SET) data was collected within Back Bay NWR at the following 9 SET stations (Long Island North 1, Long Island North 2, Long Island North 3, Long Island South 1, Long Island South 2, Long Island South 3, North Marsh 1, North Marsh 2, North Marsh 3) between 2010 and 2013. Trends ranged from -21.79 to -4.26. Overall, the average refuge-level trend was -9.12 ± 1.79 (mean ± SE).

Trends of changes in Salt marsh Elevation (mm)

Figure 1. Map showing locations, trend directionality, and trend magnitude of SET stations within Back Bay. Radii of positve (blue) and negative (red) points show the magnitude of linear trends.

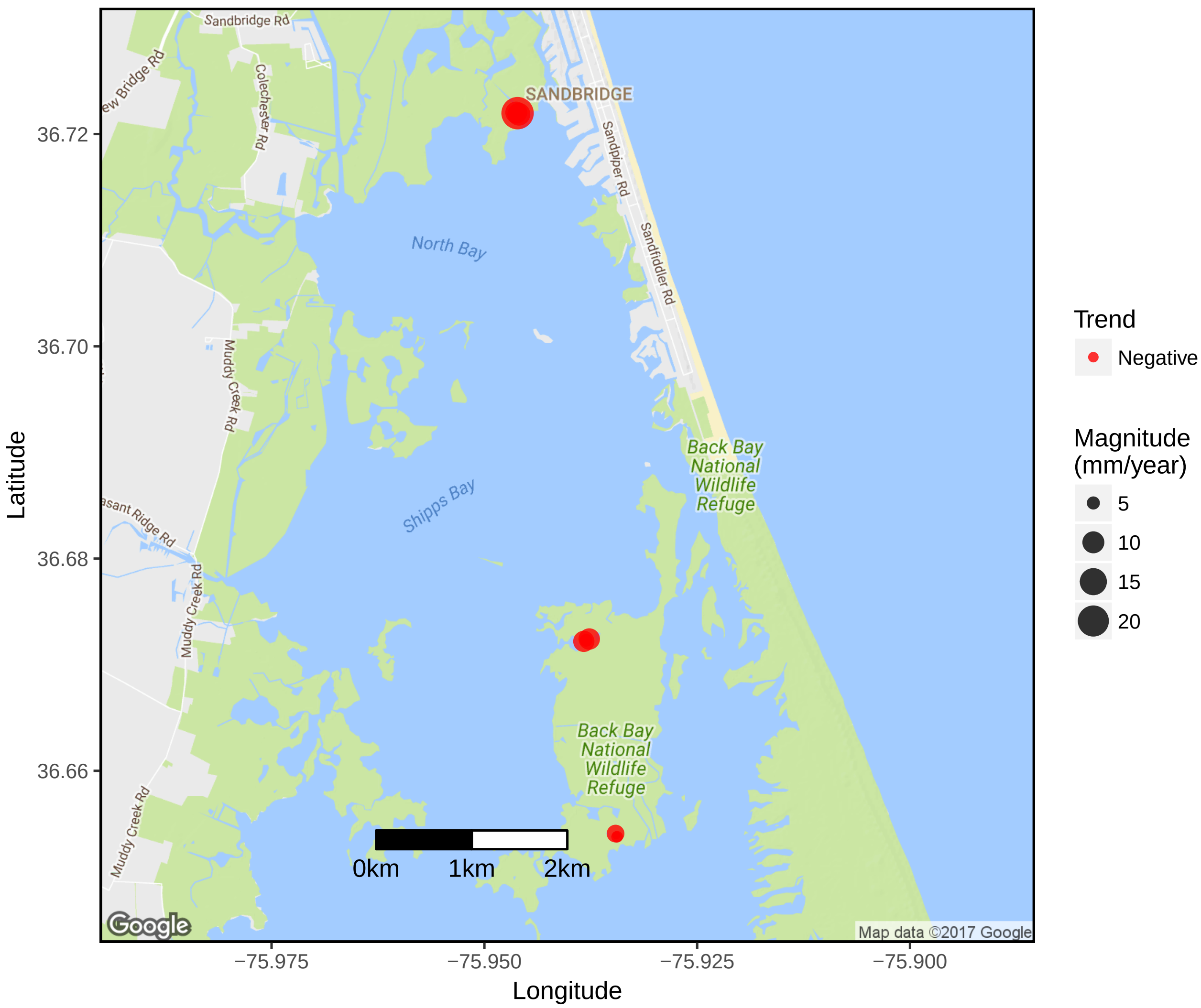


Table 1. Trends of surface elevation table (SET) stations within Back Bay. Means and SEs for trends are shown for both linear models with and without observers.

	SET_Name	Mean	SE	CV	Mean.obs	SE.obs	CV.obs
1	Long Island North 1	-9.41	1.62	-0.34	-9.41	1.62	-0.34
2	Long Island North 2	-4.92	0.91	-0.37	-4.92	0.91	-0.37
3	Long Island North 3	-9.53	1.29	-0.27	-9.53	1.29	-0.27
4	Long Island South 1	-4.61	2.38	-1.03	-4.61	2.38	-1.03
5	Long Island South 2	-4.26	0.48	-0.23	-4.26	0.48	-0.23
6	Long Island South 3	-7.03	0.89	-0.25	-7.03	0.89	-0.25
7	North Marsh 1	-10.67	4.26	-0.80	-10.67	4.26	-0.80
8	North Marsh 2	-21.79	5.02	-0.46	-21.79	5.02	-0.46
9	North Marsh 3	-9.85	1.63	-0.33	-9.85	1.63	-0.33

Summary of Raw Data − Surface elevation change (mm)

Figure 2. Elevation change (mm) within Back Bay NWR. Means and SEs for each year (and within year visits) are shown along with overall linear trend.

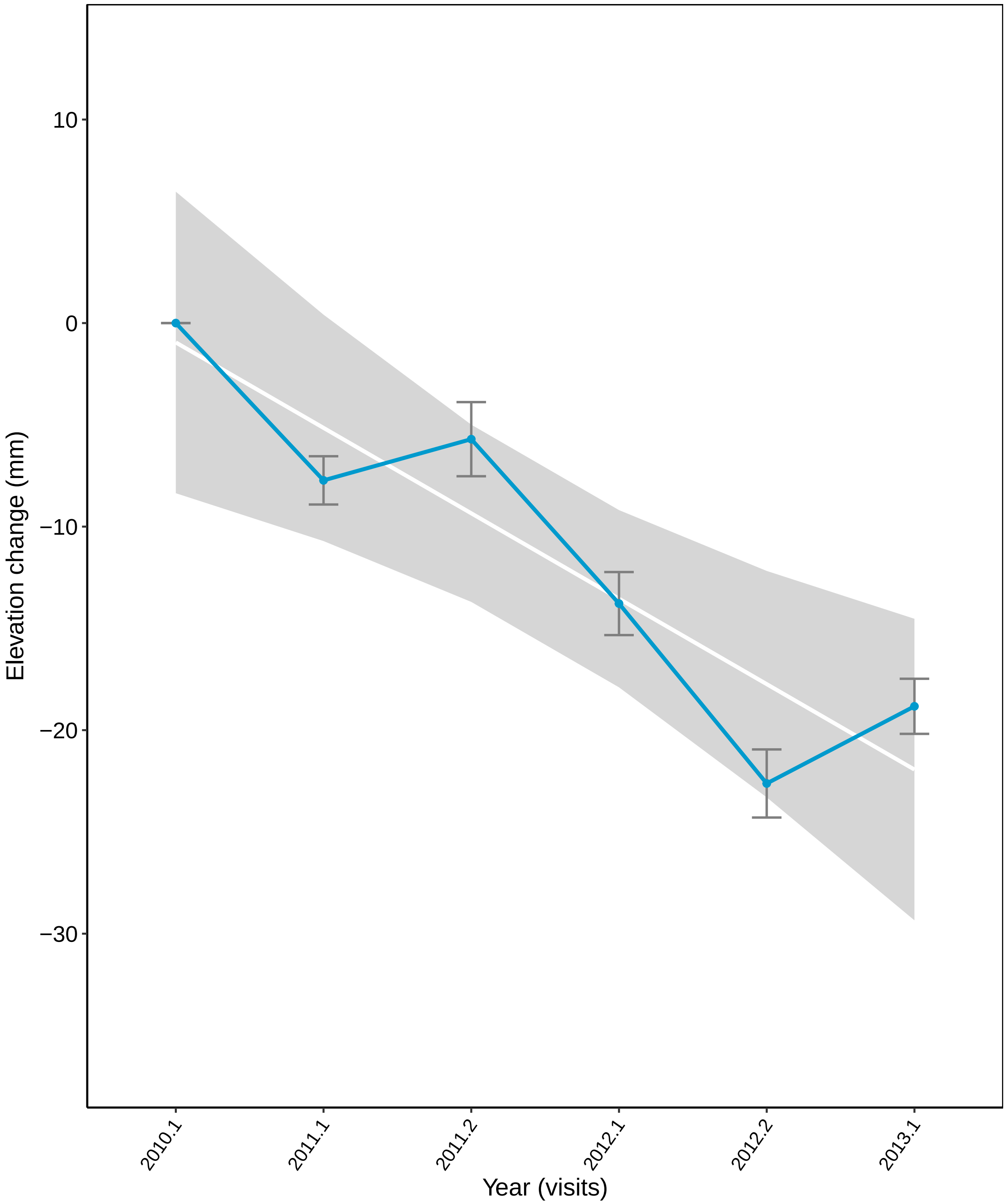


Figure 3. Summary of Site-level elevation change (mm) data within Back Bay NWR. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes.

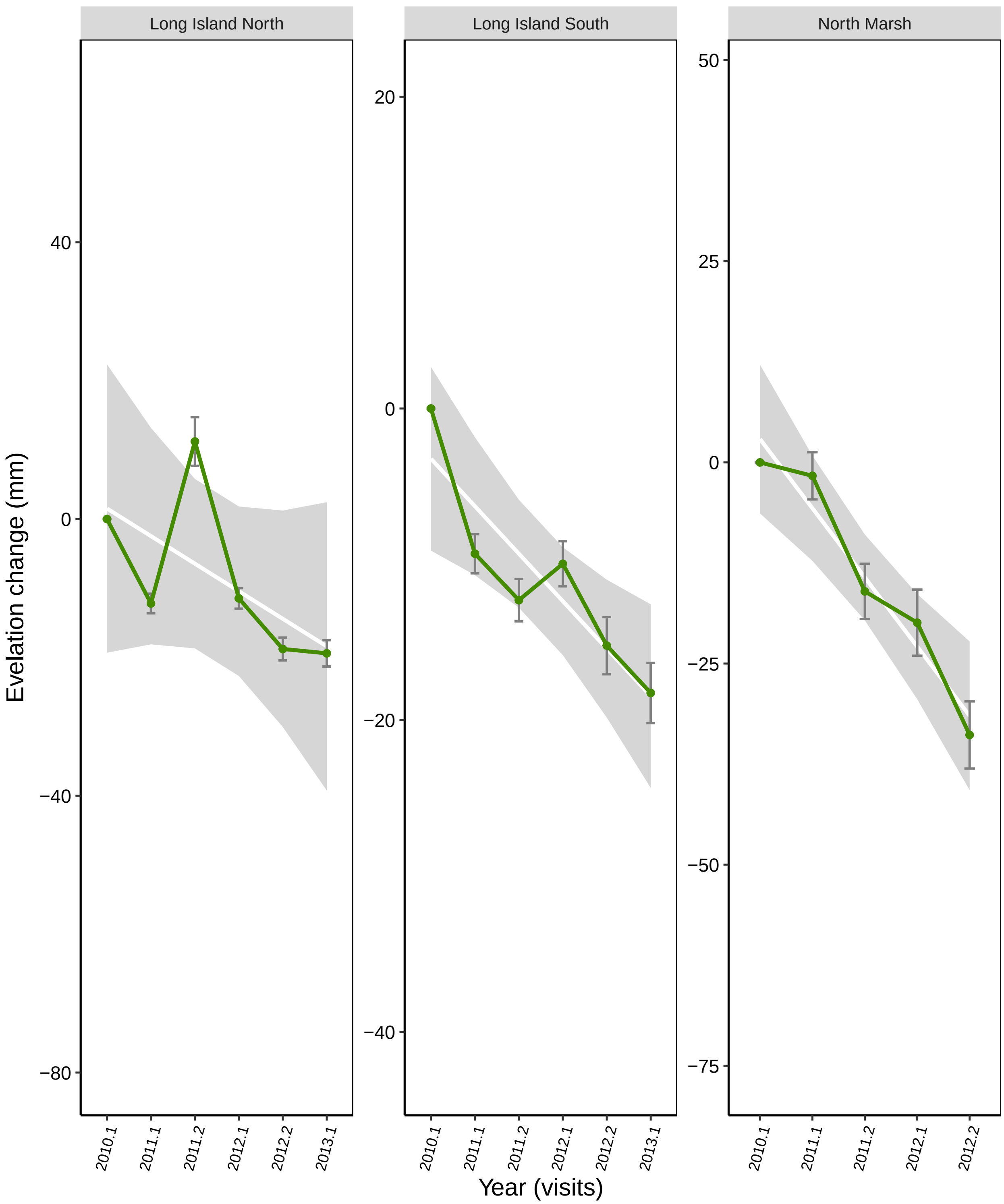
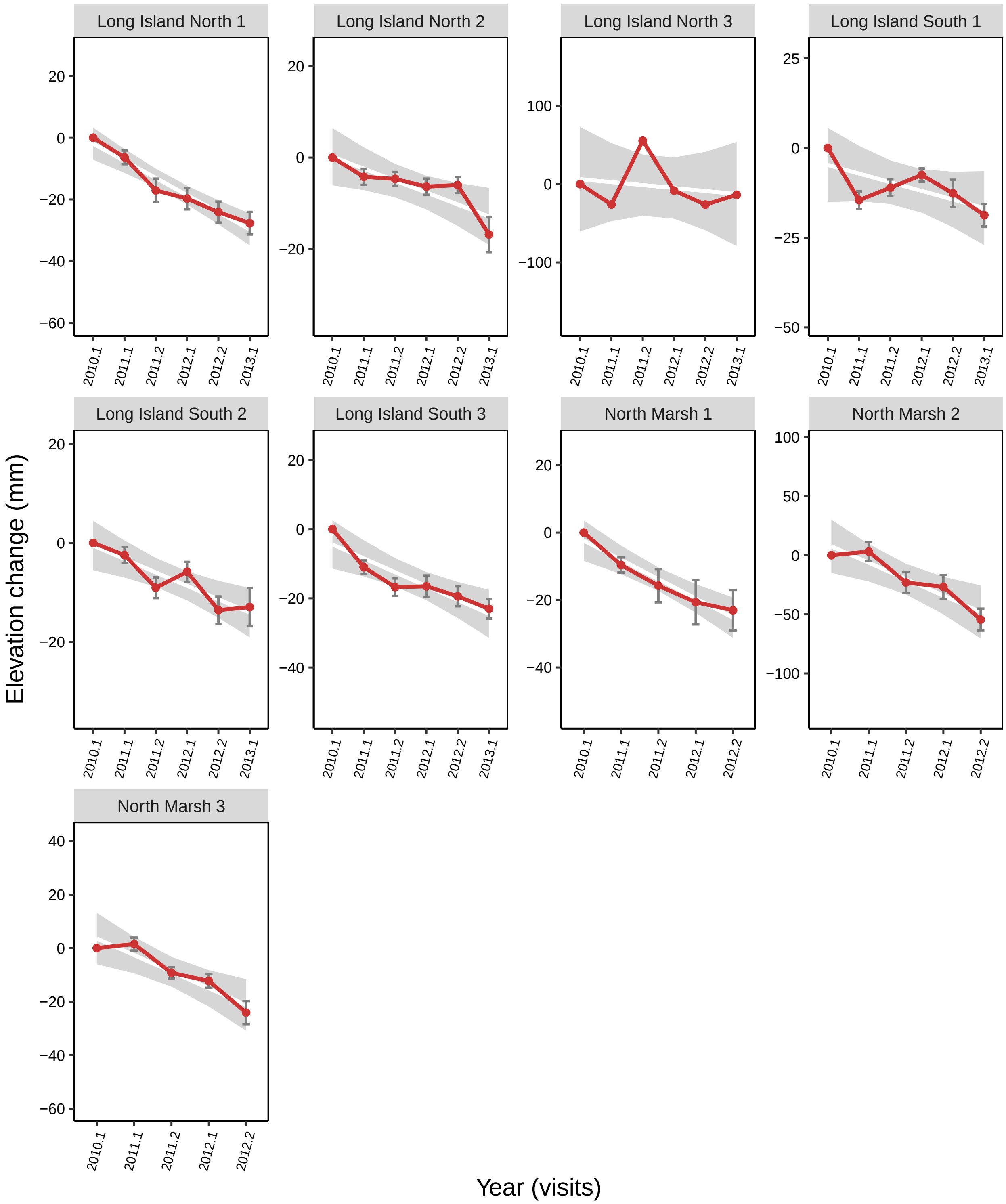


Figure 4. Summary of SET station-level elevation change (mm) data within Back Bay NWR. Means and SEs (gray bars) for each year (and within year visits) are shown along with overall linear trends. Note potentially different scales for both x and y axes.



DISCUSSION

Our primary goal in developing analytical tools for summarizing and analyzing time-series data from SET stations within USFWS Northeast Region 5 was to facilitate both region-wide, and refuge-level analyses and reporting, as well as provide meaningful products for refuge biologists that can help aid in the monitoring of change in salt marsh elevation with respect to ongoing and future management efforts. Through our initial summarization of raw SET data, we found that at the regional scale, mean delta SET (mm) is relatively stable, despite there being a large degree of variation in mean delta SET (mm) ranging from (-5.9 to 28.3 mm; see Fig. 1).

Key findings from our analyses include the importance of accounting for observer effects on measurement (data recording). While observer effects likely have little influence on region-wide mean trends in marsh elevation change (mm/year), we did find observer effects to be important at the SET station level (Fig. 2). Interestingly, there were no clear patterns in directionality and magnitude of these effects (see Appendix C for comparisons), which seem to be dependent on the particular SET station. Due to this, when taking mean estimates at the SMI unit, or refuge level, these observer effects may be dampened. Nonetheless, we recommend accounting for these effects as they will improve the accuracy of estimated rates of salt marsh elevation change. For example, in some cases we found differences between model estimates of the rate of salt marsh elevation change after accounting for observer effects (see Table 2). It is worth noting that this could have important implications when comparing rates of salt marsh elevation change to other metrics such as marsh accretion, or sea-level rise metrics, which is why we recommend moving toward adopting a linear mixed-effect modeling approach that will incorporate these observer effects and should improve the overall reliability of precision estimates of rates of salt marsh elevation change.

After comparing frequentist and Bayesian modeling approaches using percent relative standard deviations (see Fig. 3) we found similar model performance between the two methods. While the Bayesian framework may offer increased flexibility in developing more complex models to understand drivers of rates of salt marsh elevation change, we recommend using methods described in Lynch et al. (2015) for continuity, and due to there being no clear advantage (e.g., lowered variance estimates), and hence increased precision of estimates using a Bayesian framework.

Despite spending a considerable amount of time "tuning" Bayesian models and increasing MCMC iterations (i.e., 100,000) to achieve reasonable Rhat values (< 1.2), these models, in general, tended to be more sensitive to modification of non-informative priors, which is likely due to the potential for inherently small sample sizes (i.e., each regression model occurring at the pin-level over a varying numbers of years). However, within the current framework, these models could be adapted for specific cases. For example, while we did not find any clear overall patterns in improvements in model "performance" based on percent relative SD estimates (see Fig. 3), we do note that in specific cases (i.e., BKB, ESV, RHC, OYS,and WRT) Bayesian models had lower estimates of percent relative SD, indicating these models helped reduce variance estimates for salt marsh elevation change per year. However, it appears that it is largely refuge-dependent. Given that there was no overwhelming pattern favoring Bayesian vs. frequentist models used here (nor any recent use of Bayesian modeling approaches that we could find within the literature), we recommend continuing to follow methods in Lynch et al. (2015), so as to enable the comparability among different studies using this approach.

ACKOWLEDGEMENTS

We are grateful to Laura Mitchell, Susan Guiteras, Nancy Pau, Bart Wilson, and Bill Thompson for their reviews of the draft report. We have updated the current report to reflect their comments and suggesitons, which has helped improve the organization of the report. We are grateful to all USFWS staff, and Glenn Guntentspergen (USGS) who were involoved in sharing these data. Additionally, we thank Curtis George for his help in clarifying and resolving issues with these data.

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APPENDICES

Appendix A. JAGS code for models with and without observer effects.

```
# Build JAGS models

# Linear model with no observer effects.
modelstring = "

  model{

  #Priors
  b0_mu ~ dnorm(0,0.01)
  b0_tau ~ dgamma(0.01,0.01)
  b1_mu ~ dnorm(-1,1)
  b1_tau ~ dgamma(0.01,0.01)
  sG <- pow(m,2)/pow(d,2)
  rG <- m/pow(d,2)
  m ~ dgamma(0.1,0.1)
  d ~ dgamma(1,0.1)

  for ( s in 1 : Npos.pins ) {
  b0[s] ~ dnorm( b0_mu , b0_tau)
  b1[s] ~ dnorm( b1_mu , b1_tau)
  tau[s] ~ dgamma( sG , rG )
  }

  for(i in 1:Npos){
  position_tau[i] ~ dgamma(sG,rG)
  }

  for(i in 1:Nstations){
  station_tau[i] ~ dgamma(sG,rG)
  }

  #mean slope at each pin among years
  for(r in 1:Ndata) {
  y[r] ~ dnorm( mu[r] , tau[pos.pins[r]] )
  mu[r] <- b0[pos.pins[r]] + b1[pos.pins[r]] * year[r] #linear model with no observer covariate
  }

  #Derived parameters
  for(j in 1:Npos){
  position_mu[j] ~ dnorm(b1[j], position_tau[pos[j]])
  }

  pinList<-c(1,2, 3, 4, 5, 6, 7, 8, 9)
  posList<-c(0, 9, 18, 27)
  for(t in 1:Npos){
  positionMean[t] = mean(b1[pinList+posList[t]])
  }

  for(j in 1:Nstations){
```

```
  station_mu[j] ~ dnorm(position_mu[j], station_tau[stations[j]])
  }

  #arithmetic mean for station
  stationMean<-mean(positionMean)

  #end model
  }"
writeLines(modelstring, con = "modelNoObs.txt")

######################################################## Model with observer effects.
modelstring = "

  model{

  #Priors
  b0_mu ~ dnorm(0,0.01)
  b0_tau ~ dgamma(0.01,0.01)
  b1_mu ~ dnorm(-1,1)
  b1_tau ~ dgamma(0.01,0.01)
  sG <- pow(m,2)/pow(d,2)
  rG <- m/pow(d,2)
  m ~ dgamma(0.1,0.1)
  d ~ dgamma(1,0.1)

  for ( s in 1 : Npos.pins ) {
  b0[s] ~ dnorm( b0_mu , b0_tau)
  b1[s] ~ dnorm( b1_mu , b1_tau)
  tau[s] ~ dgamma( sG , rG )
  }

  for(i in 1:Npos){
  position_tau[i] ~ dgamma(sG,rG)
  }

  for(i in 1:Nstations){
  station_tau[i] ~ dgamma(sG,rG)
  }

  #mean slope at each pin among years
  for(r in 1:Ndata) {
  y[r] ~ dnorm( mu[r] , tau[pos.pins[r]] )
  mu[r] <- b0[obs[pos.pins[r]]] + b1[pos.pins[r]] * year[r]  #observer covariate as random effect
  }

  #Derived parameters
  for(j in 1:Npos){
  position_mu[j] ~ dnorm(b1[j], position_tau[pos[j]])
  }

  #mean for positions
  pinList<-c(1,2, 3, 4, 5, 6, 7, 8, 9)
  posList<-c(0, 9, 18, 27)
```

```
for(t in 1:Npos){
positionMean[t] = mean(b1[pinList+posList[t]])
}

for(j in 1:Nstations){
station_mu[j] ~ dnorm(position_mu[j], station_tau[stations[j]])
}

#arithmetic mean for station
stationMean<-mean(positionMean)

#end model
}"
```

Appendix B. Estimated linear trends (slopes) of salt marsh elevation table (SET) height (mean ± SE) for SET stations (n = 137 of 146). Where possible, means and SES were calculated by averaging 36 (i.e., 9 pins x 4 arm positions) pin-level linear model-derived slopes. Each SET station is shown along with corresponding Region, State, Refuge (Unit_Code), and Site names. For stations with NAs for Mean and SE, there were too few repeated visits within the current data set to compute these estimates.

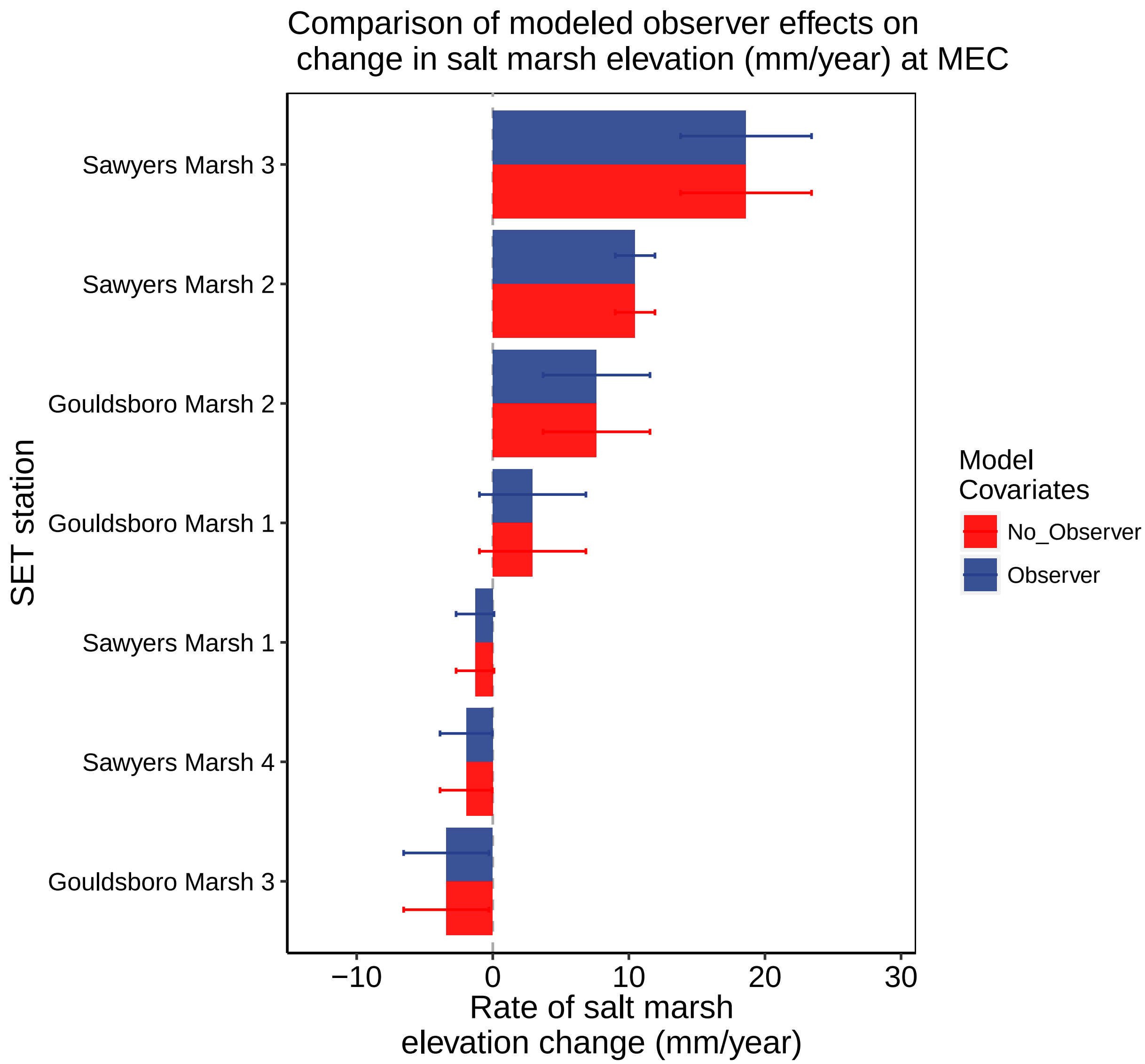
Unit_Code	SET_Name	State	Mean	SE	CV	Mean.obs	SE.obs	CV.obs
MEC	Gouldsboro Marsh 1	ME	2.93	3.91	2.67	2.93	3.91	2.67
MEC	Gouldsboro Marsh 2	ME	7.62	3.93	1.03	7.62	3.93	1.03
MEC	Gouldsboro Marsh 3	ME	-3.42	3.14	-1.84	-3.42	3.14	-1.84
MEC	Sawyers Marsh 1	ME	-1.31	1.39	-2.13	-1.31	1.39	-2.13
MEC	Sawyers Marsh 2	ME	10.46	1.46	0.28	10.46	1.46	0.28
MEC	Sawyers Marsh 3	ME	18.61	4.81	0.52	18.61	4.81	0.52
MEC	Sawyers Marsh 4	ME	-1.96	1.92	-1.96	-1.96	1.92	-1.96
RHC	Bourne 1	ME	2.25	0.28	0.25	2.25	0.28	0.25
RHC	Bourne 2	ME	-0.43	1.31	-6.07	-0.43	1.31	-6.07
RHC	Bourne 3	ME	2.72	0.51	0.38	2.72	0.51	0.38
RHC	Control 02	ME	3.45	0.12	0.07	3.40	0.14	0.08
RHC	Drakes 02	ME	-0.83	1.93	-4.64	-0.83	1.93	-4.64
RHC	Drakes 03	ME	1.51	0.67	0.88	1.51	0.67	0.88
RHC	Furbish 01	ME	-16.12	20.64	-2.56	-16.12	20.64	-2.56
RHC	Furbish 02	ME	8.28	0.72	0.17	8.28	0.72	0.17
RHC	Furbish 03	ME	-2.10	0.77	-0.74	-2.10	0.77	-0.74
RHC	Granite Point Control 02	ME	4.64	1.73	0.75	4.66	1.73	0.74
RHC	Granite Point Control 03	ME	2.37	0.16	0.13	2.49	0.19	0.15
RHC	Harbor 02	ME	-1.99	0.68	-0.68	-1.99	0.68	-0.68
RHC	ME1	ME	11.47	0.36	0.06	11.47	0.36	0.06
RHC	ME2	ME	7.99	0.14	0.03	7.91	0.15	0.04
RHC	Mile North 01	ME	-0.36	0.87	-4.84	-0.36	0.87	-4.84
RHC	Mile North 03	ME	-0.49	1.01	-4.17	-0.49	1.01	-4.17
RHC	Mile South 01	ME	1.38	0.65	0.95	1.38	0.65	0.95
RHC	Mile South 02	ME	2.67	0.63	0.47	2.67	0.63	0.47
RHC	Mile South 03	ME	5.88	2.66	0.91	5.88	2.66	0.91
RHC	Moody 1	ME	-5.89	0.71	-0.24	-5.89	0.71	-0.24
RHC	Moody 2	ME	0.64	1.06	3.33	0.64	1.06	3.33
RHC	Moody 3	ME	-0.74	1.30	-3.54	-0.74	1.30	-3.54
PKR	B2 1-80	MA	13.01	1.46	0.22	10.48	1.72	0.33
PKR	B2 4-120	MA	7.67	0.20	0.05	5.69	0.71	0.25
PKR	B2 5-40	MA	8.25	1.46	0.35	5.47	1.11	0.41
PKR	Control 3-120	MA	2.06	0.26	0.26	2.06	0.26	0.25
PKR	Control 3-40	MA	2.64	0.87	0.66	2.65	0.92	0.69
PKR	Control 4-120	MA	-1.90	0.23	-0.25	-1.90	0.23	-0.25
PKR	Knobb 01	MA	0.90	1.62	3.58	0.90	1.62	3.58
PKR	Knobb 02	MA	NA	NA	NA	NA	NA	NA
PKR	Knobb 03	MA	NA	NA	NA	NA	NA	NA
PKR	NP01	MA	NA	NA	NA	NA	NA	NA
PKR	NP02	MA	NA	NA	NA	NA	NA	NA
PKR	NP03	MA	NA	NA	NA	NA	NA	NA
PKR	SP01	MA	4.38	1.08	0.50	4.38	1.08	0.50
PKR	SP02	MA	6.72	2.95	0.88	6.72	2.95	0.88
SPT	SPT01	RI	6.00	0.21	0.07	6.47	0.14	0.04
SPT	SPT02	RI	5.26	1.31	0.50	4.47	1.02	0.46

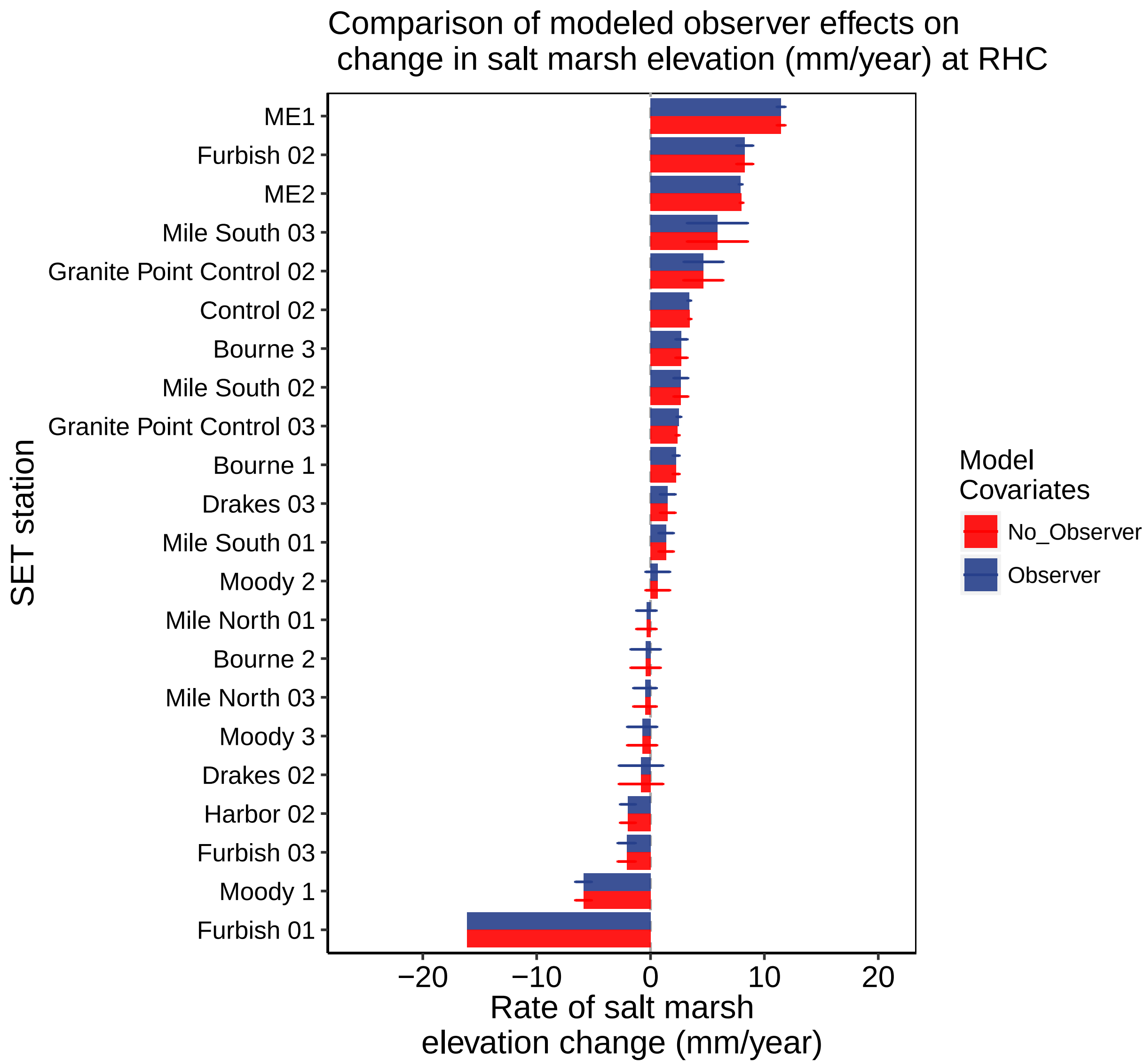
Unit_Code	SET_Name	State	Mean	SE	CV	Mean.obs	SE.obs	CV.obs
SPT	SPT03	RI	2.21	0.45	0.41	2.16	0.42	0.39
SPT	SPT04	RI	2.63	0.81	0.61	0.85	0.08	0.19
SPT	SPT05	RI	2.27	0.67	0.59	1.20	0.36	0.60
SPT	SPT06	RI	3.55	0.19	0.11	1.33	0.19	0.29
JHC	JHC01	RI	0.48	0.33	1.39	0.12	0.08	1.41
JHC	JHC02	RI	3.87	0.67	0.35	3.77	0.59	0.31
JHC	JHC03	RI	3.02	0.63	0.42	2.83	0.68	0.48
JHC	JHC04	RI	3.27	0.52	0.32	3.14	0.47	0.30
JHC	JHC05	RI	0.71	0.25	0.70	0.11	0.48	8.76
JHC	JHC06	RI	1.33	0.09	0.13	0.71	0.41	1.15
JHC	JHC07	RI	-0.61	0.55	-1.80	0.43	0.93	4.31
OYS	FC01	NY	-0.90	0.82	-1.83	4.78	3.16	1.32
OYS	FC03	NY	-2.81	1.98	-1.41	-0.03	2.20	-154.00
WRT	SP1	NY	7.54	0.84	0.22	7.26	0.77	0.21
WRT	SP2	NY	11.90	1.59	0.27	12.09	1.44	0.24
WRT	SP3	NY	5.38	0.53	0.20	5.43	0.51	0.19
WRT	WEU1	NY	2.24	2.32	2.07	1.59	2.23	2.80
WRT	WEU2	NY	3.72	0.73	0.39	0.54	0.67	2.51
WRT	WEU3	NY	1.88	2.26	2.41	0.94	1.85	3.92
WRT	WNU1	NY	6.78	1.04	0.31	6.68	1.48	0.44
WRT	WNU2	NY	7.10	2.76	0.78	6.47	3.15	0.97
WRT	WNU3	NY	-1.60	1.78	-2.23	-3.08	3.72	-2.41
WRT	WWU1	NY	4.74	0.50	0.21	4.79	0.46	0.19
WRT	WWU2	NY	3.75	0.26	0.14	3.83	0.26	0.14
WRT	WWU3	NY	2.61	0.40	0.31	2.70	0.35	0.26
EBF	AT&T Control SET 01	NJ	1.67	0.90	1.08	1.67	0.90	1.08
EBF	AT&T Control SET 02	NJ	3.98	2.62	1.32	3.98	2.62	1.32
EBF	AT&T Control SET 03	NJ	-1.06	0.38	-0.71	-1.06	0.38	-0.71
EBF	AT&T SMI 07	NJ	75.79	3.75	0.10	75.79	3.75	0.10
EBF	AT&T SMI 08	NJ	99.50	5.57	0.11	99.50	5.57	0.11
EBF	AT&T SMI 09	NJ	88.77	7.00	0.16	88.77	7.00	0.16
EBF	AT&T Treatment SET 04	NJ	0.64	0.39	1.20	0.64	0.39	1.20
EBF	AT&T Treatment SET 05	NJ	0.57	0.44	1.53	0.57	0.44	1.53
EBF	AT&T Treatment SET 06	NJ	3.68	0.73	0.40	3.68	0.73	0.40
EBF	LB-surf 1*	NJ	-18.34	1.60	-0.18	1.61	1.02	1.27
EBF	LB-surf 2*	NJ	-11.64	0.70	-0.12	7.89	1.23	0.31
EBF	Mill Crk-Cedar Run SET Purple 01	NJ	154.85	9.23	0.12	154.85	9.23	0.12
EBF	Mill Crk-Cedar Run SET Purple 02	NJ	12.31	0.50	0.08	12.31	0.50	0.08
EBF	Mill Crk-Cedar Run SET Purple 03	NJ	8.03	2.35	0.59	8.03	2.35	0.59
EBF	Motts-Mull. Wild SET 02	NJ	-0.86	1.85	-4.30	-0.86	1.85	-4.30
EBF	Motts-Mull. Wild SET 03	NJ	NA	NA	NA	NA	NA	NA
EBF	Simpkins*	NJ	-6.36	2.76	-0.87	13.05	0.67	0.10
EBF	West Creek SET 01	NJ	2.31	5.76	5.00	2.31	5.76	5.00
EBF	West Creek SET 02	NJ	5.31	3.40	1.28	5.31	3.40	1.28
EBF	West Creek SET 03	NJ	-19.69	0.90	-0.09	-19.69	0.90	-0.09
BMH	SB01	DE	-4.60	1.11	-0.48	-4.60	1.11	-0.48
BMH	SB02	DE	-4.70	3.09	-1.31	-3.57	2.98	-1.67
BMH	SB03	DE	0.40	3.38	17.05	0.40	3.38	17.05
BMH	SET01_AF	DE	-2.68	1.29	-0.96	-2.68	1.29	-0.96
BMH	SET01_BHIN	DE	9.85	4.15	0.84	9.85	4.15	0.84
BMH	SET01_GI	DE	-19.29	2.19	-0.23	-19.29	2.19	-0.23
BMH	SET01_Kent	DE	-5.62	4.99	-1.77	-5.62	4.99	-1.77

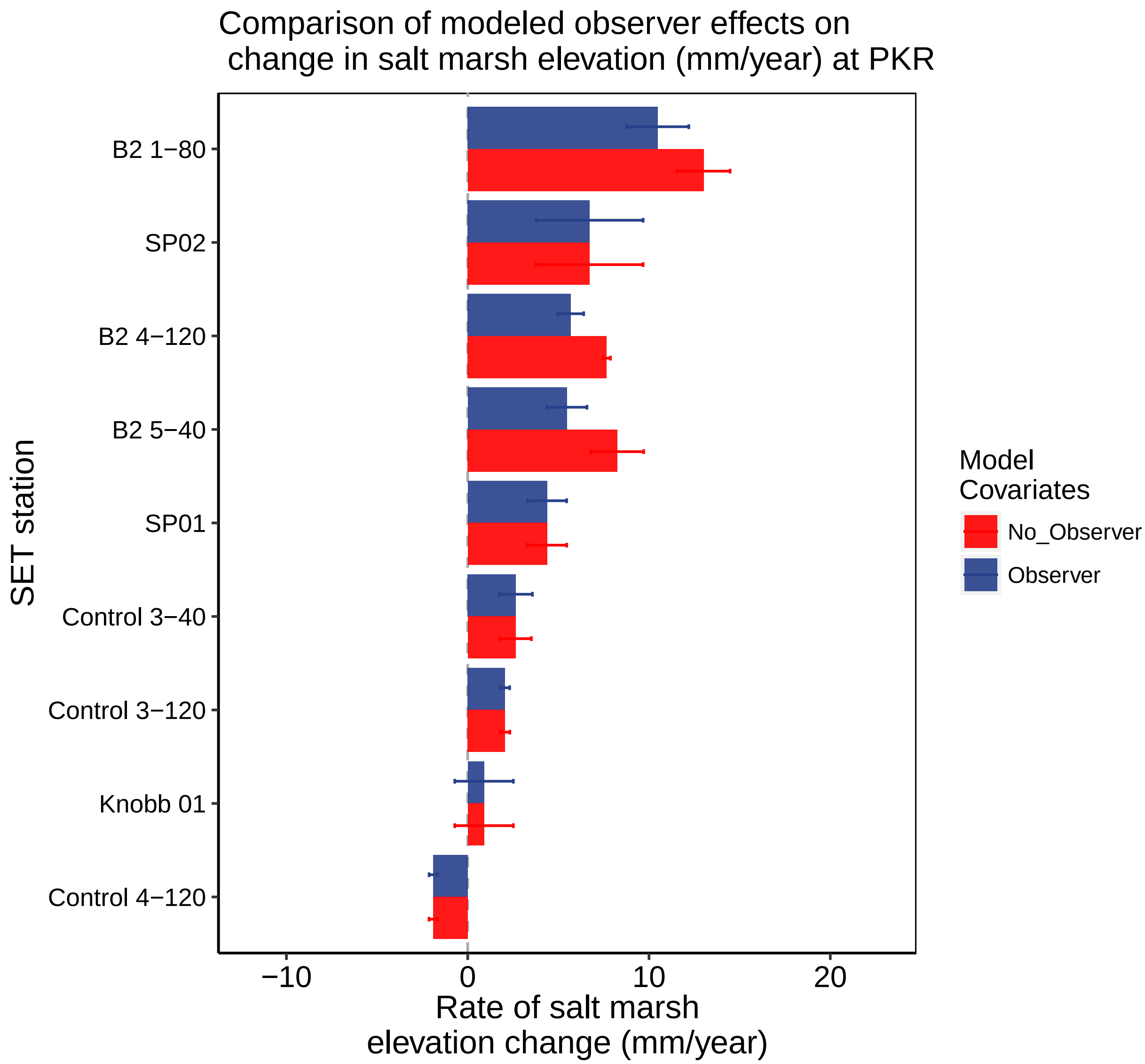
Unit_Code	SET_Name	State	Mean	SE	CV	Mean.obs	SE.obs	CV.obs
BMH	Set01-BHIS	DE	-14.74	0.80	-0.11	-14.74	0.80	-0.11
BMH	SET02_GI	DE	-15.39	4.05	-0.53	-15.39	4.05	-0.53
BMH	SET02_Kent	DE	1.99	2.80	2.82	1.99	2.80	2.82
BMH	SET03_AF	DE	25.14	13.55	1.08	25.14	13.55	1.08
BMH	SET03_GI	DE	-24.00	4.61	-0.38	-24.00	4.61	-0.38
BMH	SET03_Kent	DE	-1.11	3.39	-6.10	-1.11	3.39	-6.10
BMH	USGS_1_fertilized	DE	3.41	0.12	0.07	2.57	0.24	0.18
BMH	USGS_2_control	DE	4.40	0.35	0.16	3.67	0.49	0.26
BMH	USGS_3_control	DE	2.40	0.57	0.47	1.55	0.42	0.54
BMH	USGS_4_fertilized	DE	4.37	0.81	0.37	4.10	0.96	0.47
PMH	PH2-1 (Deep)	DE	23.83	0.65	0.05	23.83	0.65	0.05
PMH	PH2-2 (Deep)	DE	-23.77	3.51	-0.30	-23.77	3.51	-0.30
PMH	PH2-3 (Deep)	DE	21.88	2.29	0.21	21.88	2.29	0.21
PMH	PH2-4 (Deep)	DE	13.65	3.31	0.48	13.65	3.31	0.48
PMH	PH2-5 (Deep)	DE	47.99	3.27	0.14	47.99	3.27	0.14
PMH	PH2-6 (Deep)	DE	14.07	1.09	0.16	14.07	1.09	0.16
PMH	Set 1 (Deep)	DE	12.15	6.53	1.07	12.15	6.53	1.07
PMH	Set 2 (Deep)	DE	11.98	5.50	0.92	11.98	5.50	0.92
PMH	Set 3 (Deep)	DE	8.66	1.83	0.42	9.04	1.72	0.38
PMH_shallow	PH2-1 (Shallow)	DE	29.72	0.61	0.04	29.72	0.61	0.04
PMH_shallow	PH2-2 (Shallow)	DE	-12.85	1.60	-0.25	-12.85	1.60	-0.25
PMH_shallow	PH2-3 (Shallow)	DE	20.62	1.49	0.14	20.62	1.49	0.14
PMH_shallow	PH2-4 (Shallow)	DE	14.16	2.89	0.41	14.16	2.89	0.41
PMH_shallow	PH2-5 (Shallow)	DE	69.70	5.00	0.14	69.70	5.00	0.14
PMH_shallow	PH2-6 (Shallow)	DE	17.59	0.56	0.06	17.59	0.56	0.06
PMH_shallow	Set 1 (Shallow)	DE	20.84	3.28	0.31	20.84	3.28	0.31
PMH_shallow	Set 2 (Shallow)	DE	12.65	3.78	0.60	12.65	3.78	0.60
PMH_shallow	Set 3 (Shallow)	DE	14.22	1.44	0.20	13.37	1.49	0.22
ESV	Bull Plot 1	VA	5.09	1.67	0.65	5.09	1.67	0.65
ESV	Bull Plot 2	VA	2.76	1.43	1.04	2.76	1.43	1.04
ESV	Bull Plot 3	VA	1.63	0.50	0.61	1.63	0.50	0.61
ESV	ESV Plot 1	VA	1.08	0.84	1.56	1.08	0.84	1.56
ESV	ESV Plot 2	VA	2.58	0.81	0.63	2.58	0.81	0.63
ESV	ESV Plot 3	VA	2.76	0.43	0.31	2.76	0.43	0.31
ESV	FIE Plot 1	VA	5.48	0.86	0.31	5.48	0.86	0.31
ESV	FIE Plot 2	VA	3.87	0.80	0.42	3.87	0.80	0.42
ESV	FIE Plot 3	VA	4.73	0.88	0.37	4.73	0.88	0.37
ESV	FIW Plot 1	VA	4.91	0.79	0.32	4.91	0.79	0.32
ESV	FIW Plot 2	VA	7.62	1.34	0.35	7.62	1.34	0.35
ESV	FIW Plot 3	VA	2.48	0.79	0.64	2.48	0.79	0.64
BKB	Long Island North 1	VA	-9.41	1.62	-0.34	-9.41	1.62	-0.34
BKB	Long Island North 2	VA	-4.92	0.91	-0.37	-4.92	0.91	-0.37
BKB	Long Island North 3	VA	-9.53	1.29	-0.27	-9.53	1.29	-0.27
BKB	Long Island South 1	VA	-4.61	2.38	-1.03	-4.61	2.38	-1.03
BKB	Long Island South 2	VA	-4.26	0.48	-0.23	-4.26	0.48	-0.23
BKB	Long Island South 3	VA	-7.03	0.89	-0.25	-7.03	0.89	-0.25
BKB	North Marsh 1	VA	-10.67	4.26	-0.80	-10.67	4.26	-0.80
BKB	North Marsh 2	VA	-21.79	5.02	-0.46	-21.79	5.02	-0.46
BKB	North Marsh 3	VA	-9.85	1.63	-0.33	-9.85	1.63	-0.33

Appendix C. Figures comparing frequentist models with and without observer effects and figures showing the influence (directionality and magnitude) of accounting for observer (data recorder) effects.

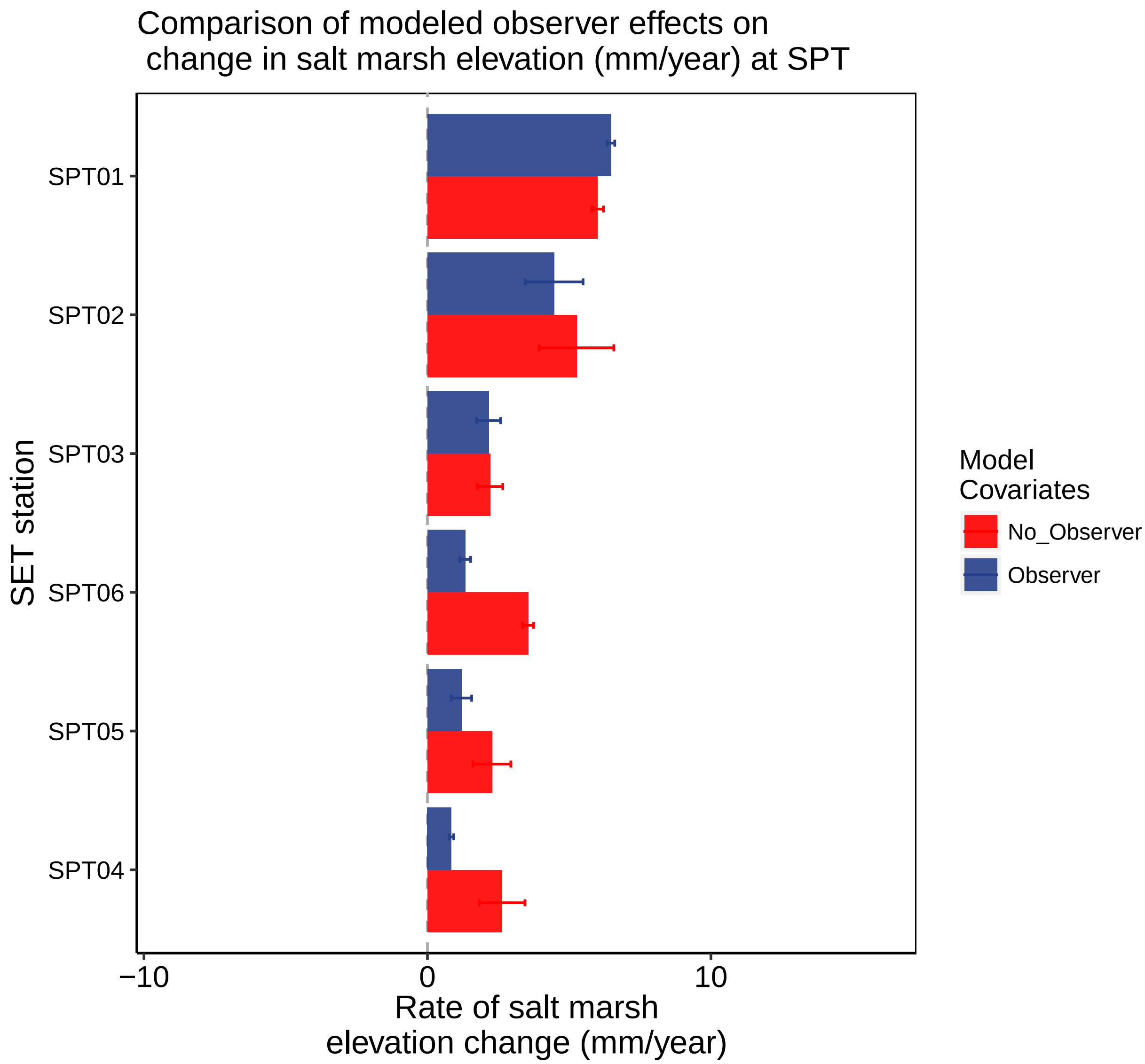
Compare model estimates of change in marsh height (mm/year) between models without observer and including observer effects.

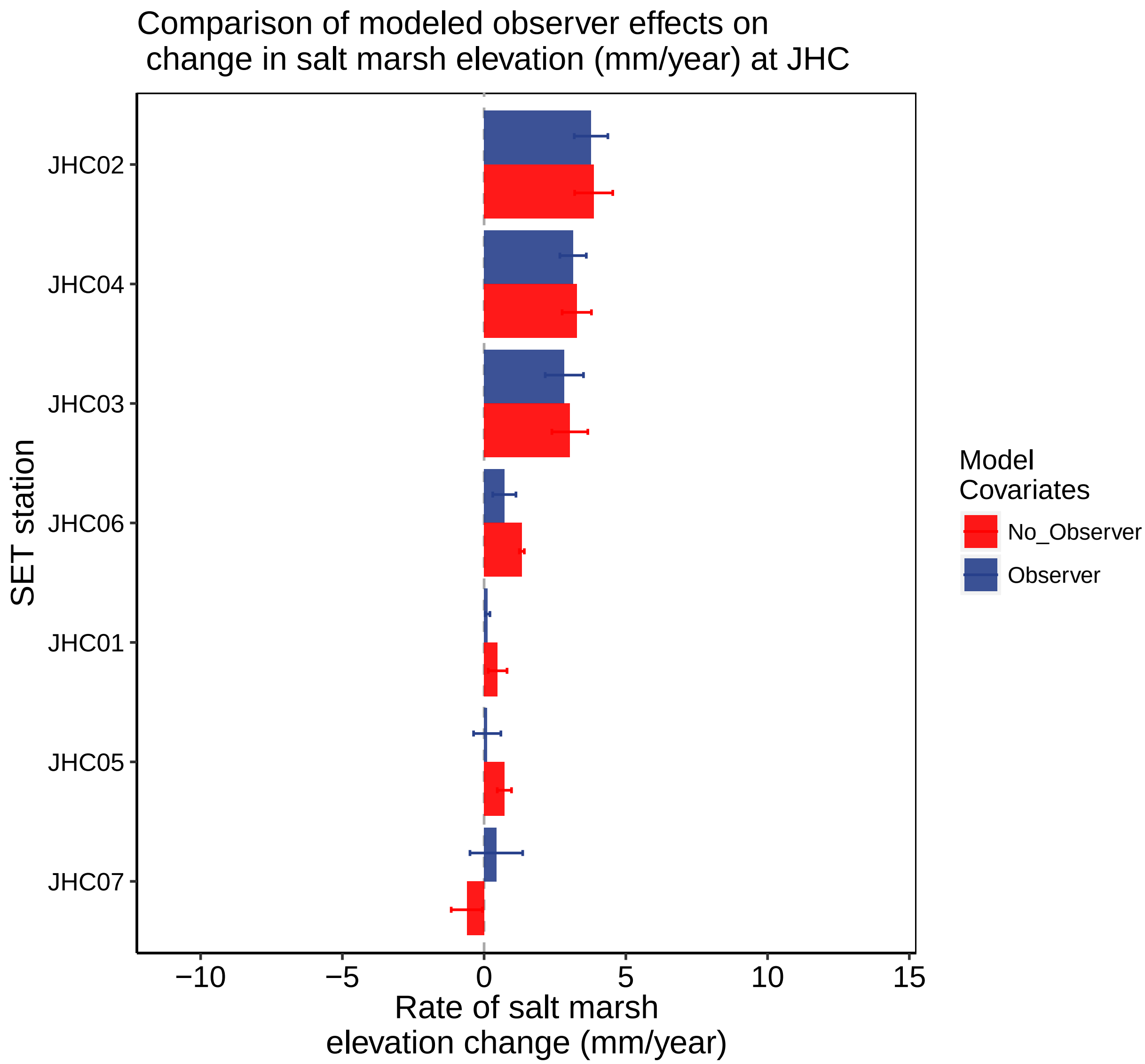


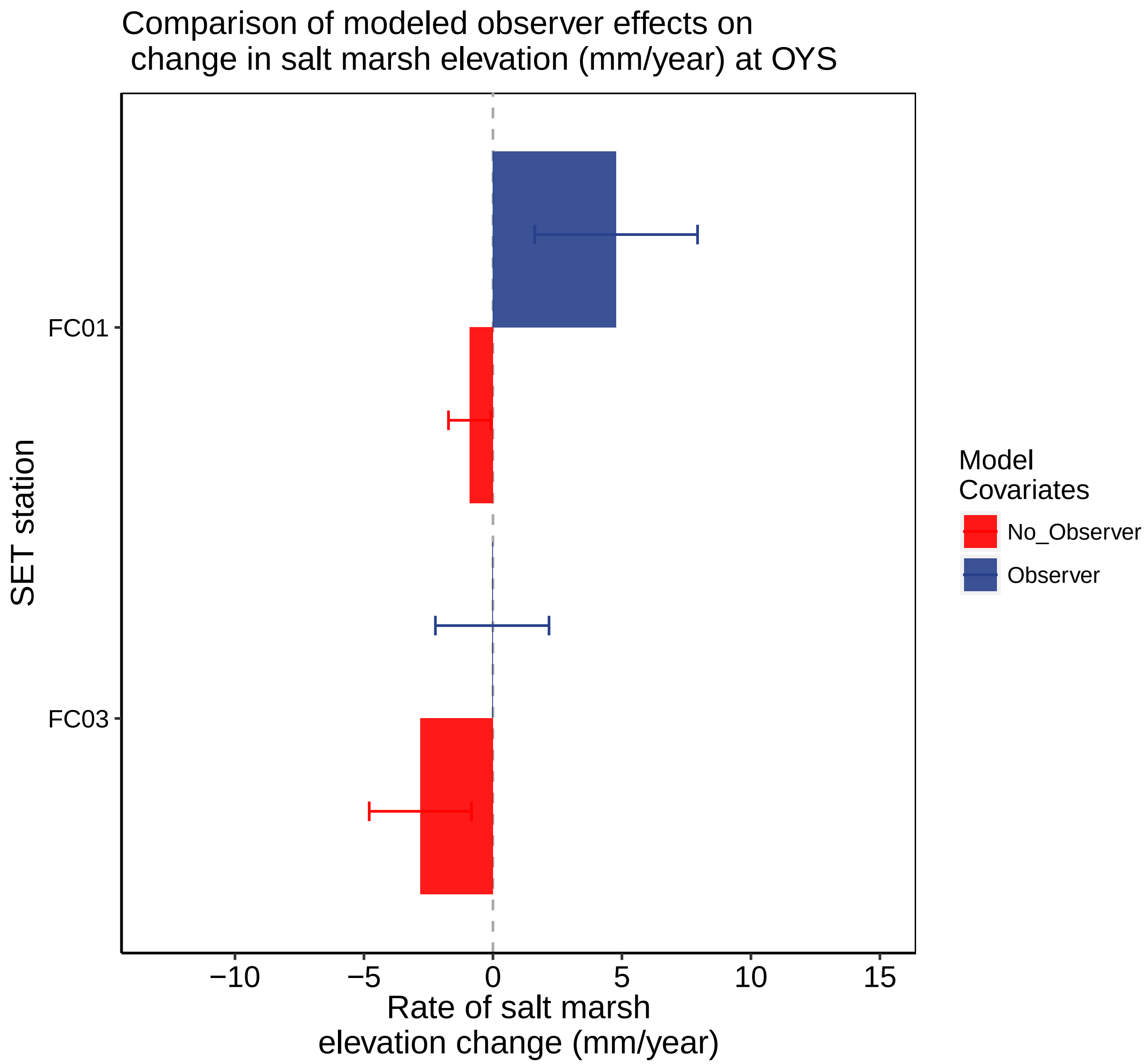

Comparison of modeled observer effects on
change in salt marsh elevation (mm/year) at RHC
ME1
Furbish 02
ME2
Mile South 03
Granite Point Control 02
Control 02
Bourne 3
Mile South 02
Granite Point Control 03
Bourne 1
Drakes 03
Mile South 01
Moody 2
Mile North 01
Bourne 2
Mile North 03
Moody 3
Drakes 02
Harbor 02
Furbish 03
Moody 1
Furbish 01
SET station
−20
−10
0
10
20
Rate of salt marsh
elevation change (mm/year)
Model
Covariates
No_Observer
Observer



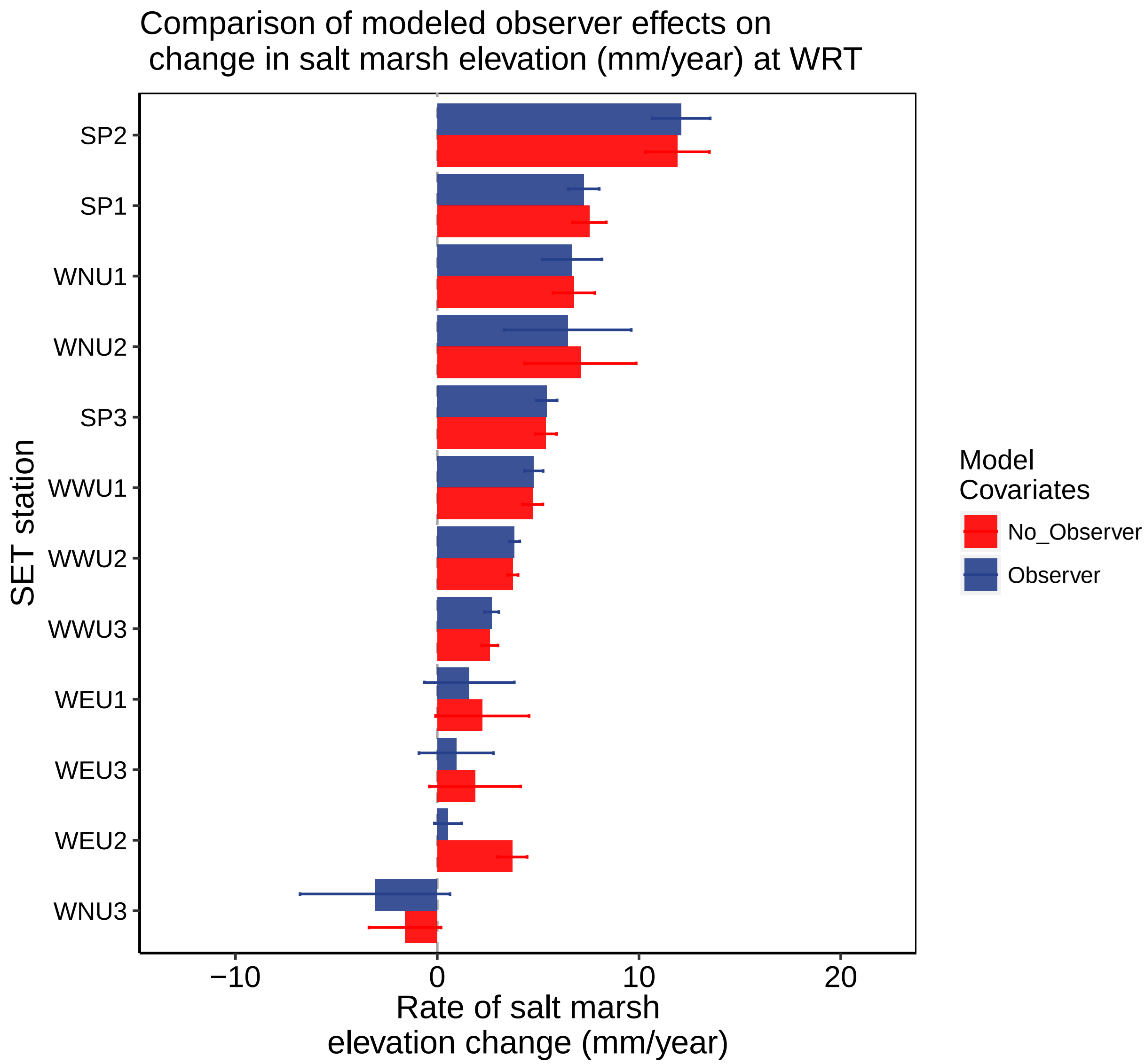
Comparison of modeled observer effects on
change in salt marsh elevation (mm/year) at PKR
SET station
B2 1−80
SP02
B2 4−120
B2 5−40
SP01
Control 3−40
Control 3−120
Knobb 01
Control 4−120
−10
0
10
20
Rate of salt marsh
elevation change (mm/year)
Model
Covariates
No_Observer
Observer

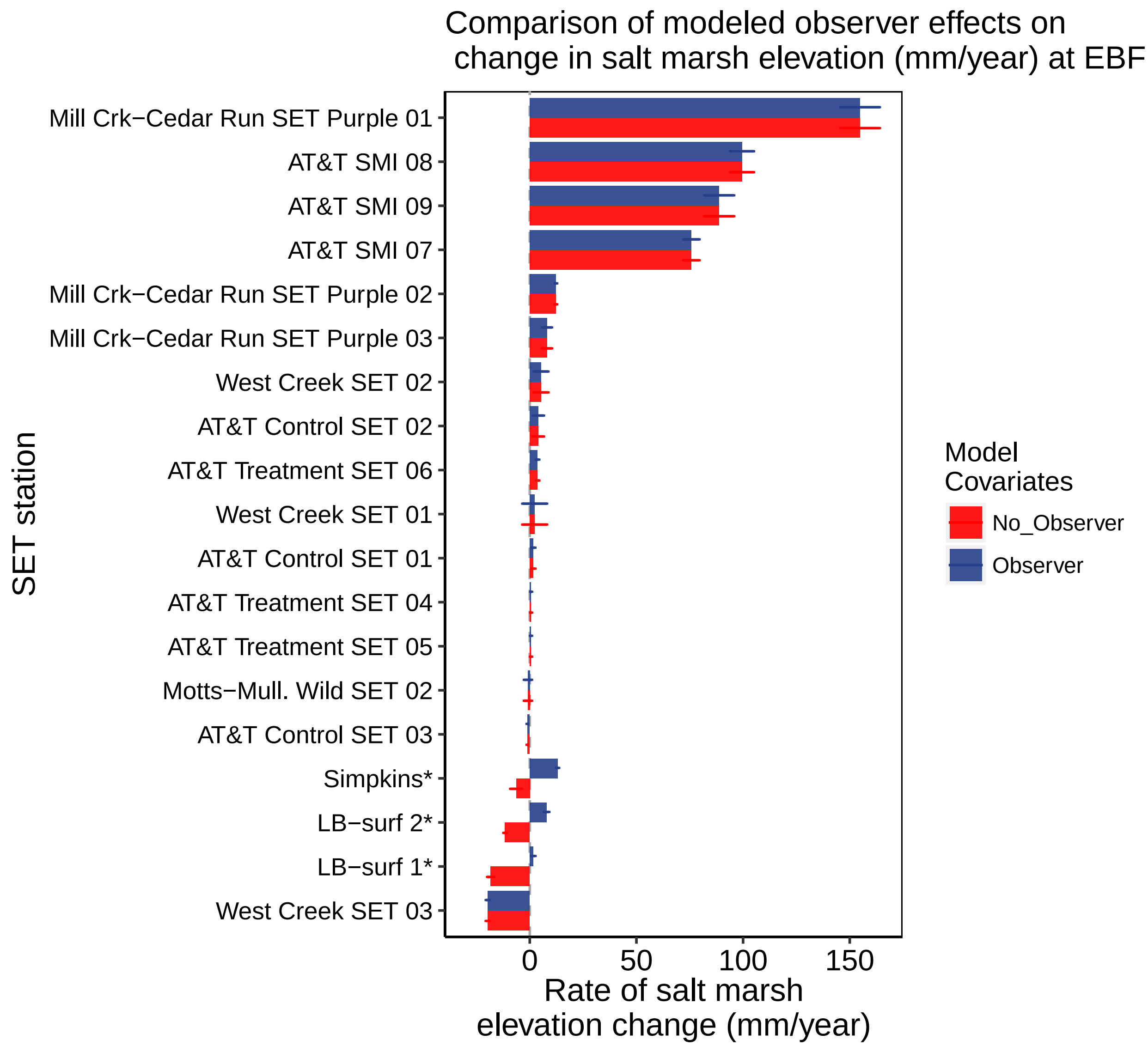

Comparison of modeled observer effects on
change in salt marsh elevation (mm/year) at SPT
SET station
SPT01
SPT02
SPT03
SPT06
SPT05
SPT04
−10
0
10
Rate of salt marsh
elevation change (mm/year)
Model
Covariates
No_Observer
Observer

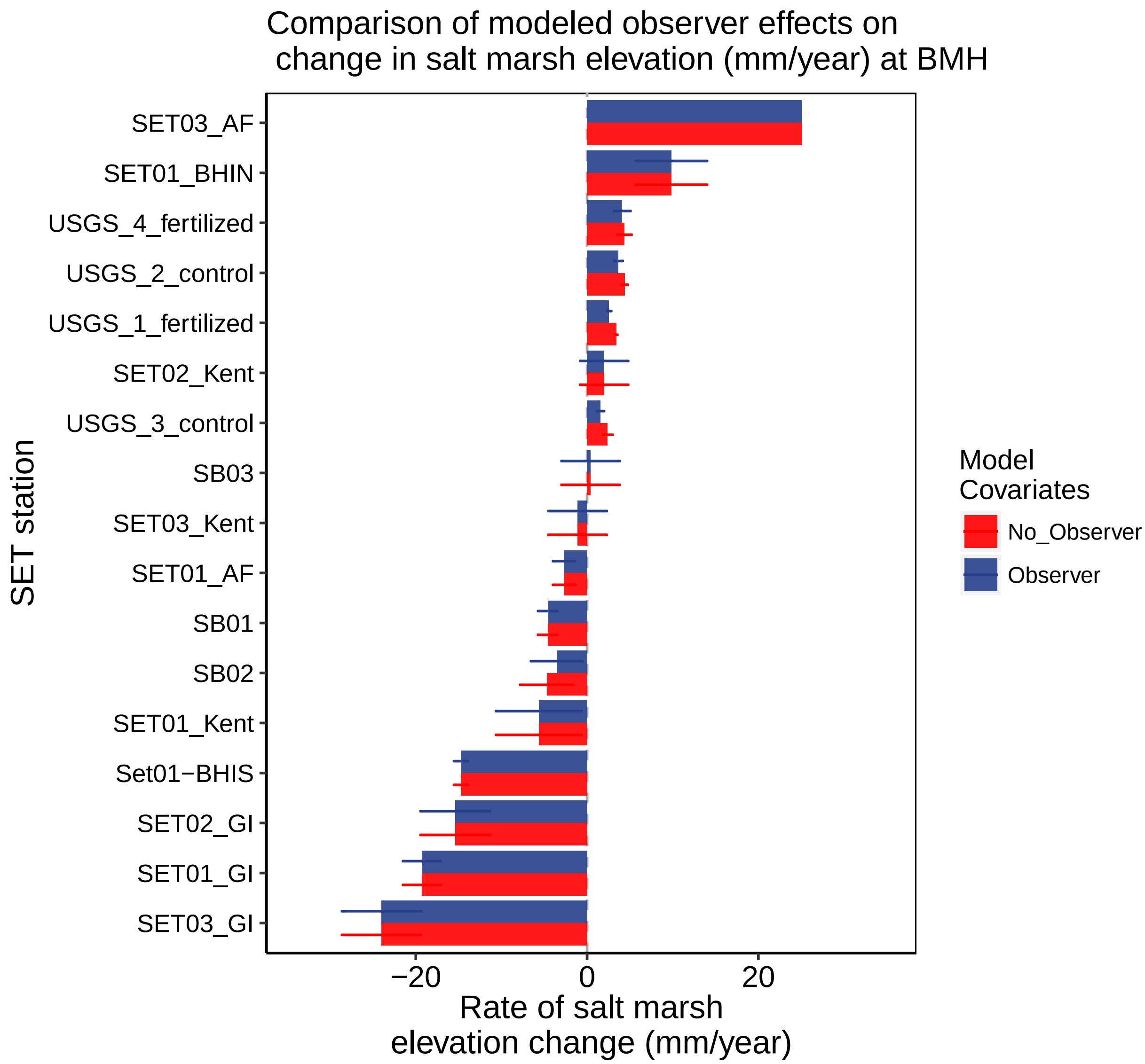

Comparison of modeled observer effects on
change in salt marsh elevation (mm/year) at JHC
JHC02
JHC04
JHC03
JHC06
JHC01
JHC05
JHC07
SET station
−10
−5
0
5
10
15
Rate of salt marsh
elevation change (mm/year)
Model
Covariates
No_Observer
Observer

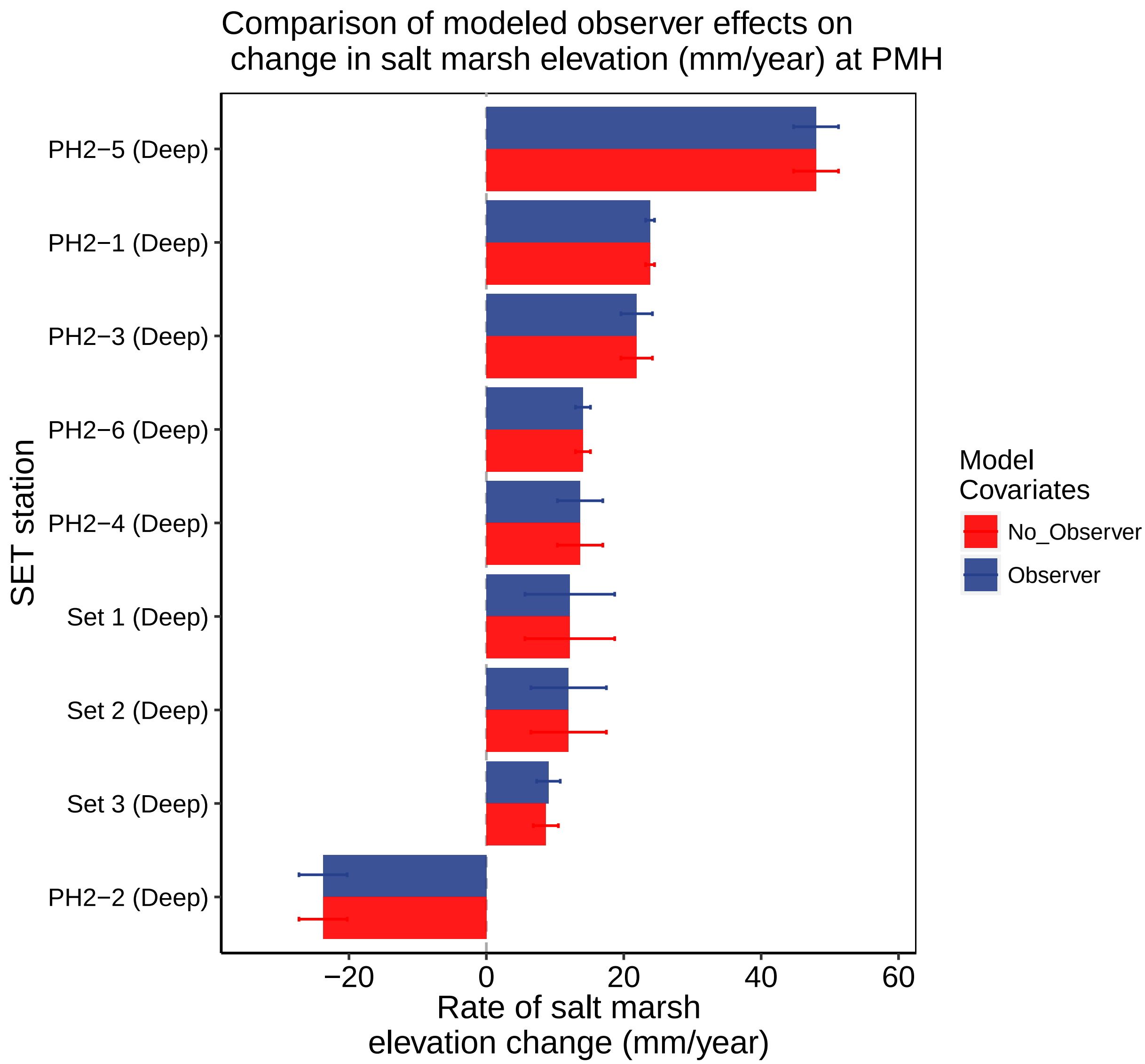


Comparison of modeled observer effects on
change in salt marsh elevation (mm/year) at OYS
SET station
FC01
FC03
−10
−5
0
5
10
15
Rate of salt marsh
elevation change (mm/year)
Model
Covariates
No_Observer
Observer

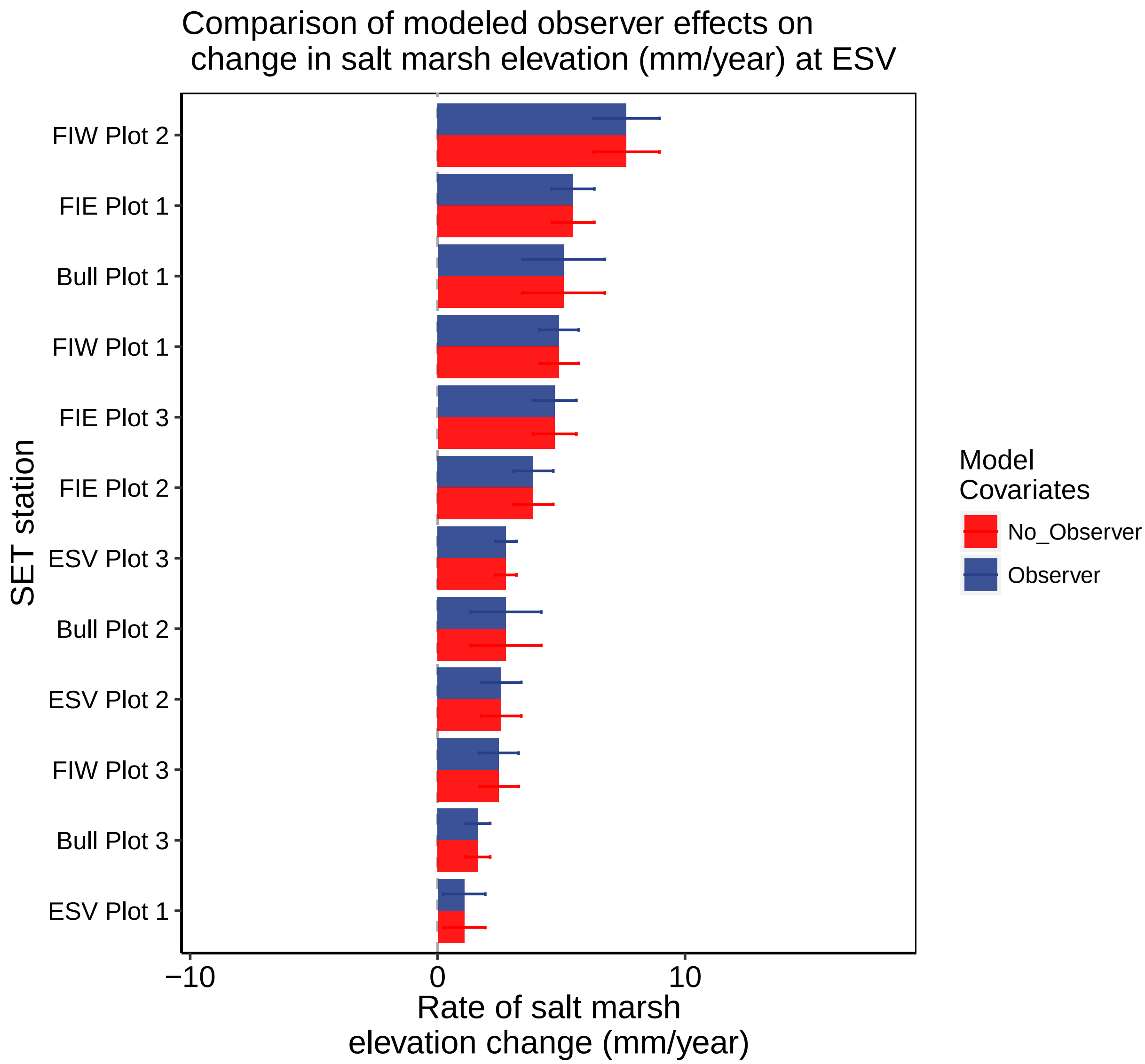

Comparison of modeled observer effects on
change in salt marsh elevation (mm/year) at WRT
SET station
SP2
SP1
WNU1
WNU2
SP3
WWU1
WWU2
WWU3
WEU1
WEU3
WEU2
WNU3
−10
0
10
20
Rate of salt marsh
elevation change (mm/year)
Model
Covariates
No_Observer
Observer

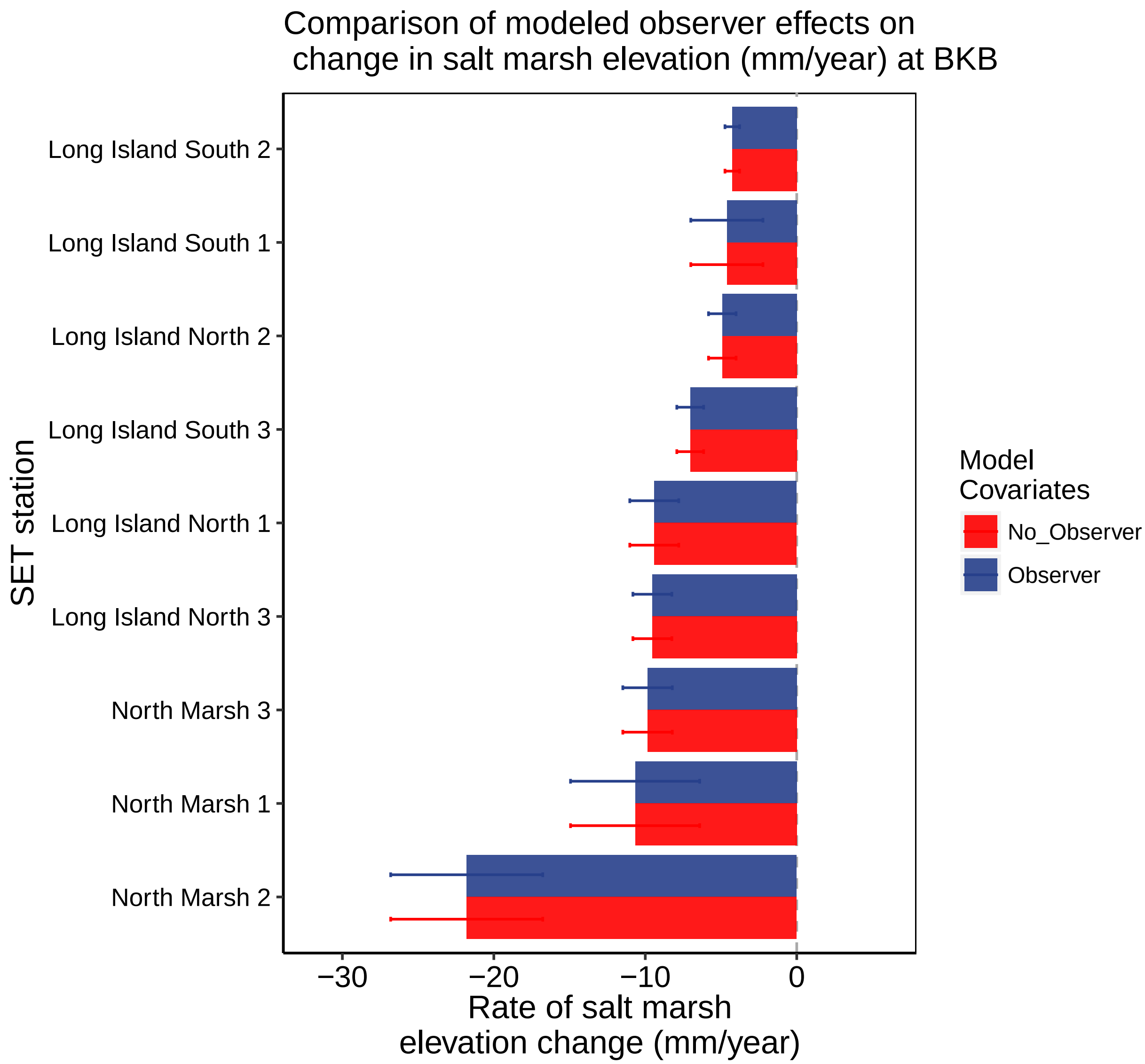

Comparison of modeled observer effects on
change in salt marsh elevation (mm/year) at EBF
Mill Crk−Cedar Run SET Purple 01
AT&T SMI 08
AT&T SMI 09
AT&T SMI 07
Mill Crk−Cedar Run SET Purple 02
Mill Crk−Cedar Run SET Purple 03
West Creek SET 02
AT&T Control SET 02
AT&T Treatment SET 06
West Creek SET 01
AT&T Control SET 01
AT&T Treatment SET 04
AT&T Treatment SET 05
Motts−Mull. Wild SET 02
AT&T Control SET 03
Simpkins*
LB−surf 2*
LB−surf 1*
West Creek SET 03
SET station
0
50
100
150
Rate of salt marsh
elevation change (mm/year)
Model
Covariates
No_Observer
Observer

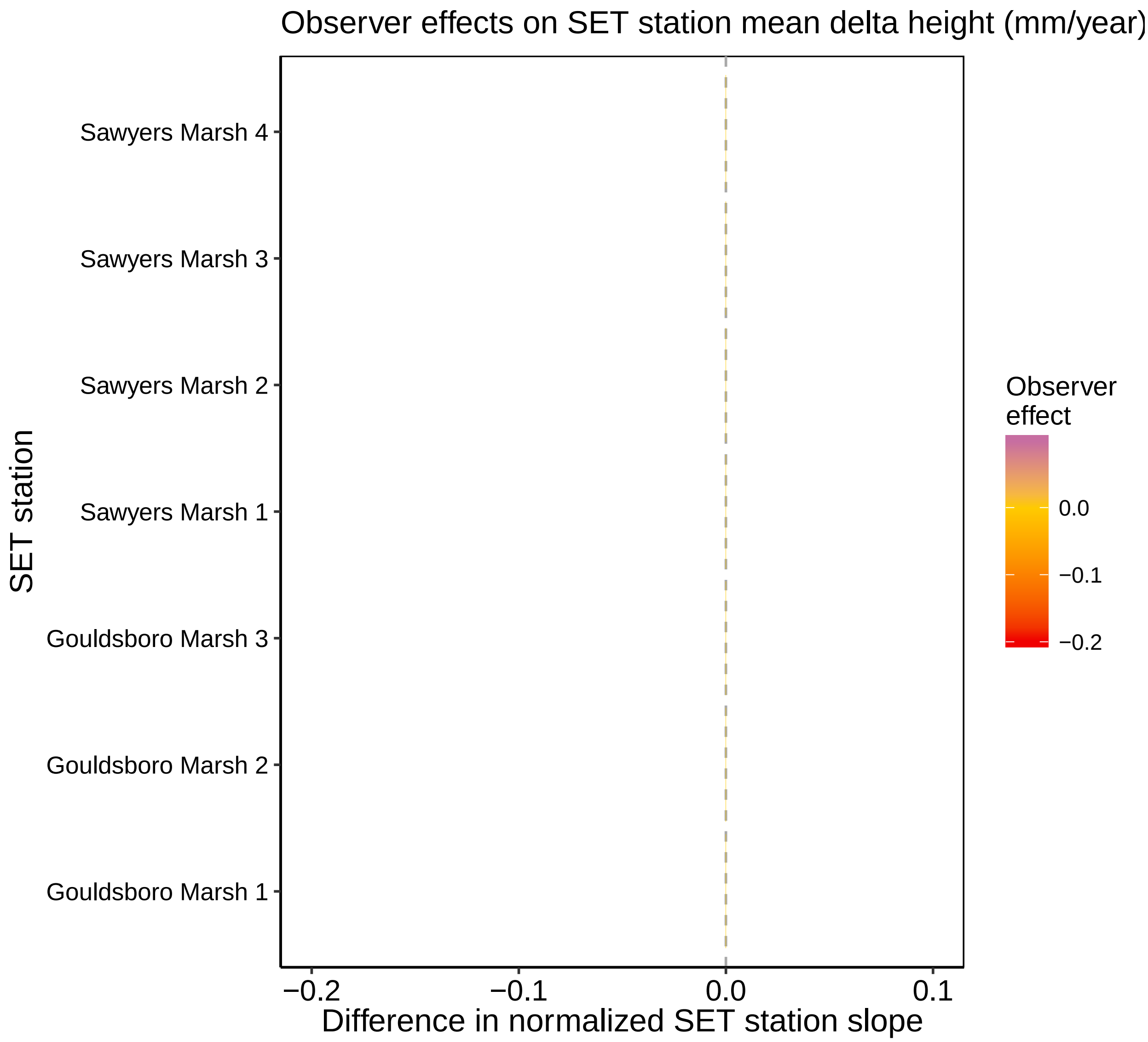

Comparison of modeled observer effects on
change in salt marsh elevation (mm/year) at BMH
SET station
SET03_AF
SET01_BHIN
USGS_4_fertilized
USGS_2_control
USGS_1_fertilized
SET02_Kent
USGS_3_control
SB03
SET03_Kent
SET01_AF
SB01
SB02
SET01_Kent
Set01−BHIS
SET02_GI
SET01_GI
SET03_GI
−20
0
20
Rate of salt marsh
elevation change (mm/year)
Model
Covariates
No_Observer
Observer

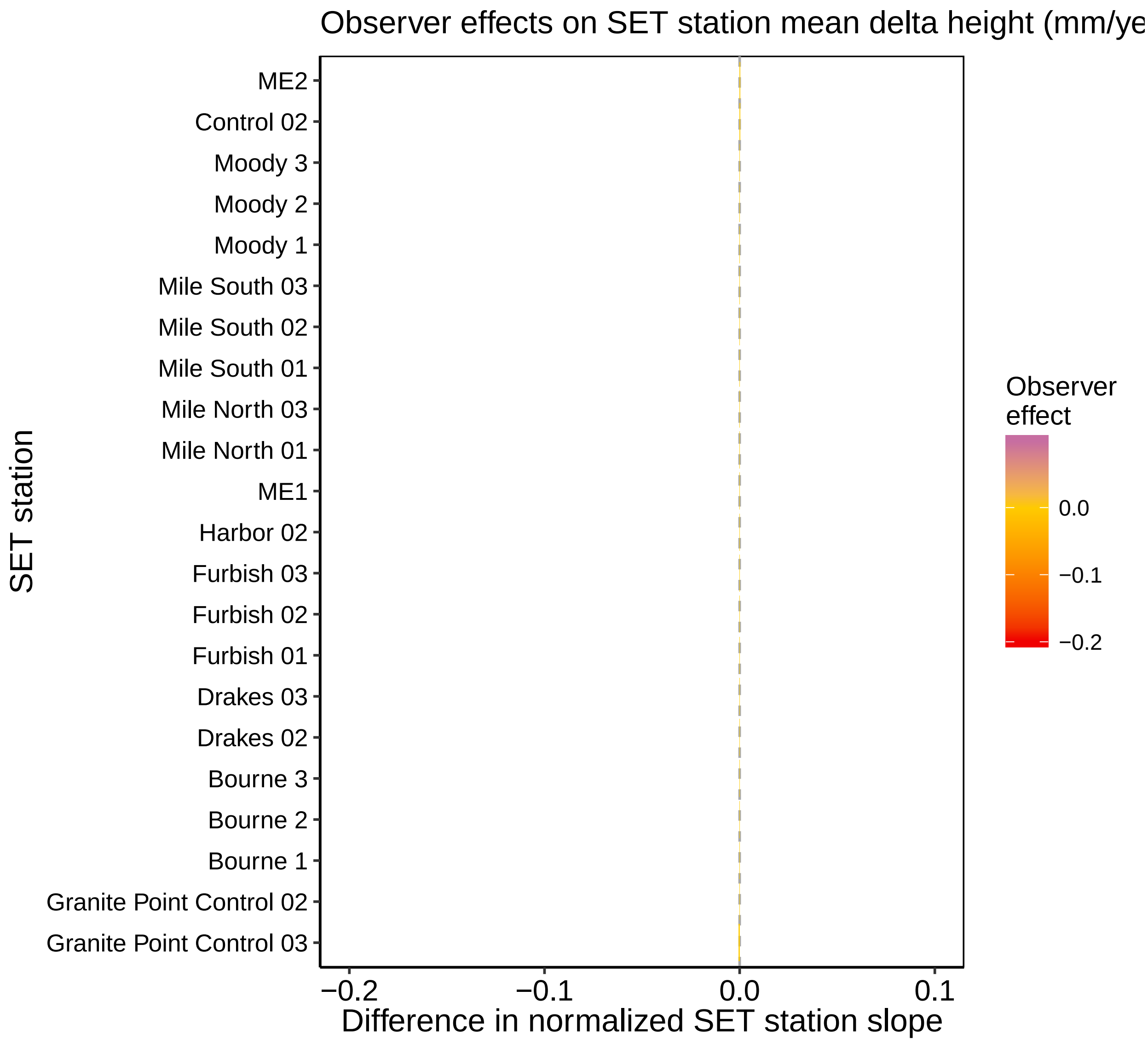


Comparison of modeled observer effects on
change in salt marsh elevation (mm/year) at PMH
SET station
PH2−5 (Deep)
PH2−1 (Deep)
PH2−3 (Deep)
PH2−6 (Deep)
PH2−4 (Deep)
Set 1 (Deep)
Set 2 (Deep)
Set 3 (Deep)
PH2−2 (Deep)
−20
0
20
40
60
Rate of salt marsh
elevation change (mm/year)
Model
Covariates
No_Observer
Observer

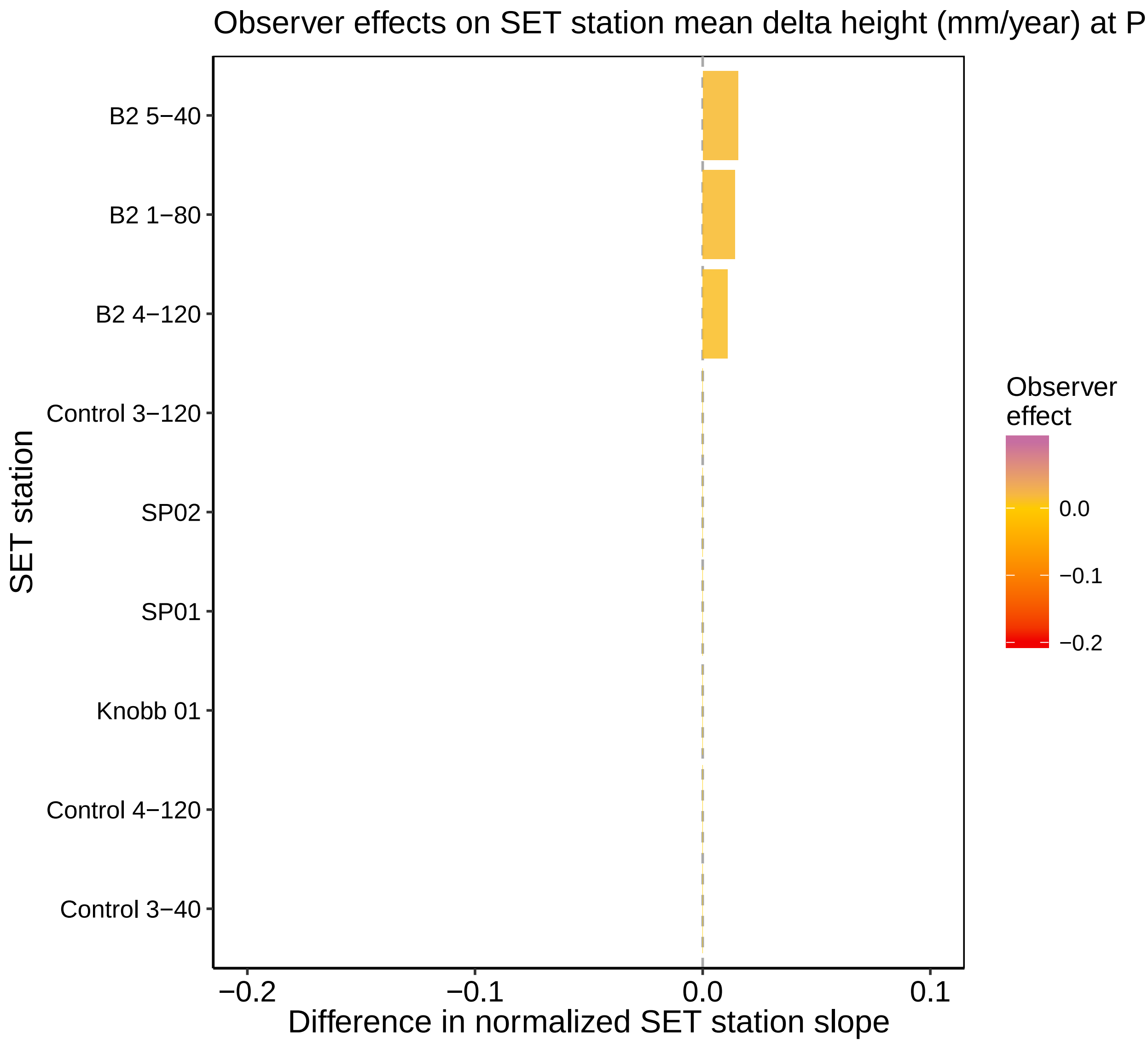

Comparison of modeled observer effects on
change in salt marsh elevation (mm/year) at ESV
FIW Plot 2
FIE Plot 1
Bull Plot 1
FIW Plot 1
FIE Plot 3
FIE Plot 2
ESV Plot 3
Bull Plot 2
ESV Plot 2
FIW Plot 3
Bull Plot 3
ESV Plot 1
SET station
−10
0
10
Rate of salt marsh
elevation change (mm/year)
Model
Covariates
No_Observer
Observer


Comparison of modeled observer effects on
change in salt marsh elevation (mm/year) at BKB
SET station
Long Island South 2
Long Island South 1
Long Island North 2
Long Island South 3
Long Island North 1
Long Island North 3
North Marsh 3
North Marsh 1
North Marsh 2
−30
−20
−10
0
Rate of salt marsh
elevation change (mm/year)
Model
Covariates
No_Observer
Observer

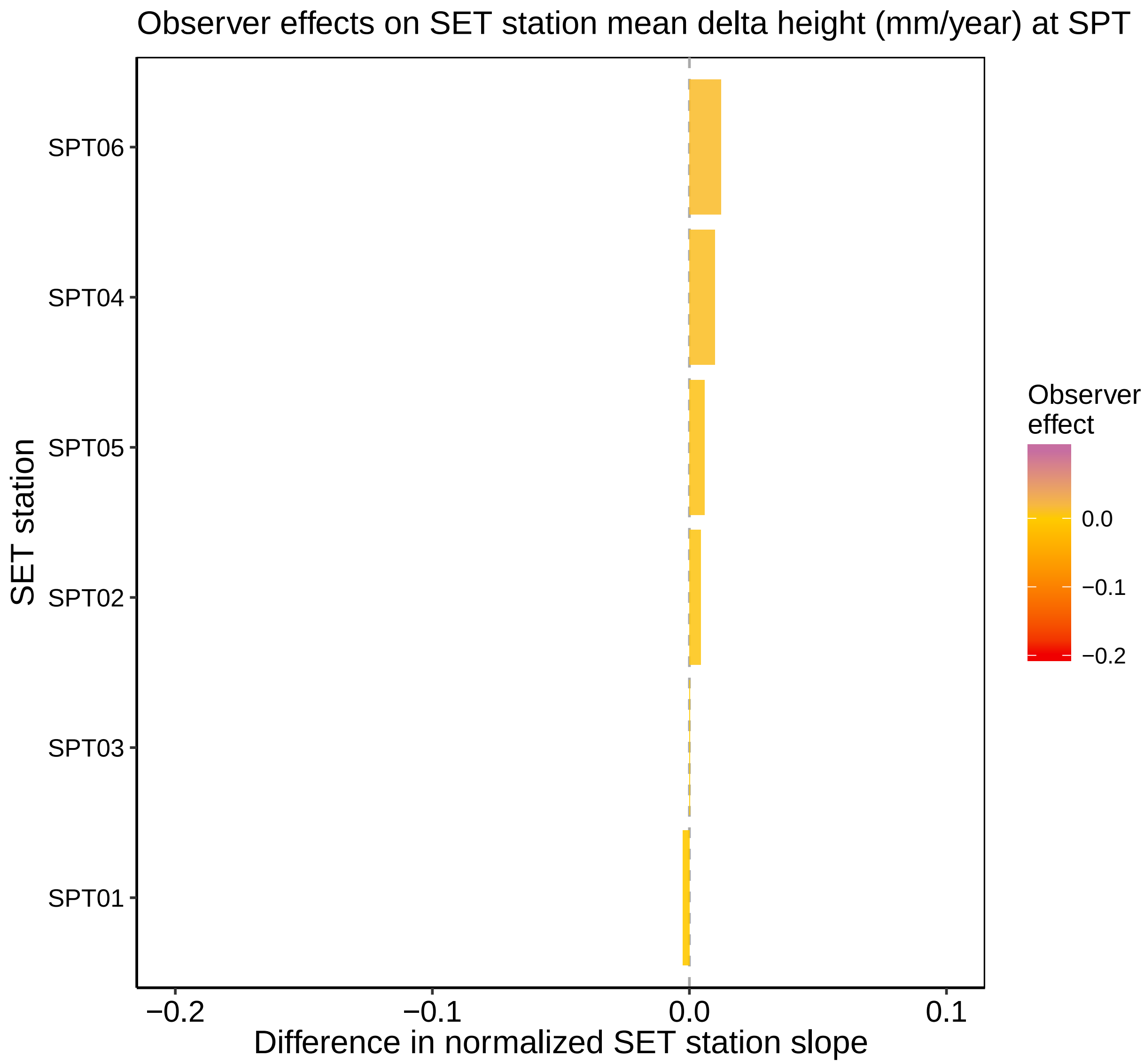

Observer effects on SET station mean delta height (mm/year)
Sawyers Marsh 4
Sawyers Marsh 3
Sawyers Marsh 2
Sawyers Marsh 1
Gouldsboro Marsh 3
Gouldsboro Marsh 2
Gouldsboro Marsh 1
SET station
−0.2
−0.1
0.0
0.1
Difference in normalized SET station slope
Observer effect
0.0
−0.1
−0.2

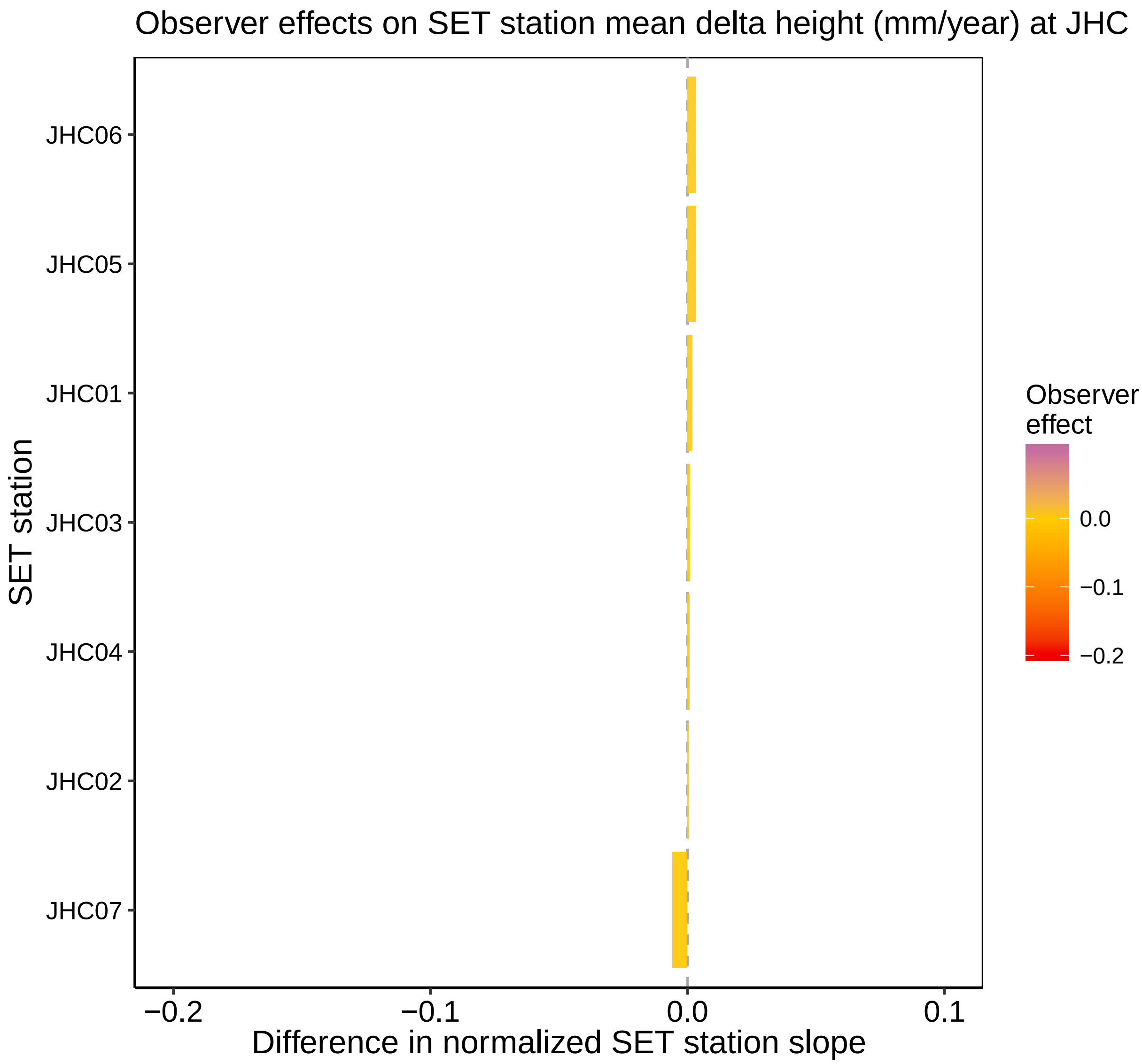


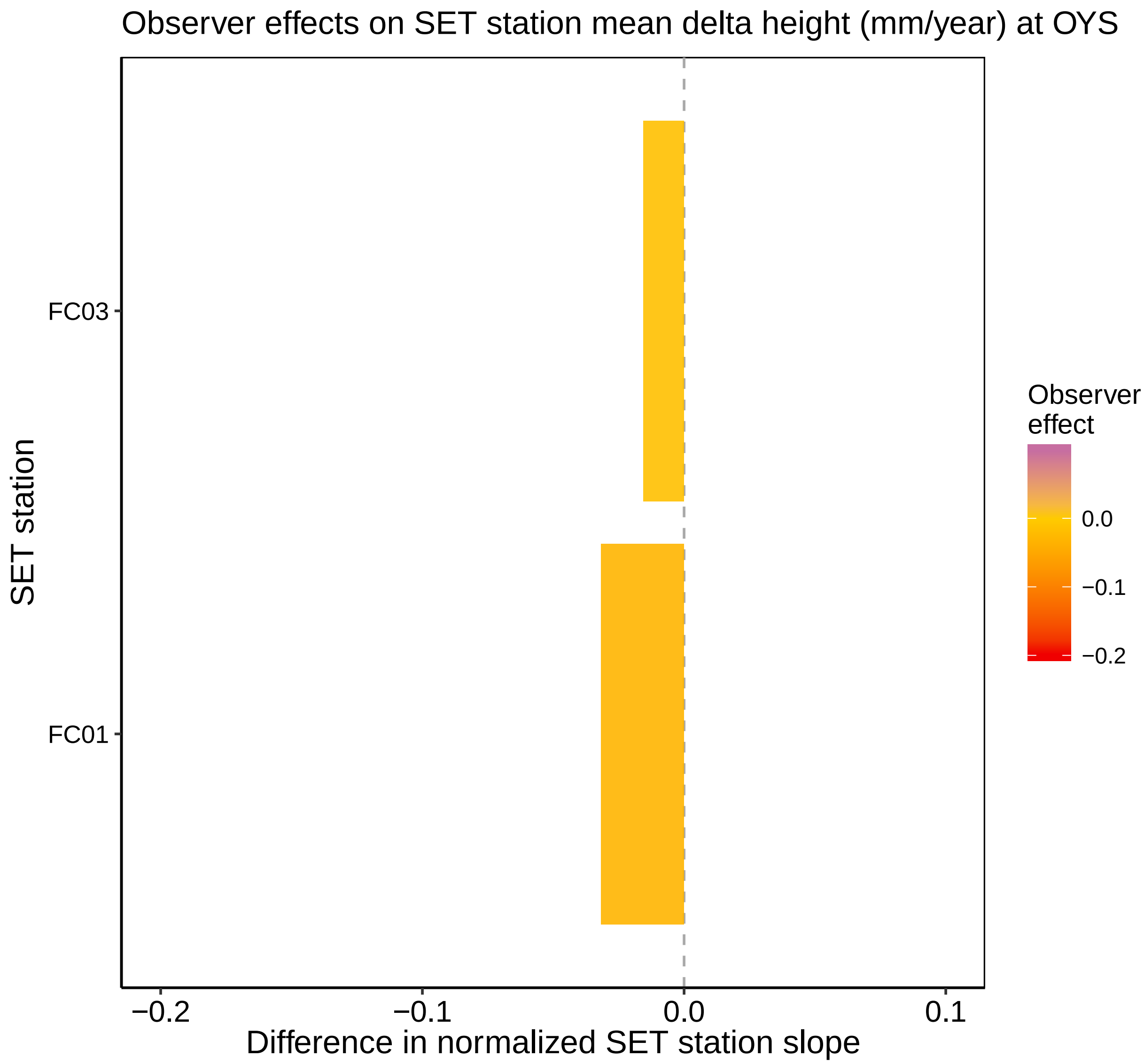
Observer effects on SET station mean delta height (mm/ye
SET station
ME2
Control 02
Moody 3
Moody 2
Moody 1
Mile South 03
Mile South 02
Mile South 01
Mile North 03
Mile North 01
ME1
Harbor 02
Furbish 03
Furbish 02
Furbish 01
Drakes 03
Drakes 02
Bourne 3
Bourne 2
Bourne 1
Granite Point Control 02
Granite Point Control 03
−0.2
−0.1
0.0
0.1
Difference in normalized SET station slope
Observer effect
0.0
−0.1
−0.2

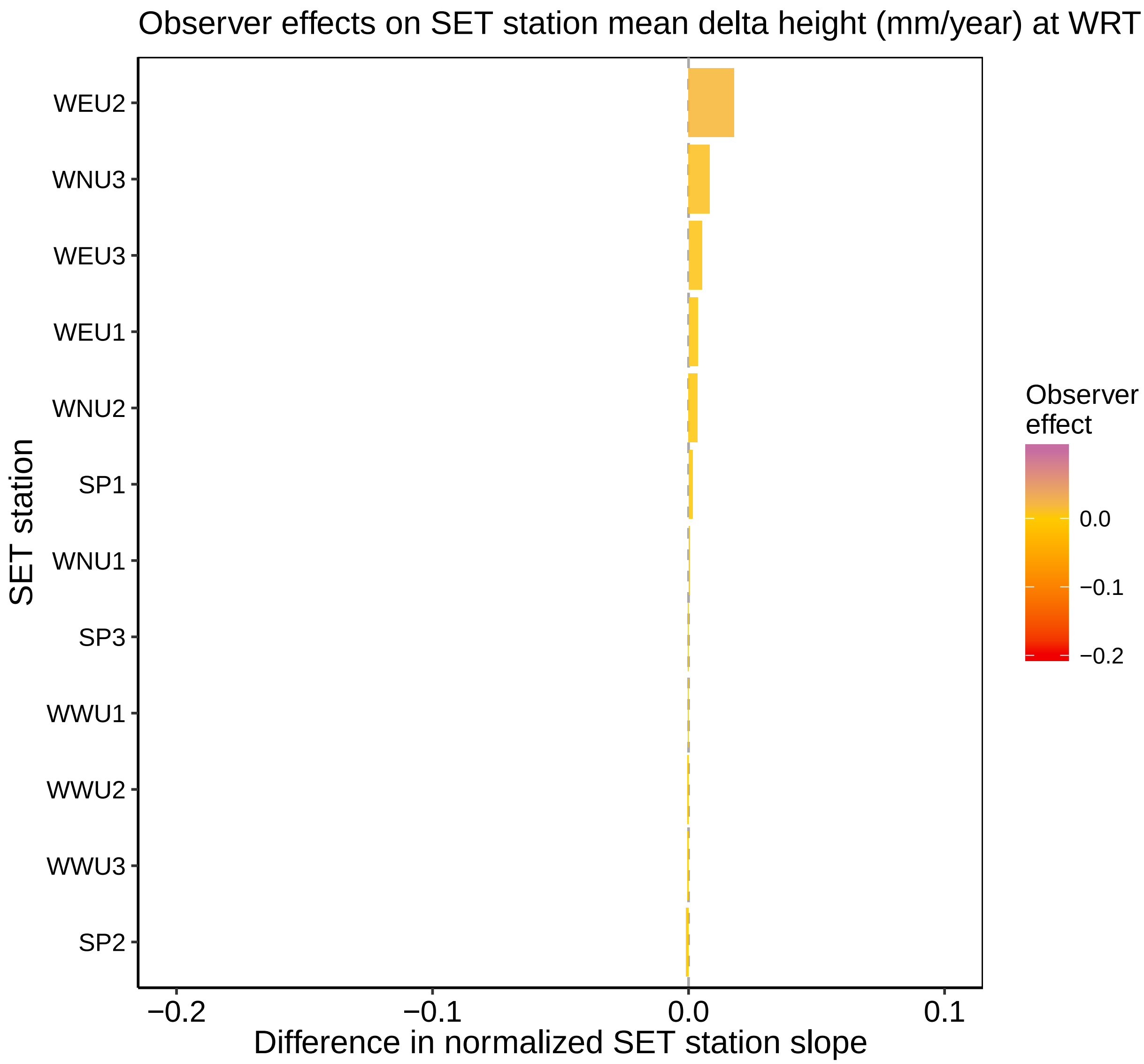


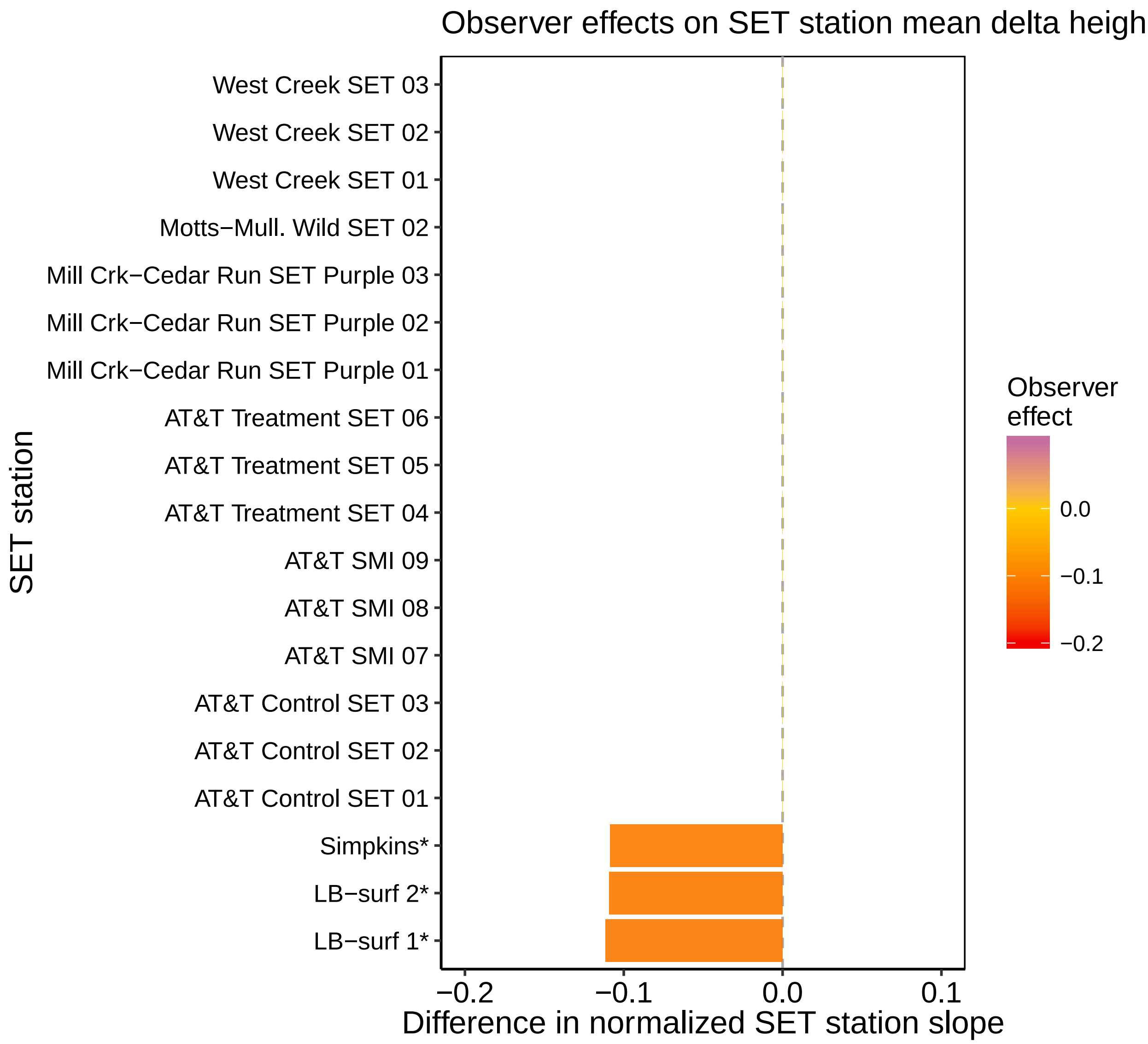
Observer effects on SET station mean delta height (mm/year) at P
SET station
B2 5−40
B2 1−80
B2 4−120
Control 3−120
SP02
SP01
Knobb 01
Control 4−120
Control 3−40
−0.2
−0.1
0.0
0.1
Difference in normalized SET station slope
Observer effect
0.0
−0.1
−0.2


Observer effects on SET station mean delta height (mm/year) at SPT
SET station
SPT06
SPT04
SPT05
SPT02
SPT03
SPT01
−0.2
−0.1
0.0
0.1
Difference in normalized SET station slope
Observer
effect
0.0
−0.1
−0.2

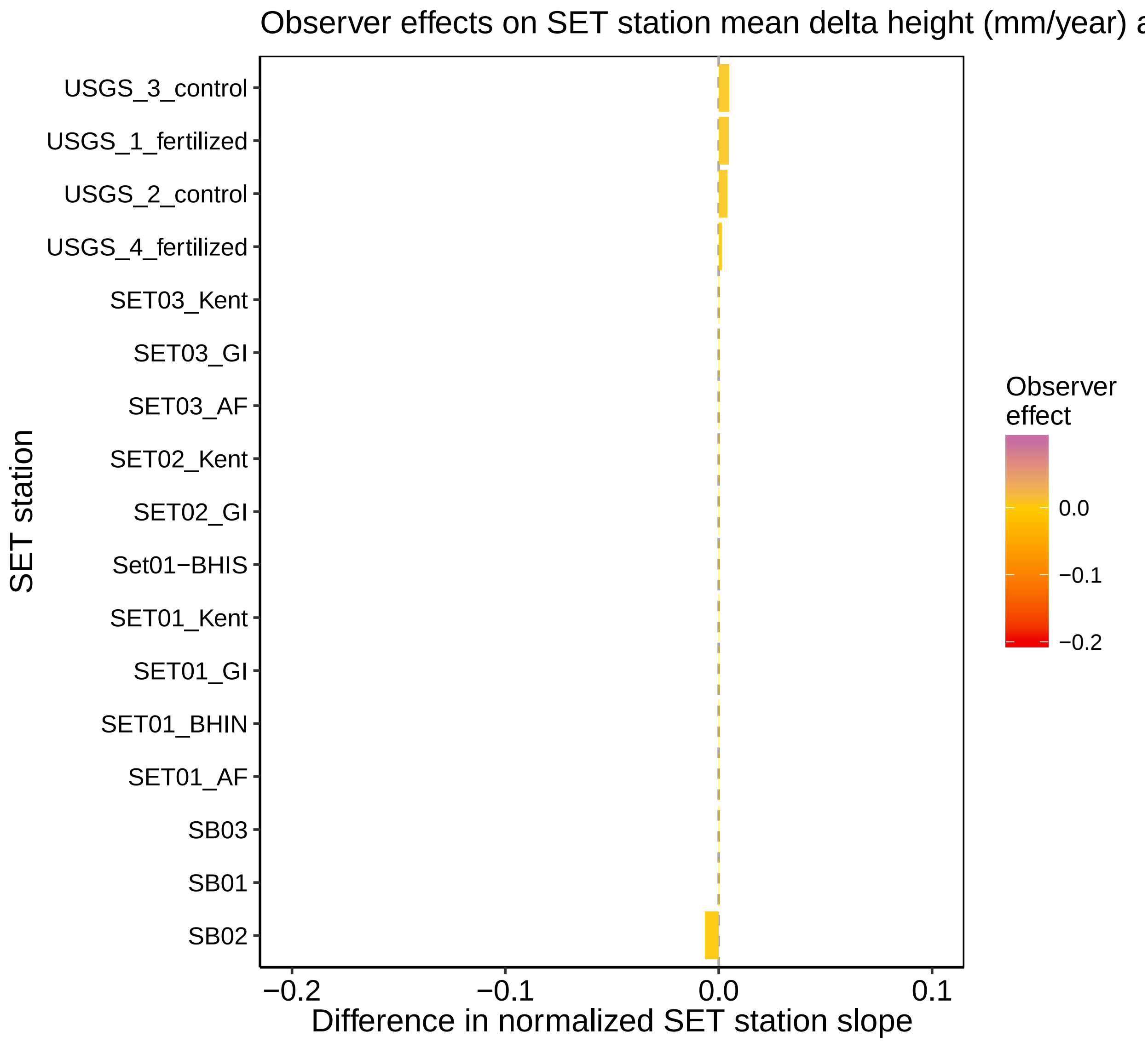

Observer effects on SET station mean delta height (mm/year) at JHC
SET station
JHC06
JHC05
JHC01
JHC03
JHC04
JHC02
JHC07
−0.2
−0.1
0.0
0.1
Difference in normalized SET station slope
Observer
effect
0.0
−0.1
−0.2


Observer effects on SET station mean delta height (mm/year) at OYS
SET station
FC03
FC01
−0.2
−0.1
0.0
0.1
Difference in normalized SET station slope
Observer effect
0.0
−0.1
−0.2

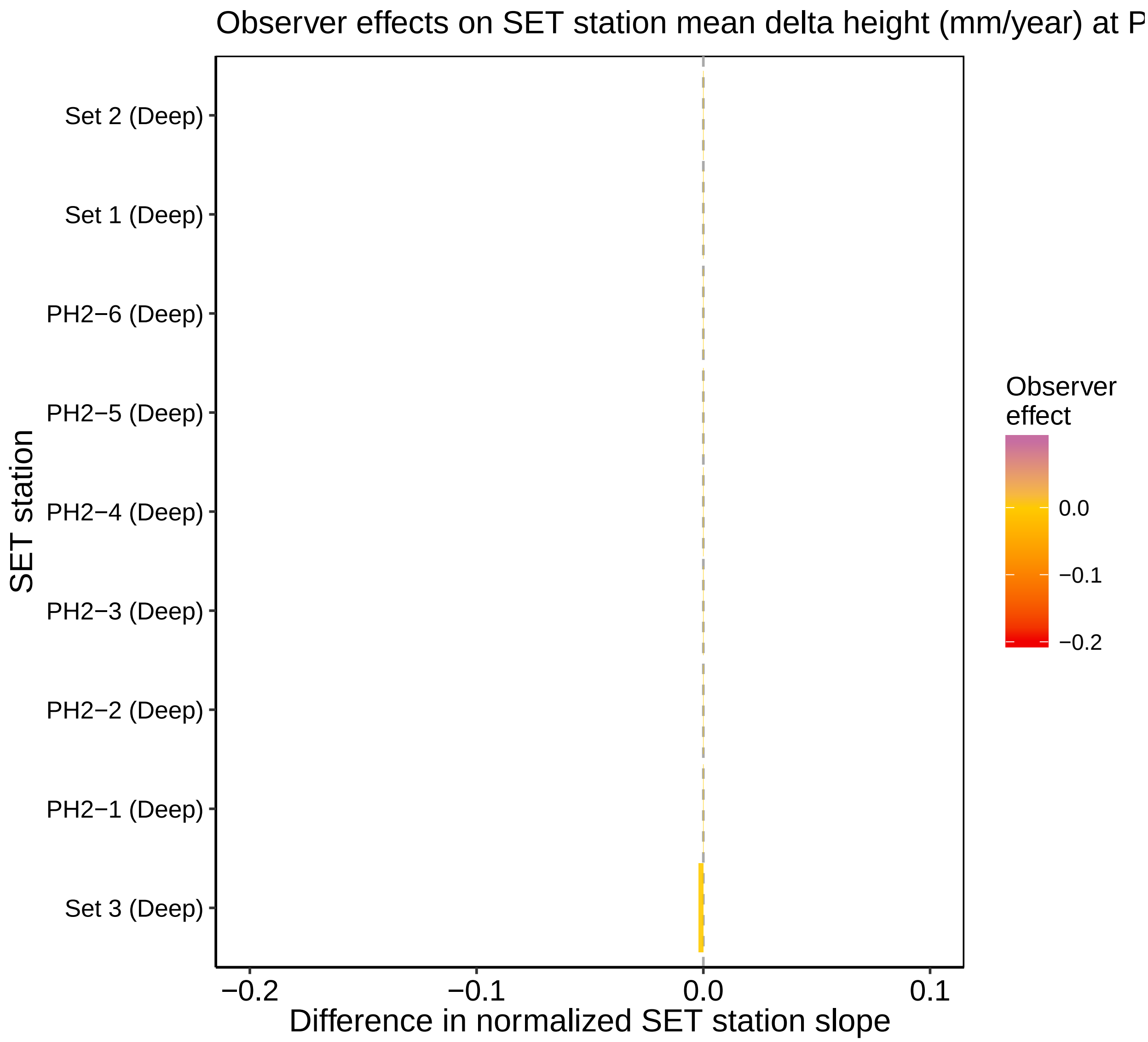

Observer effects on SET station mean delta height (mm/year) at WRT
WEU2
WNU3
WEU3
WEU1
WNU2
SP1
WNU1
SP3
WWU1
WWU2
WWU3
SP2
SET station
−0.2
−0.1
0.0
0.1
Difference in normalized SET station slope
Observer effect
0.0
−0.1
−0.2



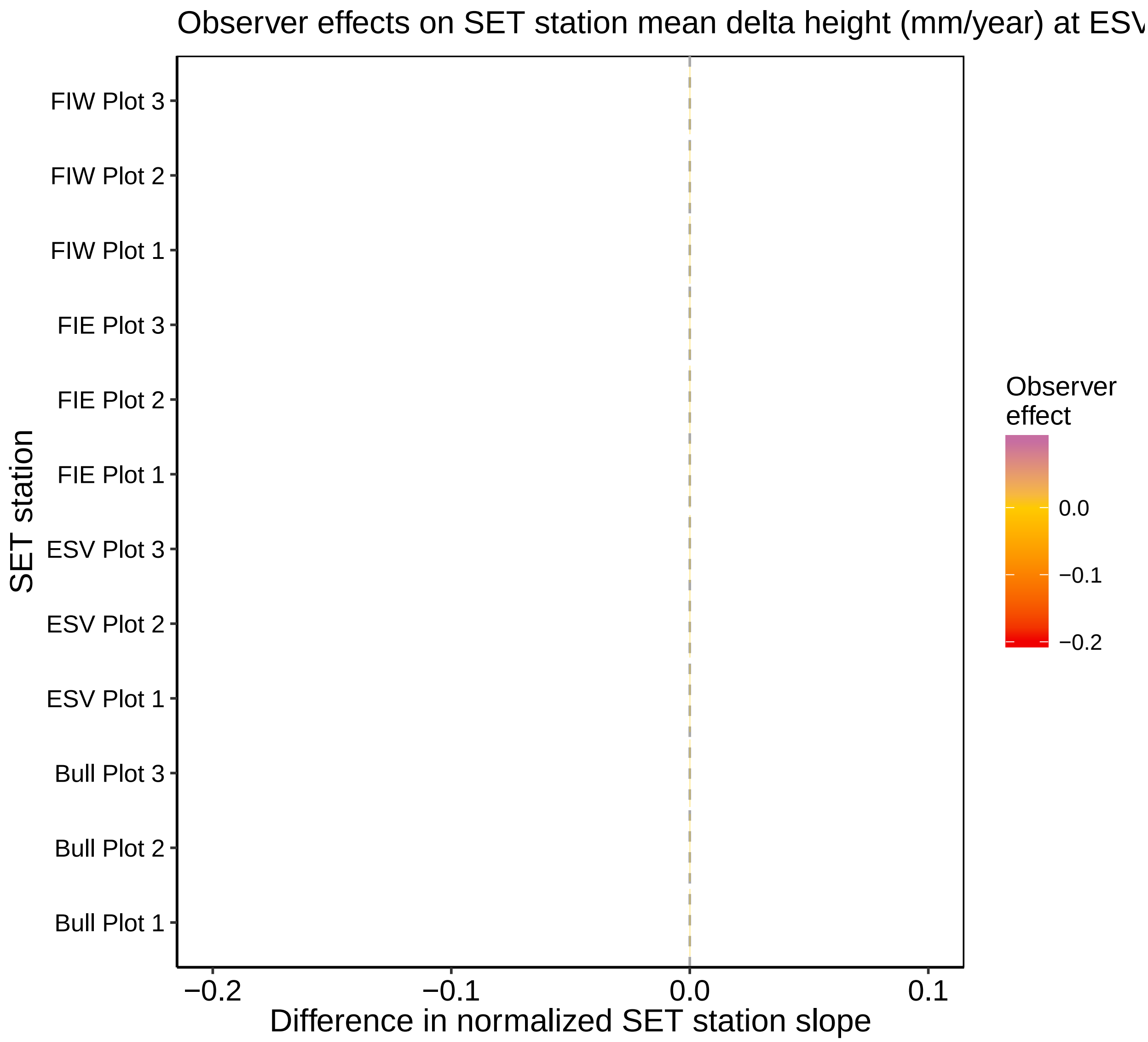
Observer effects on SET station mean delta heigh
West Creek SET 03
West Creek SET 02
West Creek SET 01
Motts−Mull. Wild SET 02
Mill Crk−Cedar Run SET Purple 03
Mill Crk−Cedar Run SET Purple 02
Mill Crk−Cedar Run SET Purple 01
AT&T Treatment SET 06
AT&T Treatment SET 05
AT&T Treatment SET 04
AT&T SMI 09
AT&T SMI 08
AT&T SMI 07
AT&T Control SET 03
AT&T Control SET 02
AT&T Control SET 01
Simpkins*
LB−surf 2*
LB−surf 1*
SET station
−0.2
−0.1
0.0
0.1
Difference in normalized SET station slope
Observer effect
0.0
−0.1
−0.2



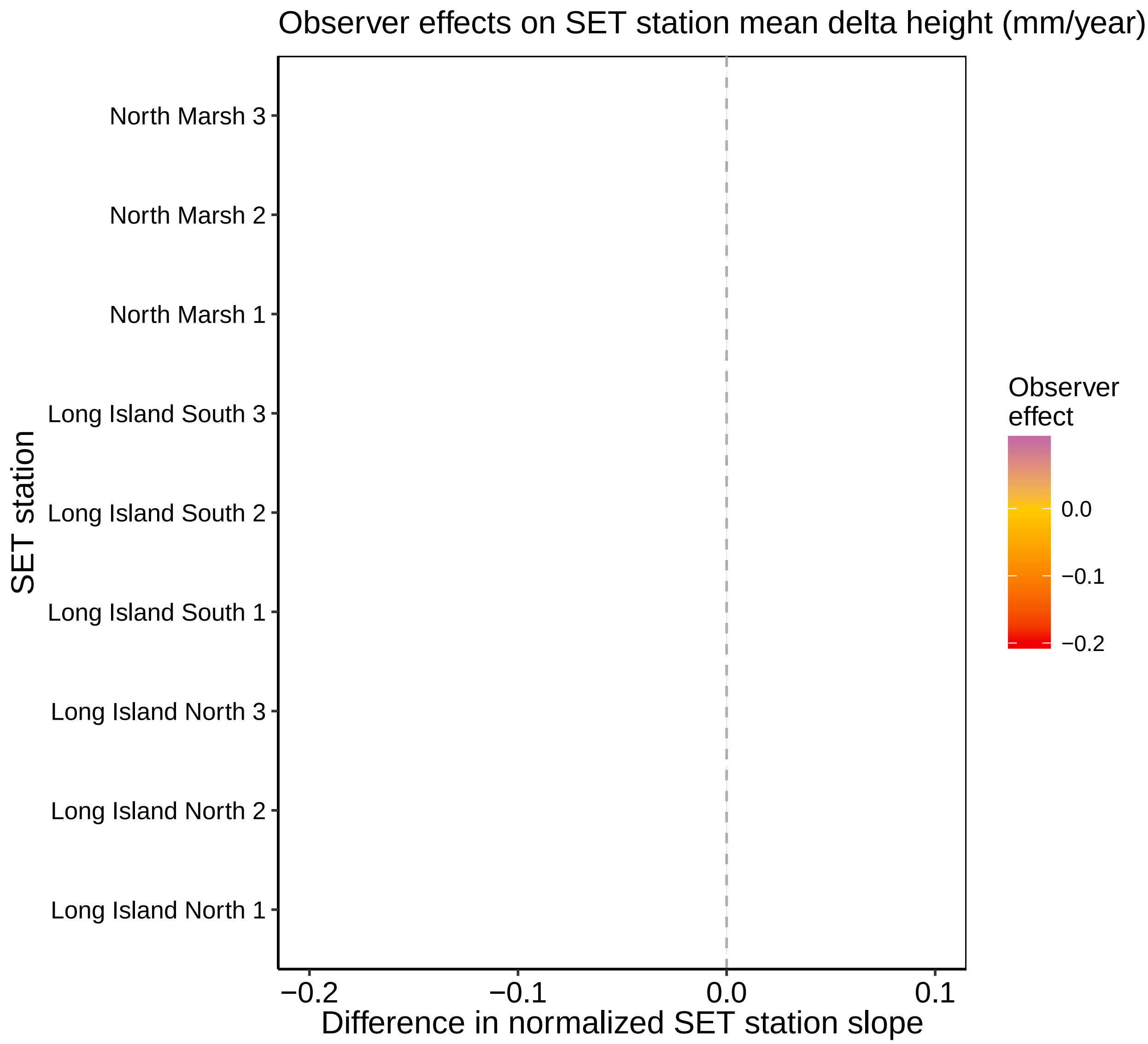
Observer effects on SET station mean delta height (mm/year) a
SET station
USGS_3_control
USGS_1_fertilized
USGS_2_control
USGS_4_fertilized
SET03_Kent
SET03_GI
SET03_AF
SET02_Kent
SET02_GI
Set01−BHIS
SET01_Kent
SET01_GI
SET01_BHIN
SET01_AF
SB03
SB01
SB02
−0.2
−0.1
0.0
0.1
Difference in normalized SET station slope
Observer effect
0.0
−0.1
−0.2



Observer effects on SET station mean delta height (mm/year) at P
SET station
Set 2 (Deep)
Set 1 (Deep)
PH2−6 (Deep)
PH2−5 (Deep)
PH2−4 (Deep)
PH2−3 (Deep)
PH2−2 (Deep)
PH2−1 (Deep)
Set 3 (Deep)
−0.2
−0.1
0.0
0.1
Difference in normalized SET station slope
Observer
effect
0.0
−0.1
−0.2



Observer effects on SET station mean delta height (mm/year) at ESV
FIW Plot 3
FIW Plot 2
FIW Plot 1
FIE Plot 3
FIE Plot 2
FIE Plot 1
ESV Plot 3
ESV Plot 2
ESV Plot 1
Bull Plot 3
Bull Plot 2
Bull Plot 1
SET station
−0.2
−0.1
0.0
0.1
Difference in normalized SET station slope
Observer effect
0.0
−0.1
−0.2


Observer effects on SET station mean delta height (mm/year)
North Marsh 3
North Marsh 2
North Marsh 1
Long Island South 3
Long Island South 2
Long Island South 1
Long Island North 3
Long Island North 2
Long Island North 1
SET station
−0.2
−0.1
0.0
0.1
Difference in normalized SET station slope
Observer
effect
0.0
−0.1
−0.2

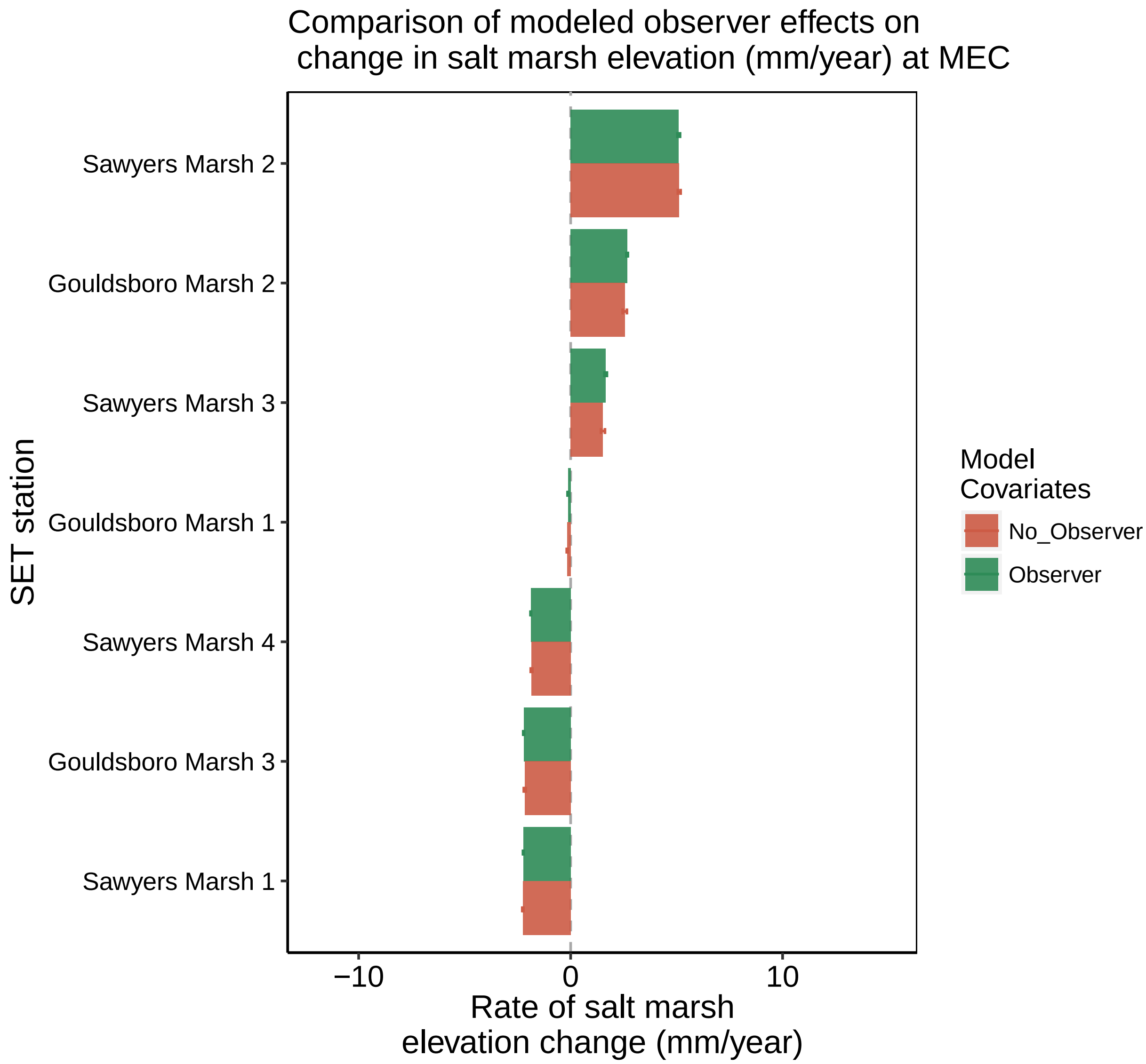
Appendix D. Bayesian-estimated linear trends (slopes) of salt marsh elevation table (SET) height (mean ± SE) for SET stations (n = 179 of 196). Where possible, means and SEs were calculated by averaging 36 (i.e., 9 pins x 4 arm positions) pin-level linear model-derived slopes. Each SET station is shown along with corresponding Region, State, Refuge (Unit_Code), and Site names. For stations with NAs for Mean and SE, there were too few repeated visits within the current data set to compute these estimates.

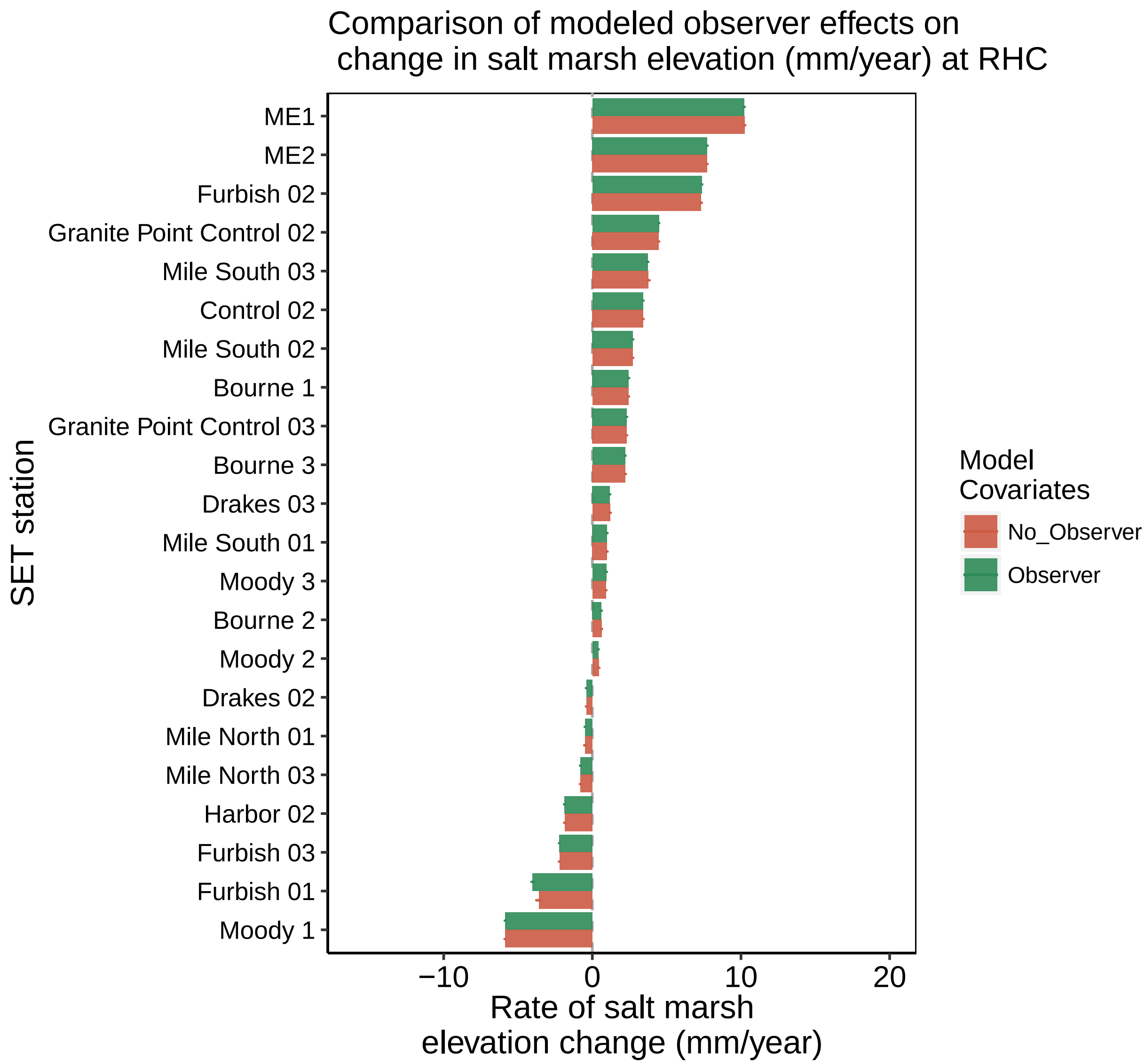
Unit_Code	SET_Name	State	Mean	SE	Mean.obs	SE.obs
MEC	Gouldsboro Marsh 1	ME	-0.16	0.02	-0.13	0.01
MEC	Gouldsboro Marsh 2	ME	2.56	0.10	2.66	0.04
MEC	Gouldsboro Marsh 3	ME	-2.16	0.05	-2.22	0.02
MEC	Sawyers Marsh 1	ME	-2.25	0.03	-2.23	0.01
MEC	Sawyers Marsh 2	ME	5.12	0.07	5.10	0.06
MEC	Sawyers Marsh 3	ME	1.52	0.09	1.65	0.06
MEC	Sawyers Marsh 4	ME	-1.84	0.04	-1.88	0.01
RHC	Bourne 1	ME	2.43	0.02	2.44	0.01
RHC	Bourne 2	ME	0.62	0.01	0.61	0.01
RHC	Bourne 3	ME	2.22	0.02	2.20	0.01
RHC	Control 02	ME	3.42	0.00	3.41	0.00
RHC	Drakes 02	ME	-0.40	0.01	-0.41	0.01
RHC	Drakes 03	ME	1.20	0.03	1.17	0.01
RHC	Furbish 01	ME	-3.60	0.16	-4.03	0.05
RHC	Furbish 02	ME	7.32	0.03	7.36	0.01
RHC	Furbish 03	ME	-2.21	0.02	-2.21	0.01
RHC	Granite Point Control 02	ME	4.48	0.00	4.48	0.00
RHC	Granite Point Control 03	ME	2.31	0.00	2.32	0.00
RHC	Harbor 02	ME	-1.87	0.02	-1.88	0.01
RHC	ME1	ME	10.24	0.03	10.21	0.02
RHC	ME2	ME	7.73	0.01	7.73	0.00
RHC	Mile North 01	ME	-0.50	0.03	-0.49	0.01
RHC	Mile North 03	ME	-0.80	0.02	-0.81	0.01
RHC	Mile South 01	ME	0.99	0.02	0.99	0.01
RHC	Mile South 02	ME	2.72	0.02	2.73	0.01
RHC	Mile South 03	ME	3.78	0.06	3.73	0.02
RHC	Moody 1	ME	-5.87	0.02	-5.87	0.01
RHC	Moody 2	ME	0.43	0.02	0.40	0.01
RHC	Moody 3	ME	0.91	0.02	0.95	0.01
PKR	B2 1-80	MA	11.08	0.03	11.02	0.01
PKR	B2 4-120	MA	6.73	0.02	6.72	0.01
PKR	B2 5-40	MA	6.74	0.03	6.72	0.01
PKR	Control 3-120	MA	2.09	0.00	2.09	0.00
PKR	Control 3-40	MA	2.14	0.01	2.10	0.00
PKR	Control 4-120	MA	-0.77	0.07	-0.98	0.07
PKR	Knobb 01	MA	0.22	0.04	0.15	0.01
PKR	Knobb 02	MA	-1.08	0.09	-0.94	0.06
PKR	Knobb 03	MA	-0.89	0.14	-0.92	0.15
PKR	NP01	MA	-0.82	0.25	-1.07	0.14
PKR	NP02	MA	-0.82	0.13	-1.03	0.07
PKR	NP03	MA	-0.70	0.31	-1.26	0.14
PKR	SP01	MA	2.55	0.04	2.56	0.02
PKR	SP02	MA	3.00	0.07	3.03	0.04
SPT	SPT01	RI	5.56	0.01	5.57	0.01
SPT	SPT02	RI	4.34	0.03	4.39	0.01

Unit_Code	SET_Name	State	Mean	SE	Mean.obs	SE.obs
SPT	SPT03	RI	2.15	0.01	2.16	0.01
SPT	SPT04	RI	1.69	0.02	1.71	0.01
SPT	SPT05	RI	1.99	0.01	1.98	0.00
SPT	SPT06	RI	3.25	0.02	3.27	0.01
JHC	JHC01	RI	0.42	0.01	0.42	0.00
JHC	JHC02	RI	3.23	0.02	3.21	0.01
JHC	JHC03	RI	2.77	0.01	2.77	0.01
JHC	JHC04	RI	3.04	0.01	3.06	0.01
JHC	JHC05	RI	0.64	0.01	0.65	0.01
JHC	JHC06	RI	1.27	0.01	1.26	0.00
JHC	JHC07	RI	-0.64	0.01	-0.63	0.01
OYS	FC01	NY	-0.59	0.02	-0.57	0.01
OYS	FC03	NY	-2.04	0.01	-2.03	0.01
WRT	SP1	NY	6.85	0.00	6.63	0.01
WRT	SP2	NY	11.69	0.01	11.91	0.01
WRT	SP3	NY	5.06	0.01	5.07	0.01
WRT	WEU1	NY	1.68	0.04	1.79	0.01
WRT	WEU2	NY	2.27	0.03	2.32	0.01
WRT	WEU3	NY	1.55	0.03	1.49	0.01
WRT	WNU1	NY	5.26	0.04	5.23	0.01
WRT	WNU2	NY	5.99	0.04	6.00	0.01
WRT	WNU3	NY	-1.48	0.03	-1.54	0.01
WRT	WWU1	NY	4.58	0.00	4.74	0.00
WRT	WWU2	NY	3.65	0.00	3.69	0.00
WRT	WWU3	NY	2.65	0.01	2.67	0.00
EBF	AT&T Control SET 01	NJ	1.50	0.00	1.46	0.00
EBF	AT&T Control SET 02	NJ	2.33	0.01	1.83	0.01
EBF	AT&T Control SET 03	NJ	-1.07	0.00	-0.98	0.00
EBF	AT&T SMI 07	NJ	23.75	1.80	-0.02	0.05
EBF	AT&T SMI 08	NJ	54.25	0.34	-0.12	0.05
EBF	AT&T SMI 09	NJ	42.27	0.37	-0.11	0.05
EBF	AT&T Treatment SET 04	NJ	0.60	0.00	0.60	0.00
EBF	AT&T Treatment SET 05	NJ	0.47	0.00	0.47	0.00
EBF	AT&T Treatment SET 06	NJ	2.64	0.01	2.62	0.01
EBF	LB-surf 1*	NJ	-15.62	0.07	-15.79	0.03
EBF	LB-surf 2*	NJ	-7.52	0.06	-7.53	0.05
EBF	Mill Crk-Cedar Run SET Purple 01	NJ	13.99	2.00	-0.30	0.05
EBF	Mill Crk-Cedar Run SET Purple 02	NJ	2.33	0.10	2.53	0.08
EBF	Mill Crk-Cedar Run SET Purple 03	NJ	3.58	0.05	3.65	0.03
EBF	Motts-Mull. Wild SET 02	NJ	-0.43	0.04	-0.32	0.02
EBF	Motts-Mull. Wild SET 03	NJ	-1.07	0.11	-0.95	0.08
EBF	Simpkins*	NJ	-3.57	0.04	-3.60	0.02
EBF	West Creek SET 01	NJ	-3.17	0.07	-3.21	0.05
EBF	West Creek SET 02	NJ	1.17	0.05	1.22	0.02
EBF	West Creek SET 03	NJ	-3.62	0.09	-3.53	0.06
BMH	SB01	DE	-2.50	0.05	-2.53	0.02
BMH	SB02	DE	-3.17	0.07	-3.15	0.02
BMH	SB03	DE	-1.39	0.06	-1.28	0.02
BMH	SET01_AF	DE	-1.53	0.06	-1.40	0.02
BMH	SET01_BHIN	DE	2.27	0.13	2.17	0.05
BMH	SET01_GI	DE	-4.15	0.09	-4.08	0.07
BMH	SET01_Kent	DE	-3.67	0.07	-3.69	0.03

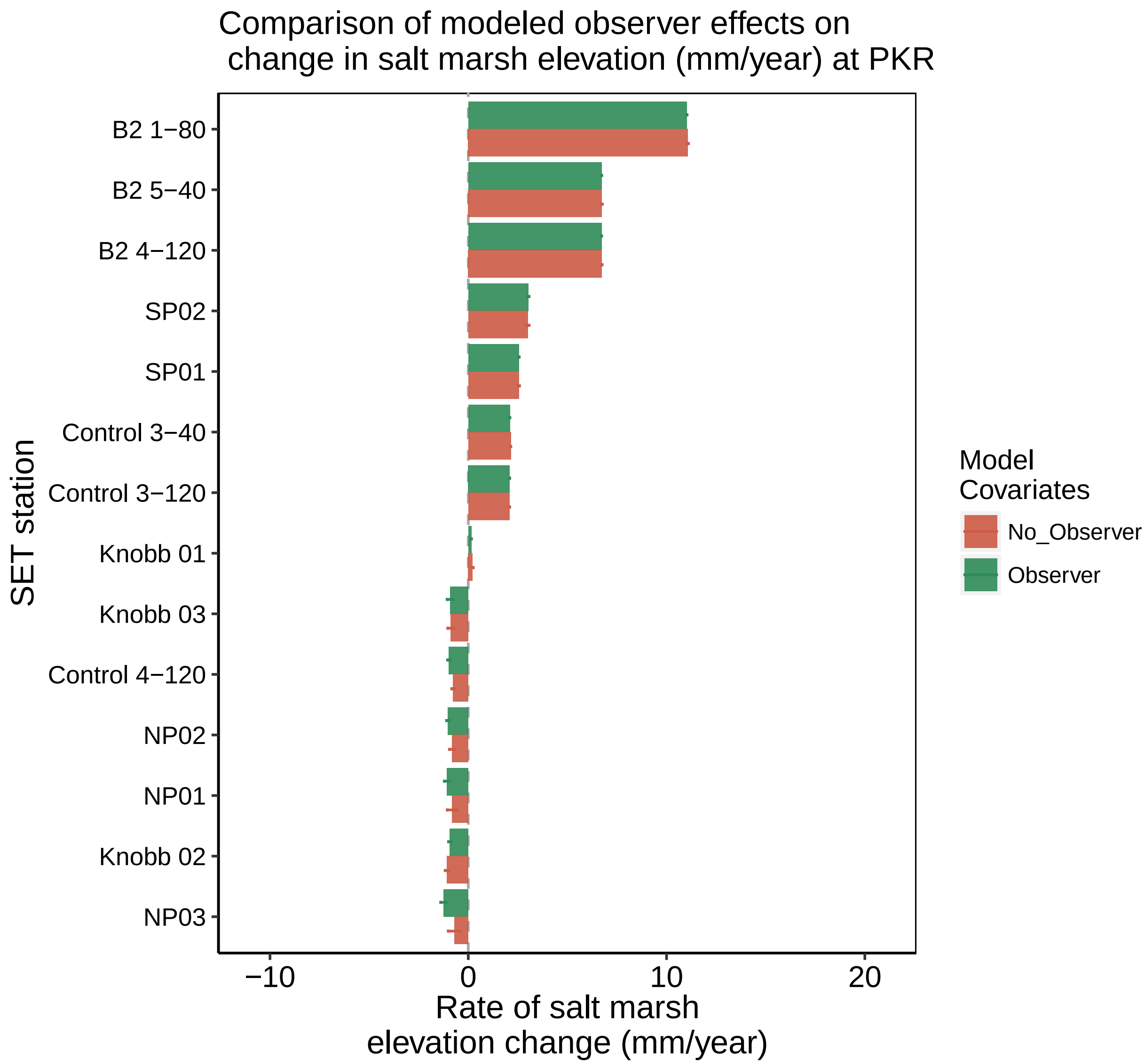
Unit_Code	SET_Name	State	Mean	SE	Mean.obs	SE.obs
BMH	Set01-BHIS	DE	-5.08	0.17	-4.66	0.08
BMH	SET02_GI	DE	-3.74	0.10	-3.89	0.04
BMH	SET02_Kent	DE	0.17	0.06	0.15	0.02
BMH	SET03_AF	DE	-2.29	0.05	-2.48	0.04
BMH	SET03_GI	DE	-3.71	0.07	-3.89	0.06
BMH	SET03_Kent	DE	-0.31	0.06	-0.24	0.02
BMH	USGS_1_fertilized	DE	3.42	0.00	3.05	0.00
BMH	USGS_2_control	DE	4.30	0.00	4.06	0.00
BMH	USGS_3_control	DE	2.21	0.00	1.35	0.00
BMH	USGS_4_fertilized	DE	4.27	0.00	4.09	0.00
PMH	PH2-1 (Deep)	DE	22.80	0.03	22.98	0.01
PMH	PH2-2 (Deep)	DE	-19.13	0.05	-19.35	0.02
PMH	PH2-3 (Deep)	DE	20.67	0.05	20.83	0.02
PMH	PH2-4 (Deep)	DE	10.35	0.06	10.29	0.02
PMH	PH2-5 (Deep)	DE	45.35	0.09	46.90	0.02
PMH	PH2-6 (Deep)	DE	12.09	0.07	12.16	0.02
PMH	Set 1 (Deep)	DE	3.42	0.11	3.29	0.04
PMH	Set 2 (Deep)	DE	2.02	0.07	2.07	0.03
PMH	Set 3 (Deep)	DE	5.18	0.08	5.17	0.04
PMH_shallow	PH2-1 (Shallow)	DE	2.09	0.07	2.00	0.08
PMH_shallow	PH2-2 (Shallow)	DE	-7.36	0.10	-7.33	0.04
PMH_shallow	PH2-3 (Shallow)	DE	19.75	0.03	19.77	0.01
PMH_shallow	PH2-4 (Shallow)	DE	11.13	0.06	11.28	0.02
PMH_shallow	PH2-5 (Shallow)	DE	52.23	0.23	64.12	0.06
PMH_shallow	PH2-6 (Shallow)	DE	15.21	0.06	15.34	0.02
PMH_shallow	Set 1 (Shallow)	DE	2.64	0.16	2.32	0.05
PMH_shallow	Set 2 (Shallow)	DE	12.78	0.72	7.10	0.36
PMH_shallow	Set 3 (Shallow)	DE	4.35	0.14	4.59	0.07
ESV	Bull Plot 1	VA	2.92	0.01	2.93	0.01
ESV	Bull Plot 2	VA	2.37	0.00	2.42	0.00
ESV	Bull Plot 3	VA	1.45	0.01	1.49	0.00
ESV	ESV Plot 1	VA	0.92	0.01	0.89	0.00
ESV	ESV Plot 2	VA	1.09	0.01	1.08	0.00
ESV	ESV Plot 3	VA	2.51	0.00	2.53	0.00
ESV	FIE Plot 1	VA	4.65	0.01	4.66	0.01
ESV	FIE Plot 2	VA	2.55	0.01	2.55	0.00
ESV	FIE Plot 3	VA	4.02	0.01	4.02	0.01
ESV	FIW Plot 1	VA	3.86	0.01	4.12	0.01
ESV	FIW Plot 2	VA	4.74	0.03	4.86	0.01
ESV	FIW Plot 3	VA	2.31	0.01	2.50	0.00
BKB	Long Island North 1	VA	-7.13	0.03	-7.12	0.01
BKB	Long Island North 2	VA	-3.33	0.01	-3.33	0.01
BKB	Long Island North 3	VA	-2.51	0.08	-2.68	0.07
BKB	Long Island South 1	VA	-3.44	0.04	-3.46	0.01
BKB	Long Island South 2	VA	-3.27	0.02	-3.28	0.01
BKB	Long Island South 3	VA	-5.76	0.03	-5.76	0.01
BKB	North Marsh 1	VA	-4.16	0.07	-4.15	0.02
BKB	North Marsh 2	VA	-12.16	0.16	-11.84	0.05
BKB	North Marsh 3	VA	-4.61	0.05	-4.68	0.02

Appendix E. Figures comparing Bayesian estimates of salt marsh elevation change (mm/year) at each SET sation from models without and including observer effects and figures showing the influence (directionality and magnitude) of accounting for observer (data recorder) effects.

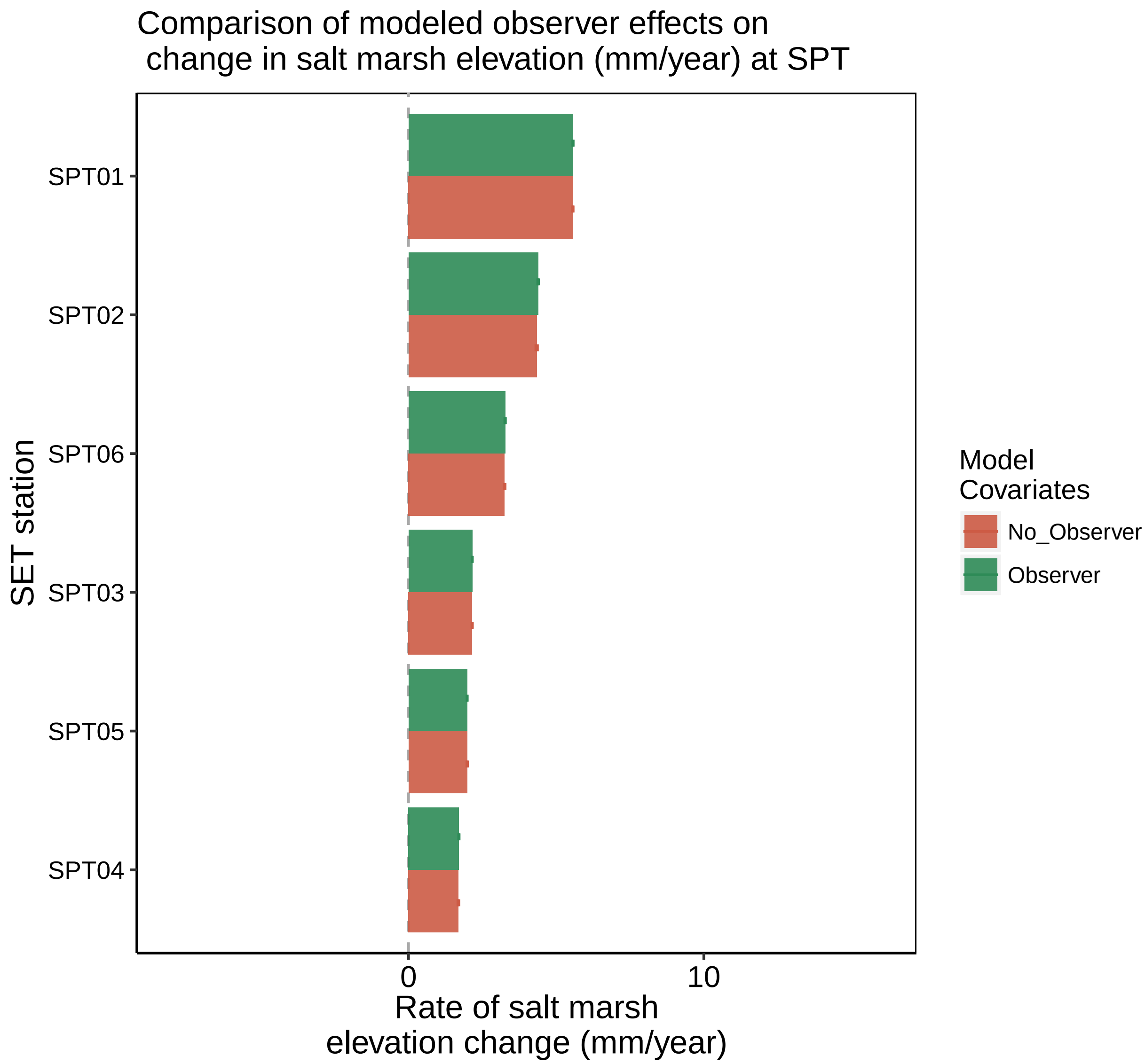


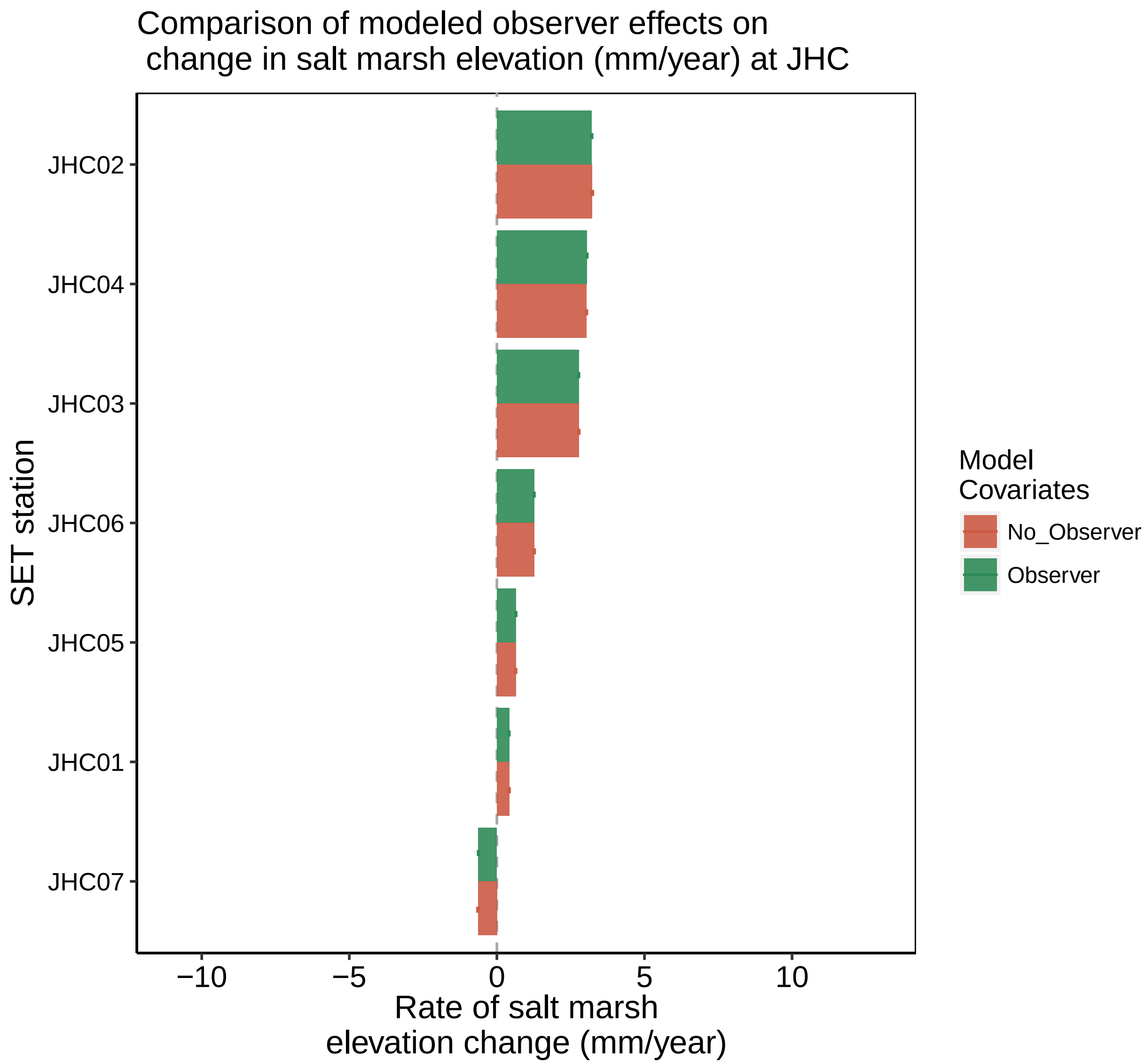


Comparison of modeled observer effects on
change in salt marsh elevation (mm/year) at RHC
SET station
ME1
ME2
Furbish 02
Granite Point Control 02
Mile South 03
Control 02
Mile South 02
Bourne 1
Granite Point Control 03
Bourne 3
Drakes 03
Mile South 01
Moody 3
Bourne 2
Moody 2
Drakes 02
Mile North 01
Mile North 03
Harbor 02
Furbish 03
Furbish 01
Moody 1
−10
0
10
20
Rate of salt marsh
elevation change (mm/year)
Model
Covariates
No_Observer
Observer

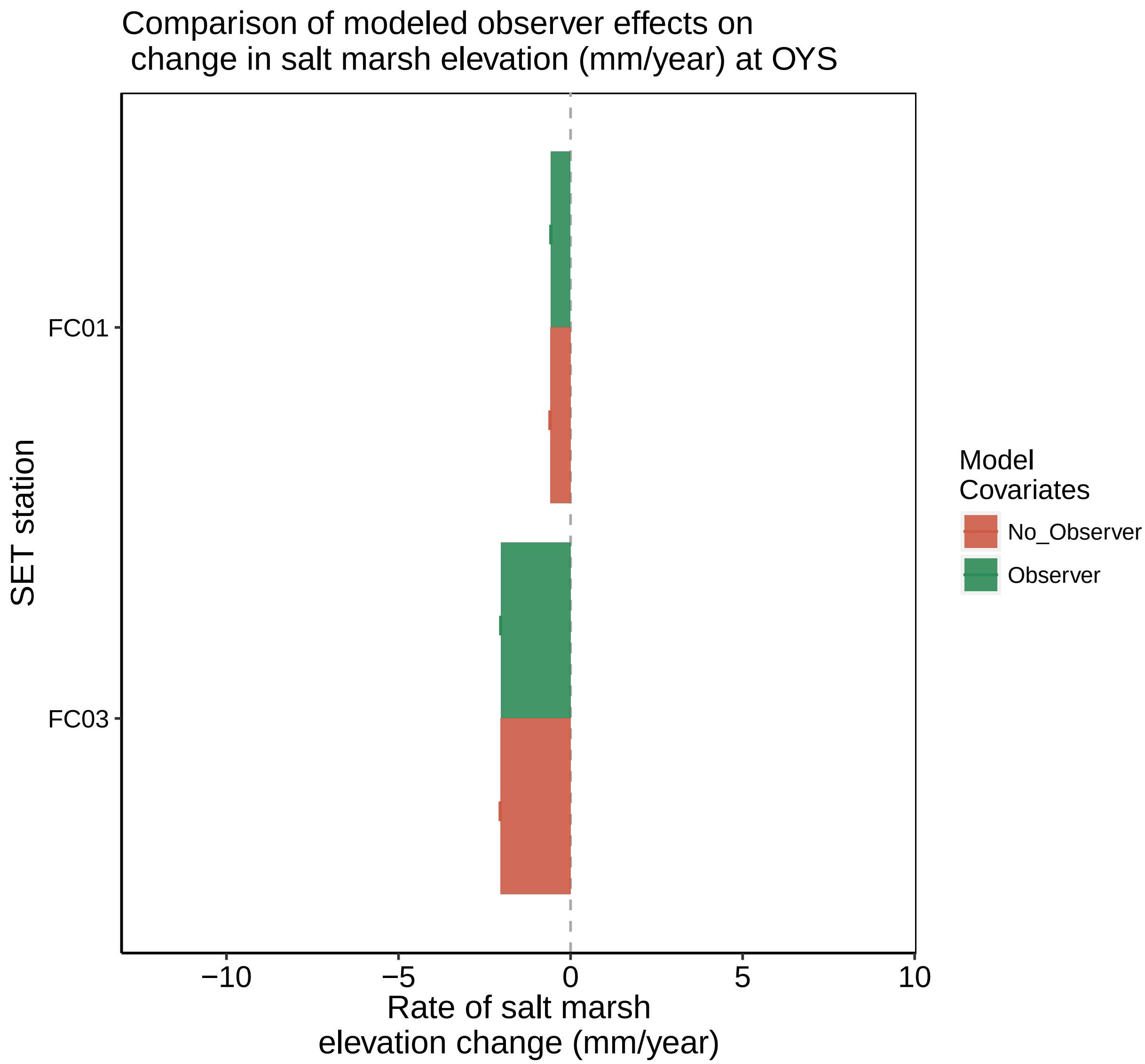


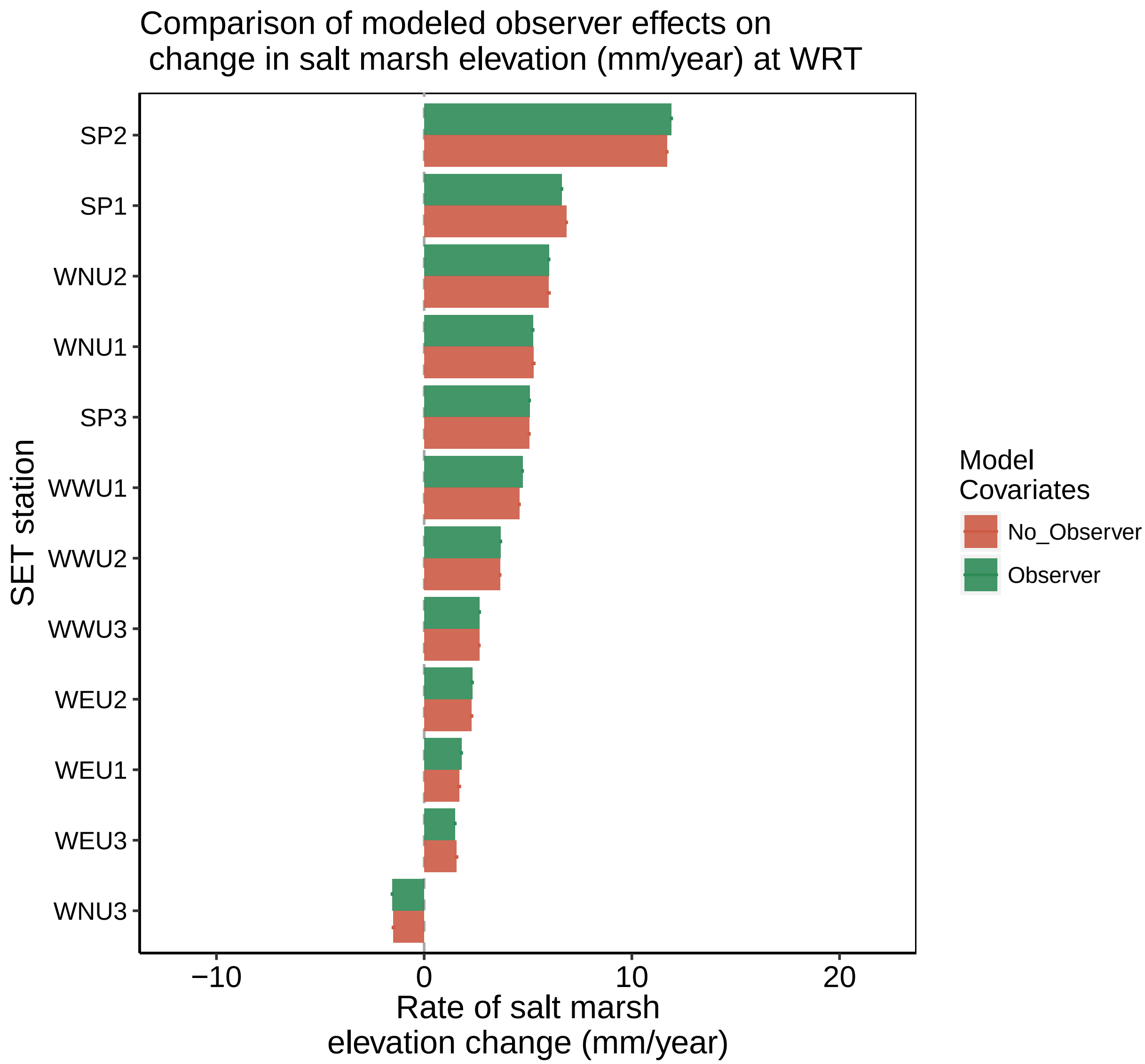
Comparison of modeled observer effects on
change in salt marsh elevation (mm/year) at PKR
B2 1−80
B2 5−40
B2 4−120
SP02
SP01
Control 3−40
Control 3−120
Knobb 01
Knobb 03
Control 4−120
NP02
NP01
Knobb 02
NP03
SET station
−10
0
10
20
Rate of salt marsh
elevation change (mm/year)
Model
Covariates
No_Observer
Observer

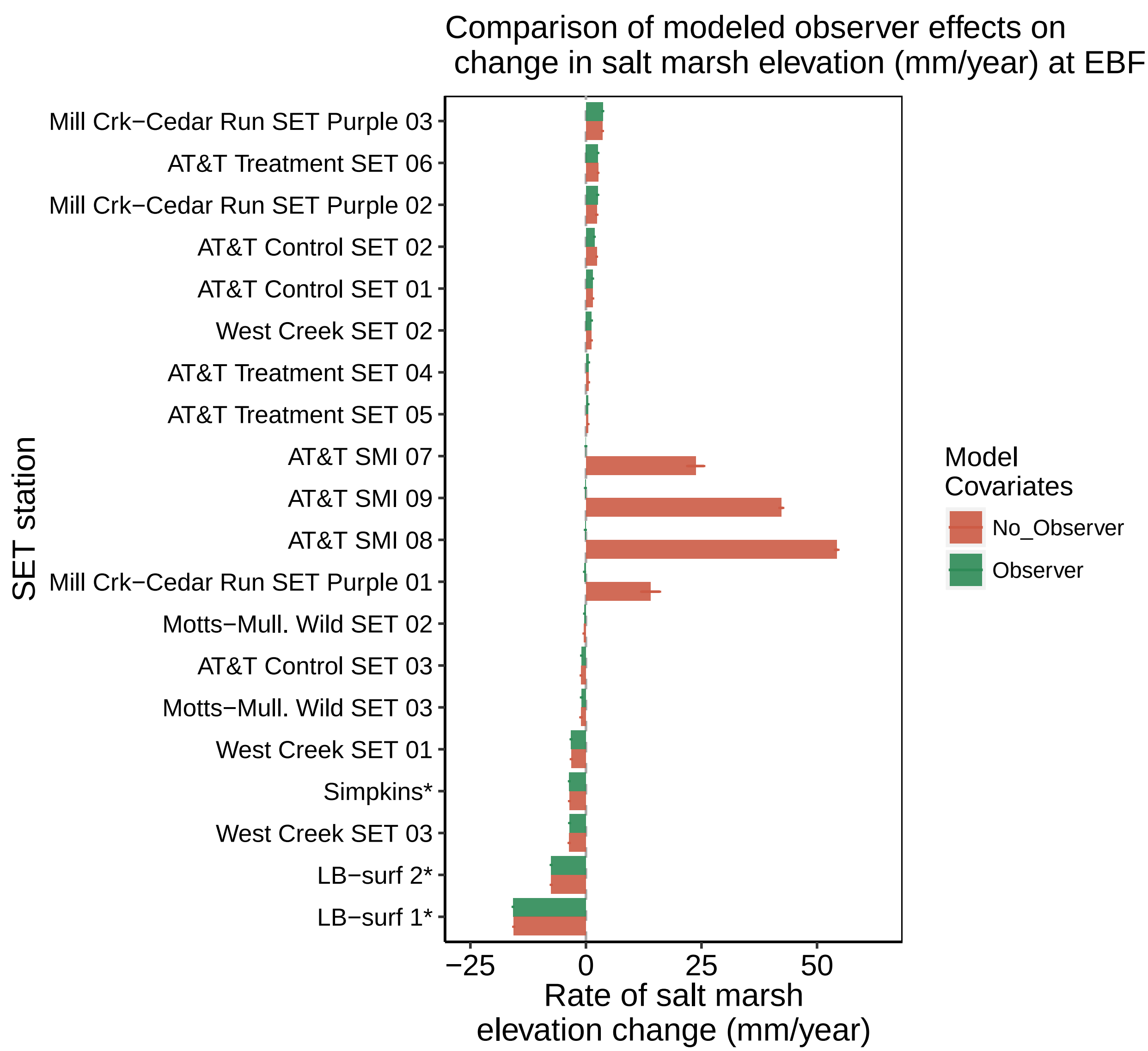

Comparison of modeled observer effects on
change in salt marsh elevation (mm/year) at SPT
SET station
SPT01
SPT02
SPT06
SPT03
SPT05
SPT04
0
10
Rate of salt marsh
elevation change (mm/year)
Model
Covariates
No_Observer
Observer

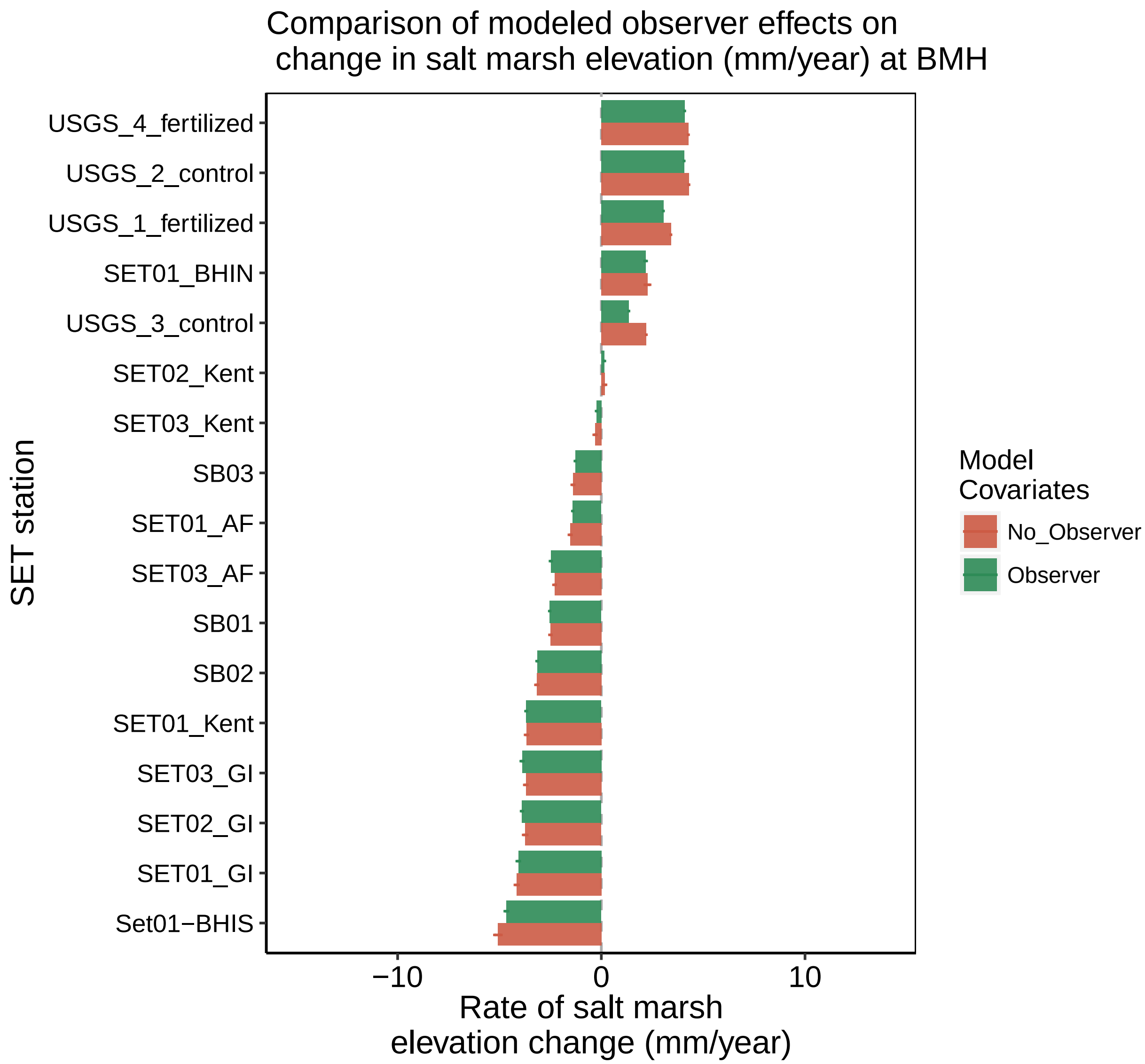


Comparison of modeled observer effects on
change in salt marsh elevation (mm/year) at JHC
JHC02
JHC04
JHC03
JHC06
JHC05
JHC01
JHC07
SET station
−10
−5
0
5
10
Rate of salt marsh
elevation change (mm/year)
Model
Covariates
No_Observer
Observer

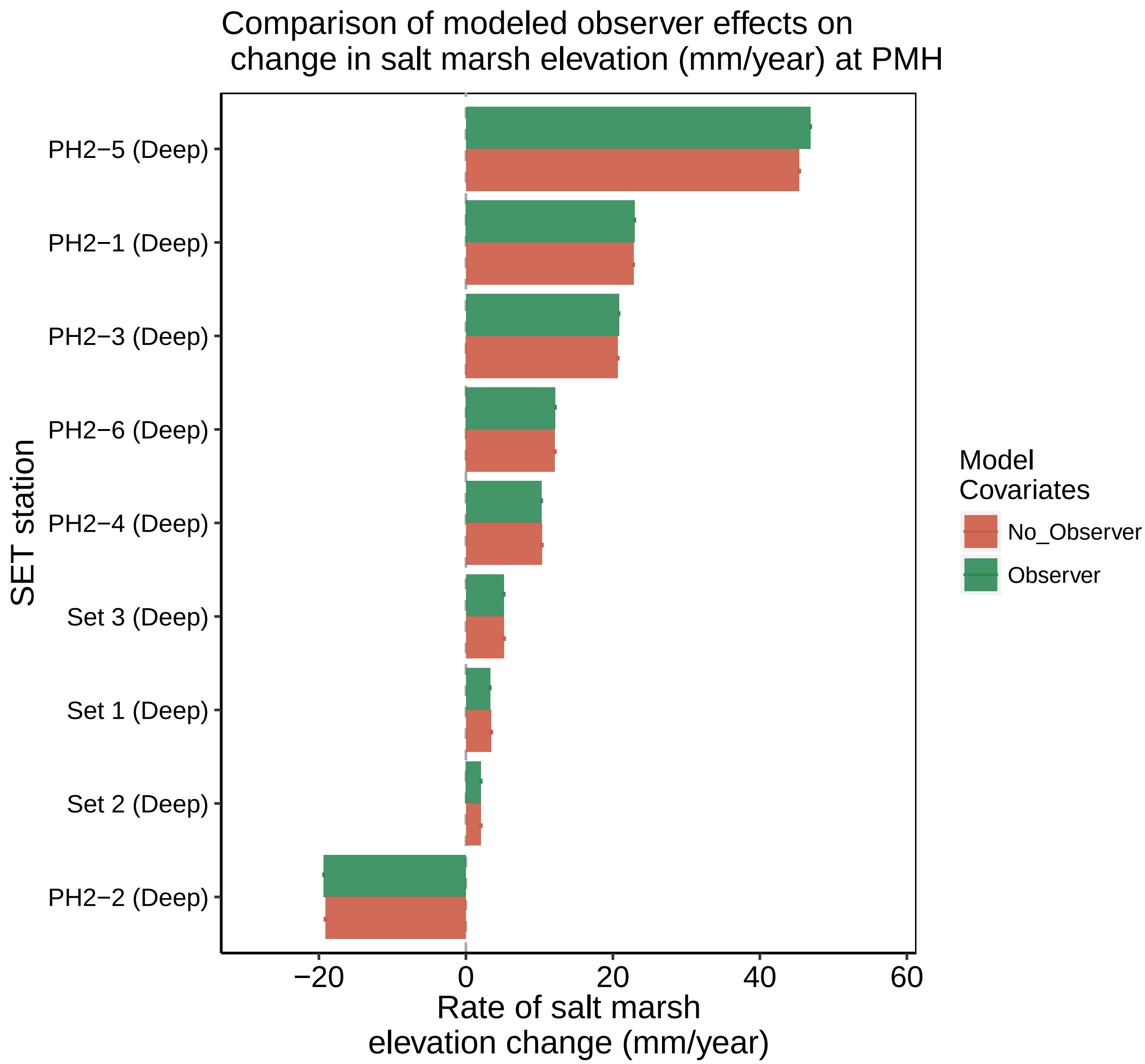

Comparison of modeled observer effects on
change in salt marsh elevation (mm/year) at OYS
SET station
FC01
FC03
−10
−5
0
5
10
Rate of salt marsh
elevation change (mm/year)
Model
Covariates
No_Observer
Observer

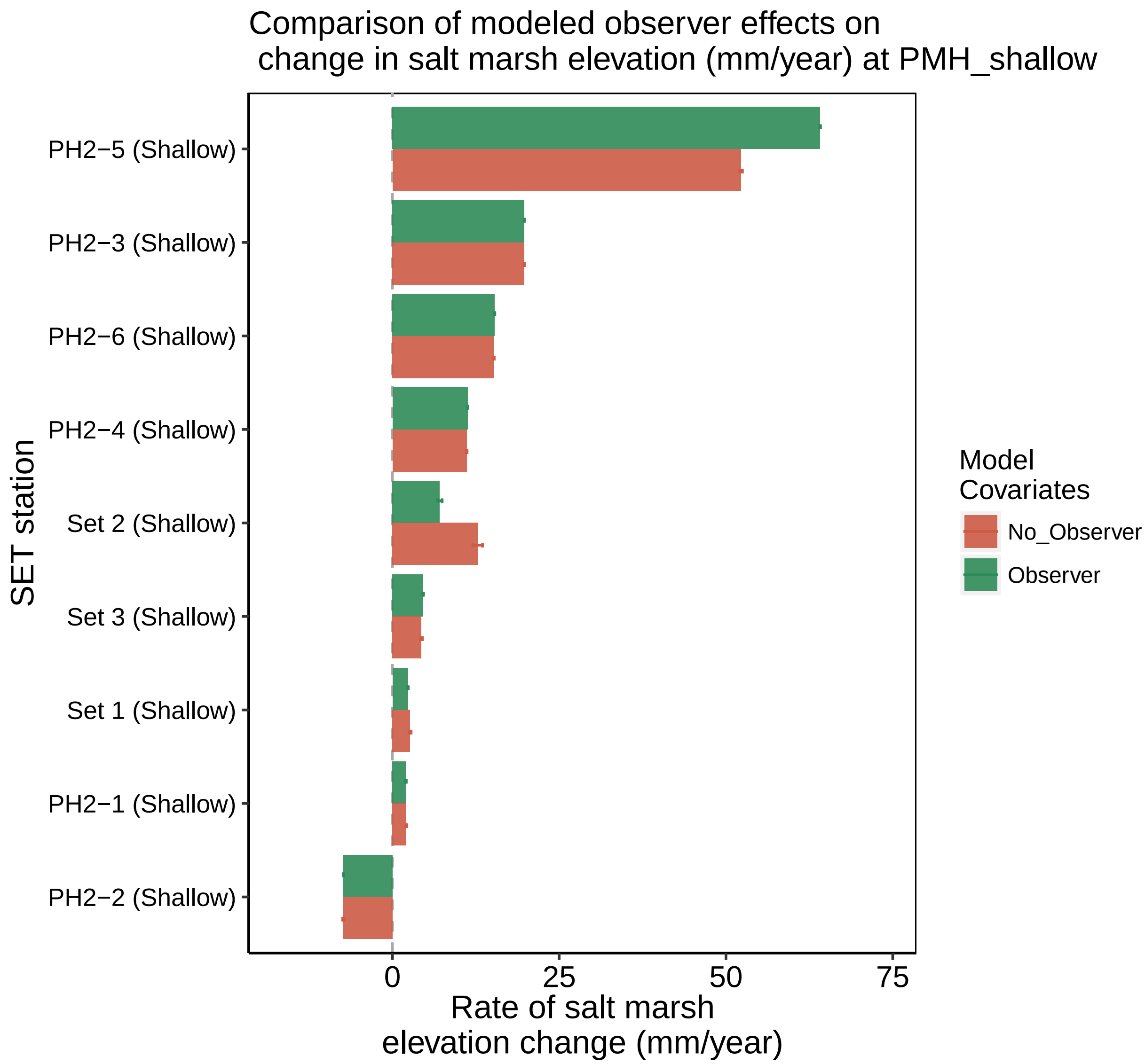

Comparison of modeled observer effects on
change in salt marsh elevation (mm/year) at WRT
SET station
SP2
SP1
WNU2
WNU1
SP3
WWU1
WWU2
WWU3
WEU2
WEU1
WEU3
WNU3
−10
0
10
20
Rate of salt marsh
elevation change (mm/year)
Model
Covariates
No_Observer
Observer

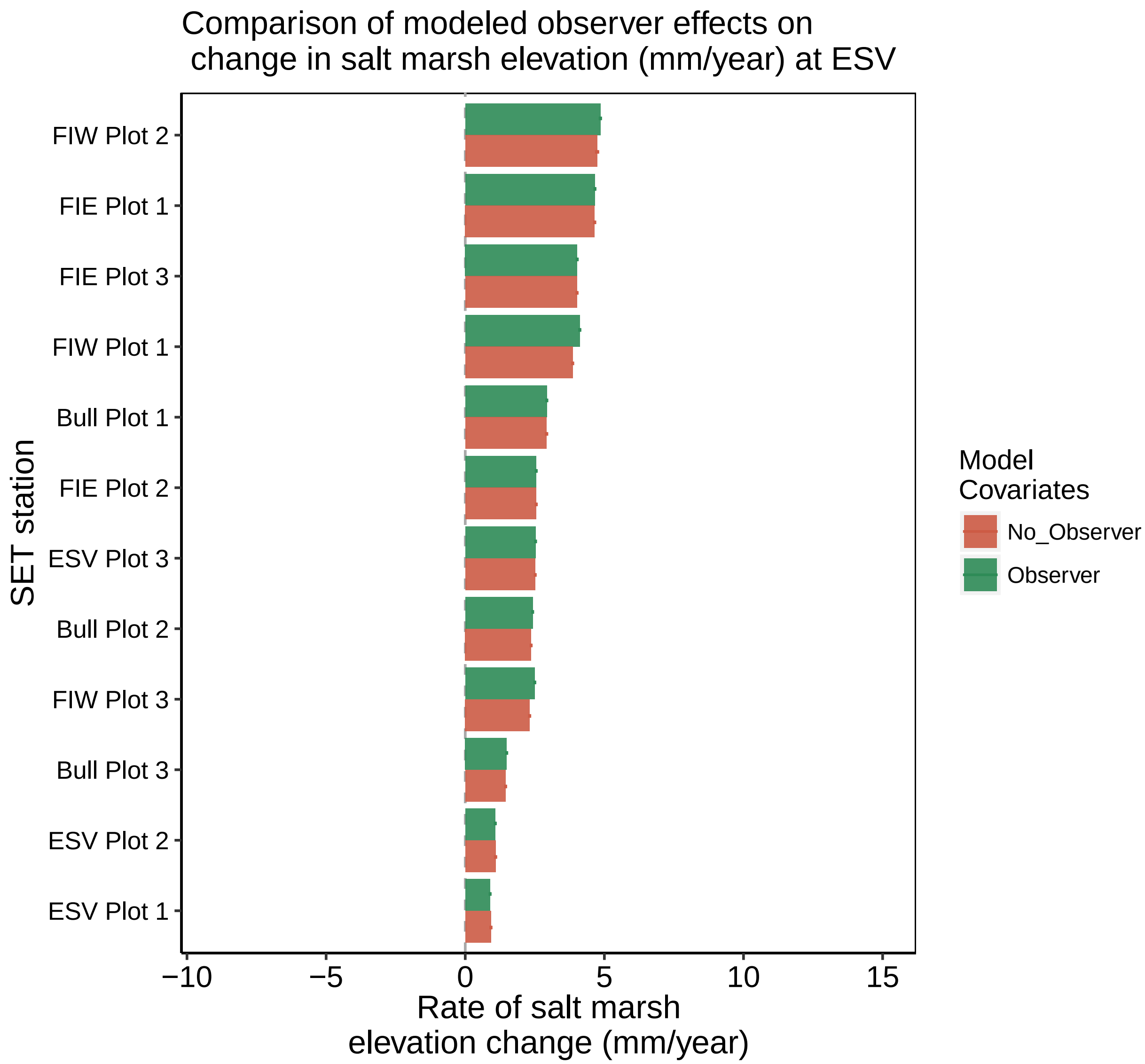

Comparison of modeled observer effects on
change in salt marsh elevation (mm/year) at EBF
SET station
Mill Crk−Cedar Run SET Purple 03
AT&T Treatment SET 06
Mill Crk−Cedar Run SET Purple 02
AT&T Control SET 02
AT&T Control SET 01
West Creek SET 02
AT&T Treatment SET 04
AT&T Treatment SET 05
AT&T SMI 07
AT&T SMI 09
AT&T SMI 08
Mill Crk−Cedar Run SET Purple 01
Motts−Mull. Wild SET 02
AT&T Control SET 03
Motts−Mull. Wild SET 03
West Creek SET 01
Simpkins*
West Creek SET 03
LB−surf 2*
LB−surf 1*
−25
0
25
50
Rate of salt marsh
elevation change (mm/year)
Model
Covariates
No_Observer
Observer

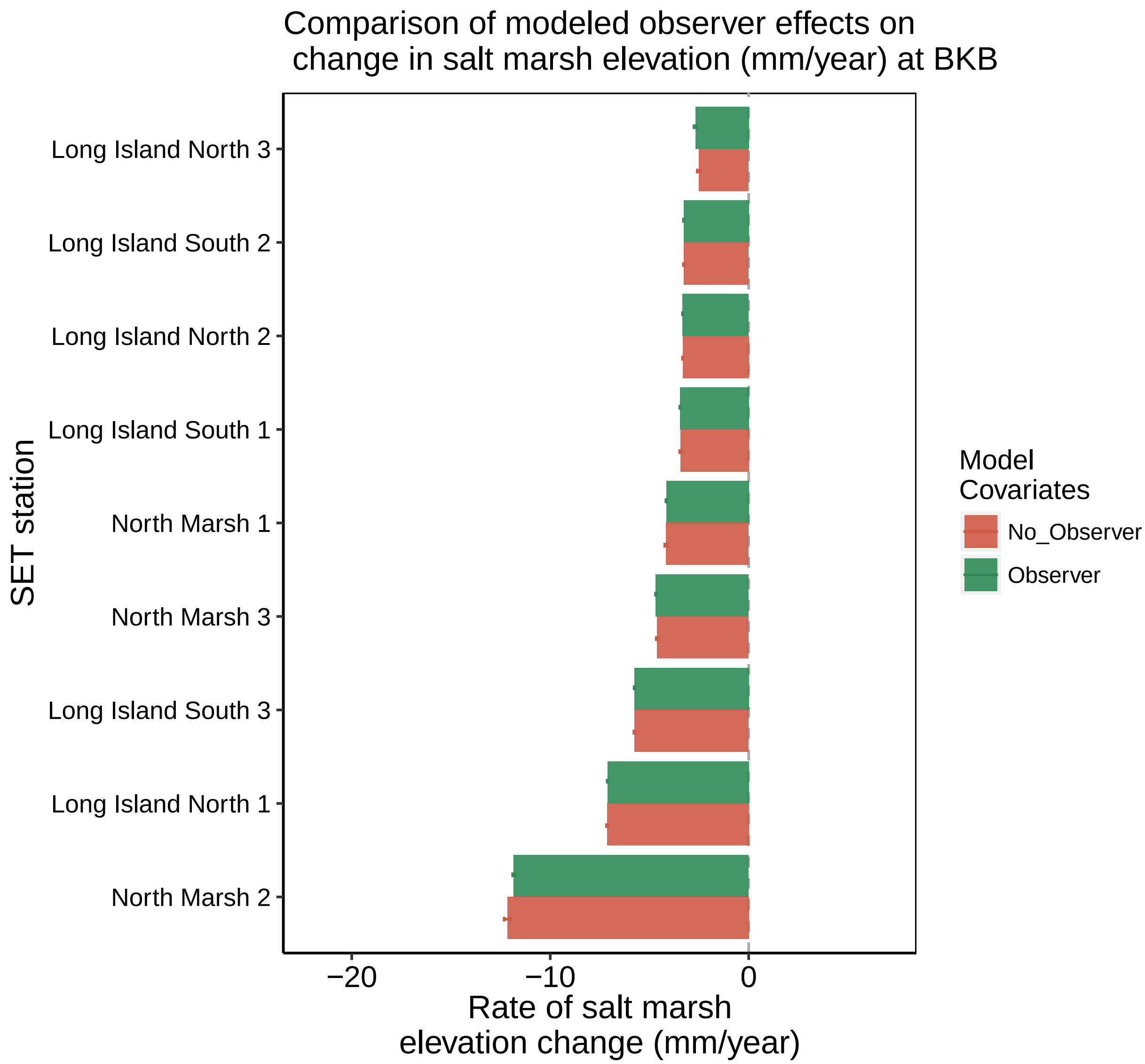


Comparison of modeled observer effects on
change in salt marsh elevation (mm/year) at BMH
SET station
USGS_4_fertilized
USGS_2_control
USGS_1_fertilized
SET01_BHIN
USGS_3_control
SET02_Kent
SET03_Kent
SB03
SET01_AF
SET03_AF
SB01
SB02
SET01_Kent
SET03_GI
SET02_GI
SET01_GI
Set01−BHIS
−10
0
10
Rate of salt marsh
elevation change (mm/year)
Model
Covariates
No_Observer
Observer

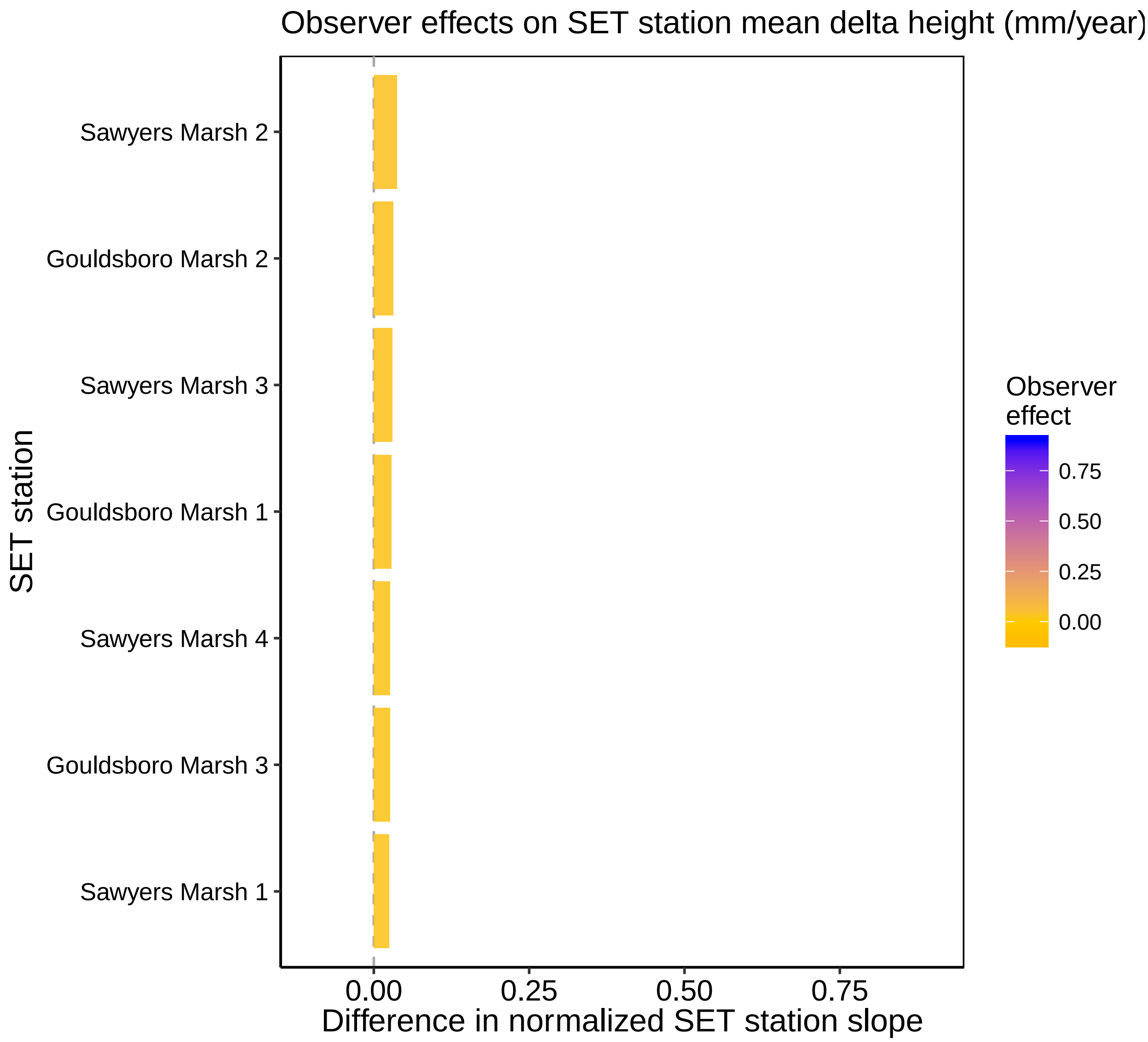

Comparison of modeled observer effects on
change in salt marsh elevation (mm/year) at PMH
SET station
PH2−5 (Deep)
PH2−1 (Deep)
PH2−3 (Deep)
PH2−6 (Deep)
PH2−4 (Deep)
Set 3 (Deep)
Set 1 (Deep)
Set 2 (Deep)
PH2−2 (Deep)
−20
0
20
40
60
Rate of salt marsh
elevation change (mm/year)
Model
Covariates
No_Observer
Observer


Comparison of modeled observer effects on
change in salt marsh elevation (mm/year) at PMH_shallow
SET station
PH2−5 (Shallow)
PH2−3 (Shallow)
PH2−6 (Shallow)
PH2−4 (Shallow)
Set 2 (Shallow)
Set 3 (Shallow)
Set 1 (Shallow)
PH2−1 (Shallow)
PH2−2 (Shallow)
0
25
50
75
Rate of salt marsh
elevation change (mm/year)
Model
Covariates
No_Observer
Observer

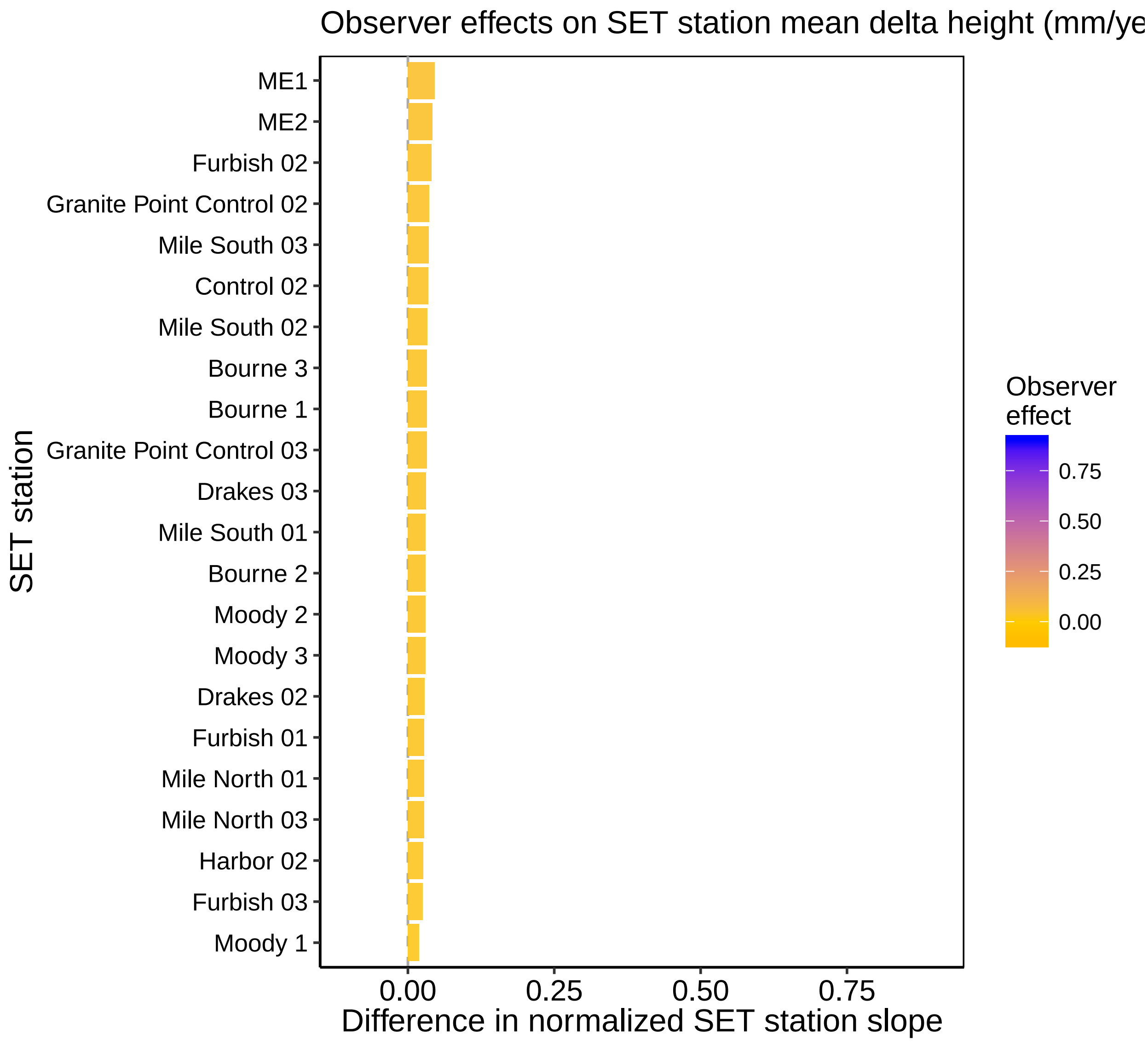

Comparison of modeled observer effects on
change in salt marsh elevation (mm/year) at ESV
SET station
FIW Plot 2
FIE Plot 1
FIE Plot 3
FIW Plot 1
Bull Plot 1
FIE Plot 2
ESV Plot 3
Bull Plot 2
FIW Plot 3
Bull Plot 3
ESV Plot 2
ESV Plot 1
−10
−5
0
5
10
15
Rate of salt marsh
elevation change (mm/year)
Model
Covariates
No_Observer
Observer

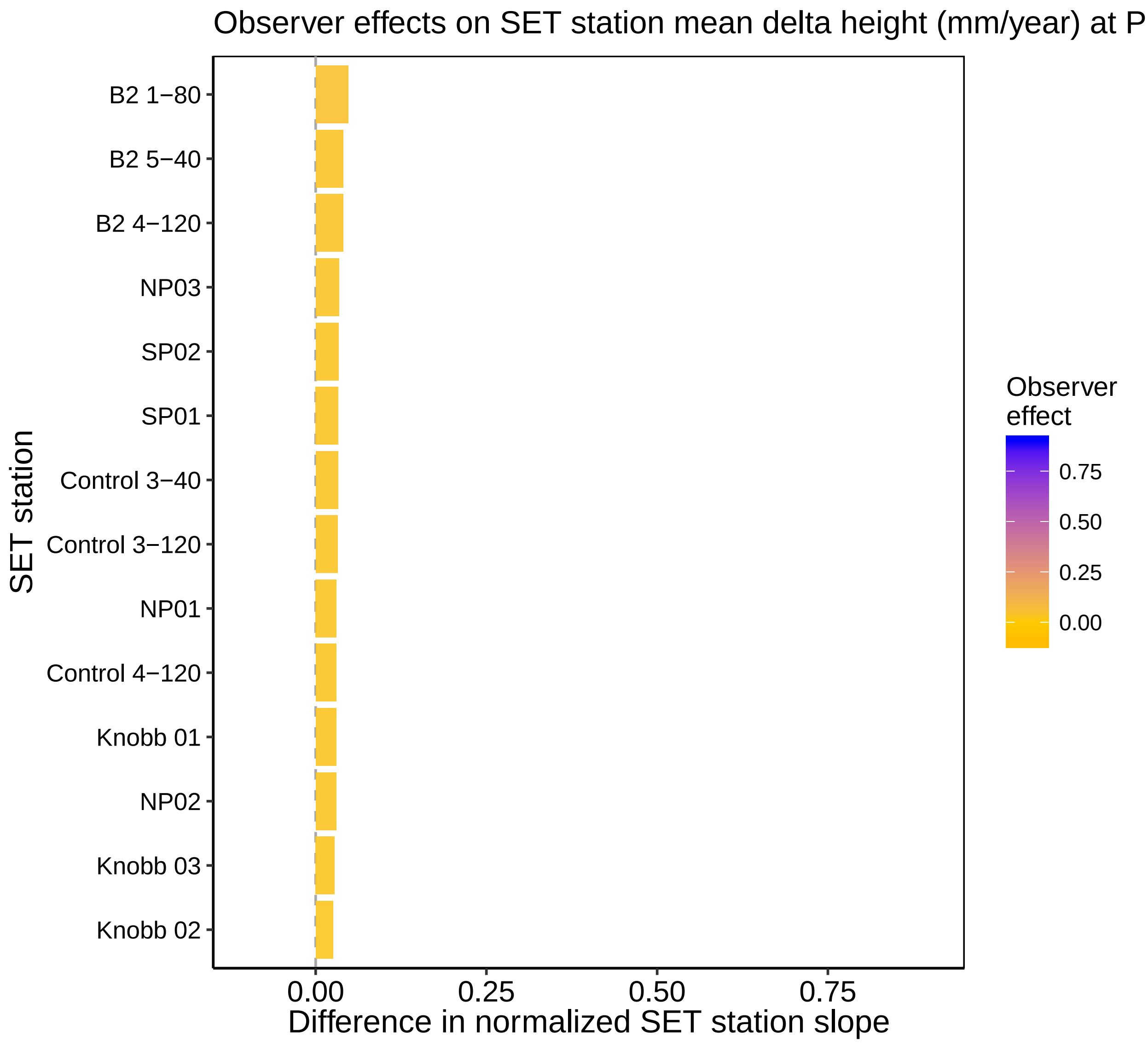


Comparison of modeled observer effects on
change in salt marsh elevation (mm/year) at BKB
SET station
Long Island North 3
Long Island South 2
Long Island North 2
Long Island South 1
North Marsh 1
North Marsh 3
Long Island South 3
Long Island North 1
North Marsh 2
−20
−10
0
Rate of salt marsh
elevation change (mm/year)
Model
Covariates
No_Observer
Observer

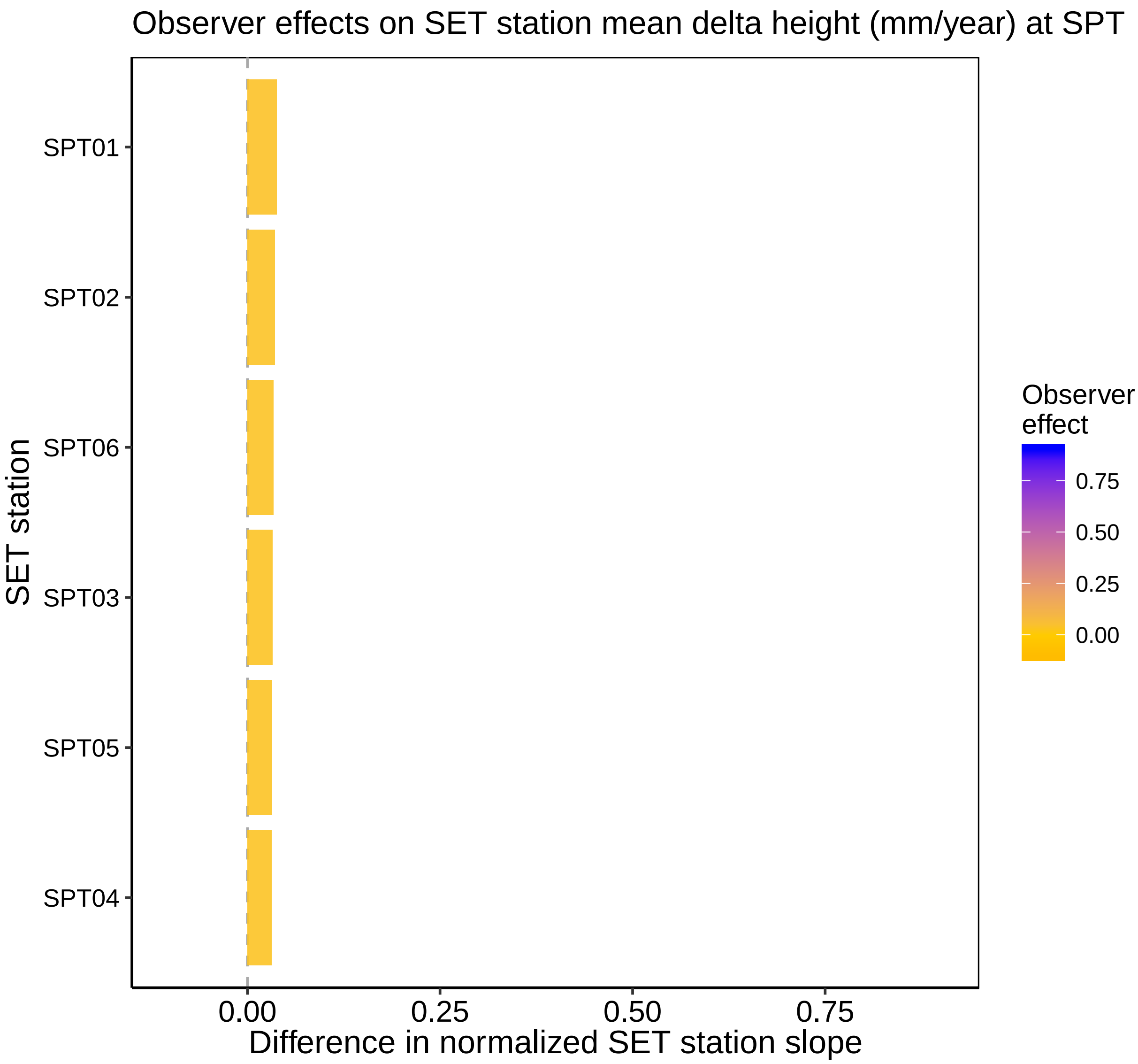


Observer effects on SET station mean delta height (mm/year)
Sawyers Marsh 2
Gouldsboro Marsh 2
Sawyers Marsh 3
Gouldsboro Marsh 1
Sawyers Marsh 4
Gouldsboro Marsh 3
Sawyers Marsh 1
SET station
0.00
0.25
0.50
0.75
Difference in normalized SET station slope
Observer effect
0.75
0.50
0.25
0.00

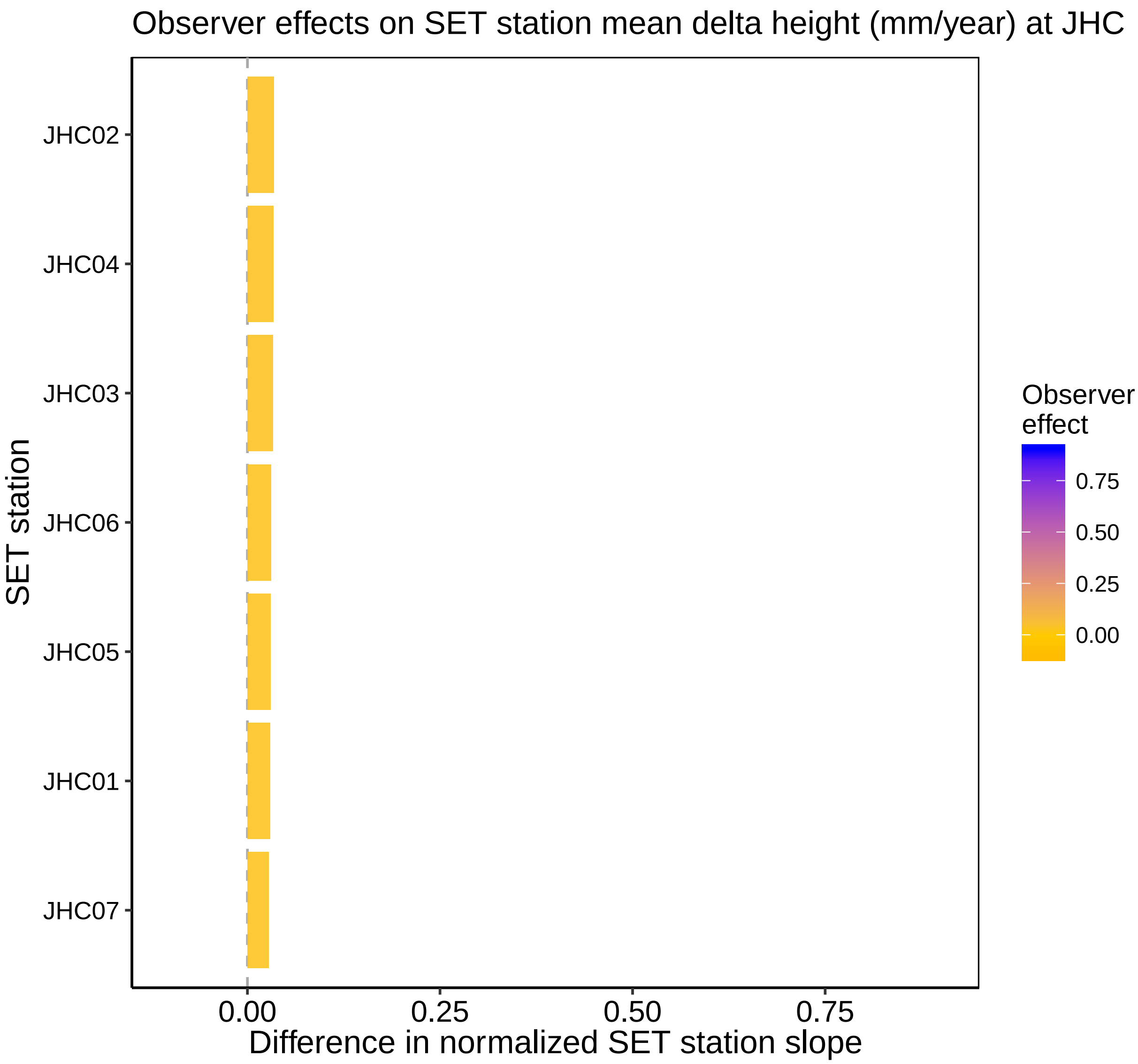

Observer effects on SET station mean delta height (mm/ye
SET station
ME1
ME2
Furbish 02
Granite Point Control 02
Mile South 03
Control 02
Mile South 02
Bourne 3
Bourne 1
Granite Point Control 03
Drakes 03
Mile South 01
Bourne 2
Moody 2
Moody 3
Drakes 02
Furbish 01
Mile North 01
Mile North 03
Harbor 02
Furbish 03
Moody 1
0.00
0.25
0.50
0.75
Difference in normalized SET station slope
Observer
effect
0.75
0.50
0.25
0.00



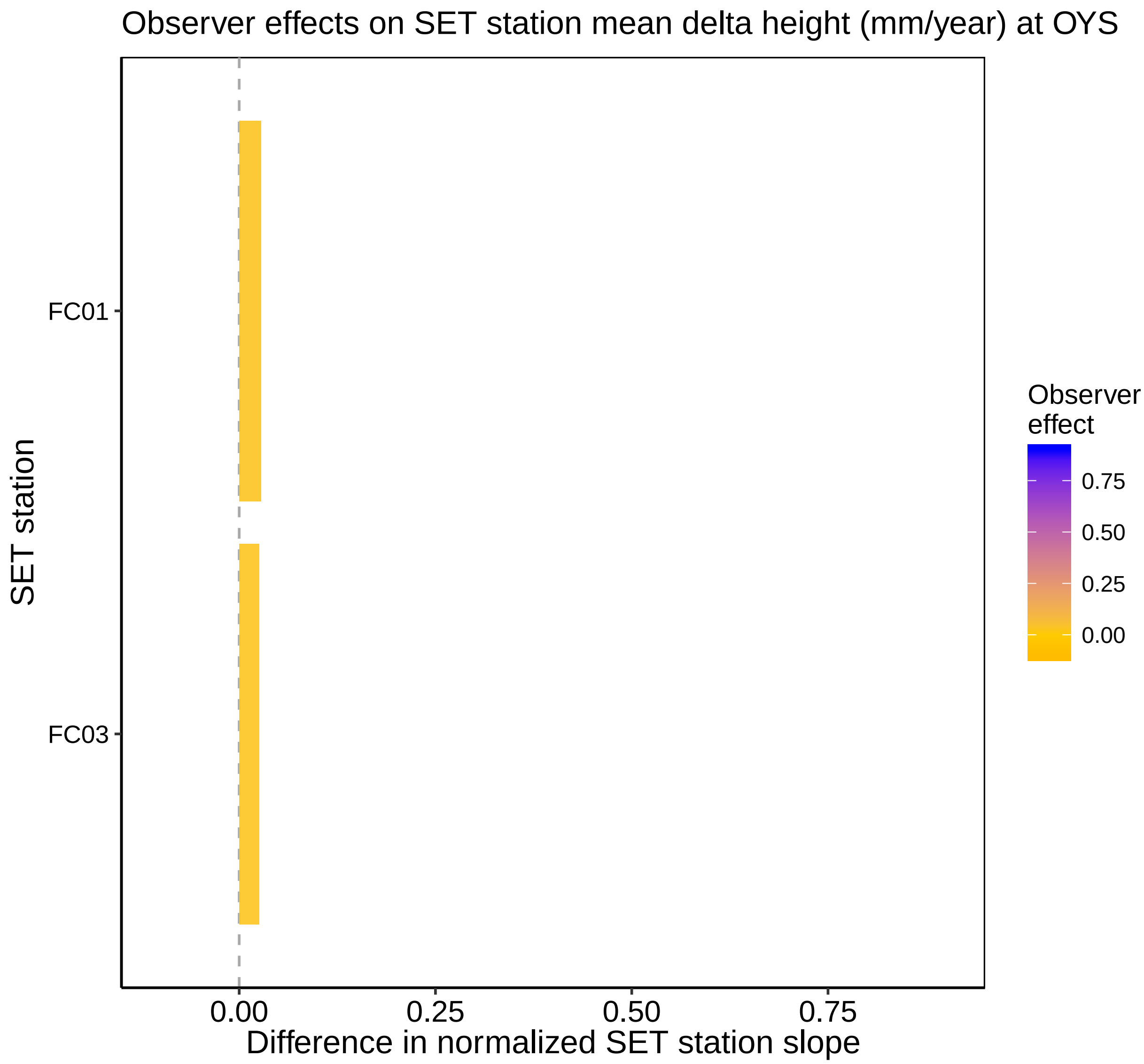
Observer effects on SET station mean delta height (mm/year) at P
SET station
B2 1−80
B2 5−40
B2 4−120
NP03
SP02
SP01
Control 3−40
Control 3−120
NP01
Control 4−120
Knobb 01
NP02
Knobb 03
Knobb 02
0.00
0.25
0.50
0.75
Difference in normalized SET station slope
Observer
effect
0.75
0.50
0.25
0.00



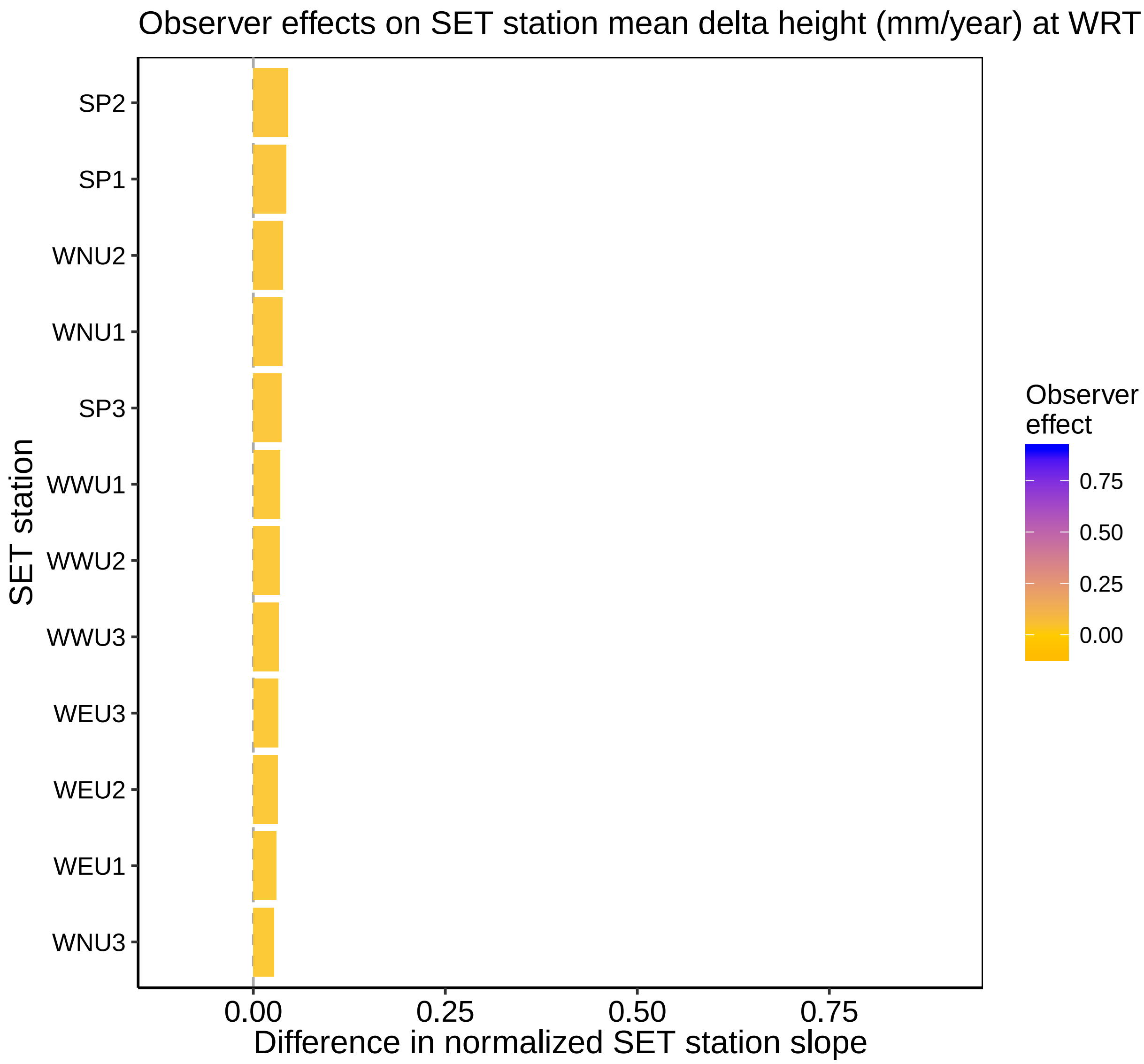
Observer effects on SET station mean delta height (mm/year) at SPT
SET station
SPT01
SPT02
SPT06
SPT03
SPT05
SPT04
0.00
0.25
0.50
0.75
Difference in normalized SET station slope
Observer effect
0.75
0.50
0.25
0.00



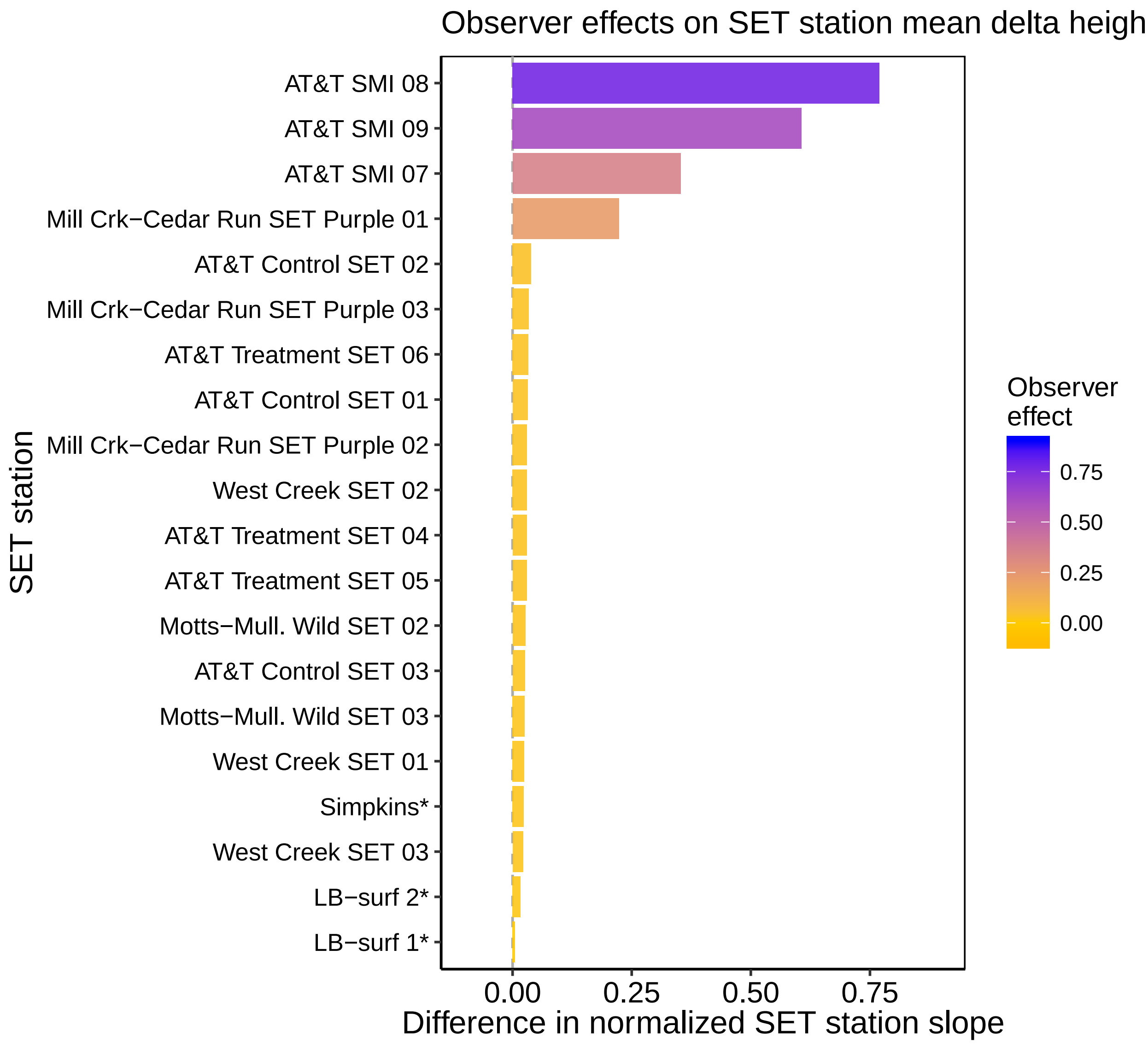
Observer effects on SET station mean delta height (mm/year) at JHC
SET station
JHC02
JHC04
JHC03
JHC06
JHC05
JHC01
JHC07
0.00
0.25
0.50
0.75
Difference in normalized SET station slope
Observer effect
0.75
0.50
0.25
0.00

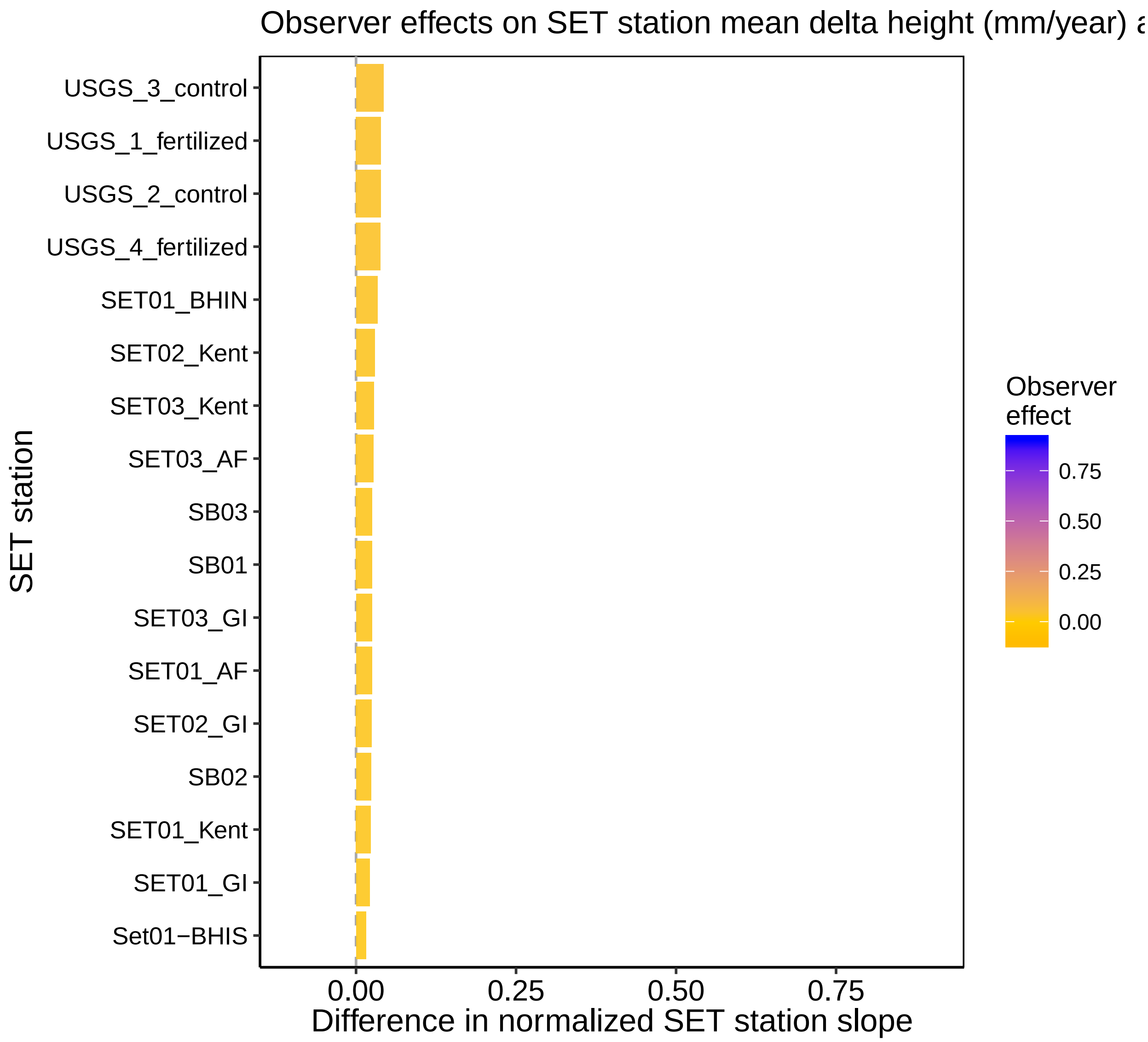


Observer effects on SET station mean delta height (mm/year) at OYS
SET station
FC01
FC03
0.00
0.25
0.50
0.75
Difference in normalized SET station slope
Observer
effect
0.75
0.50
0.25
0.00

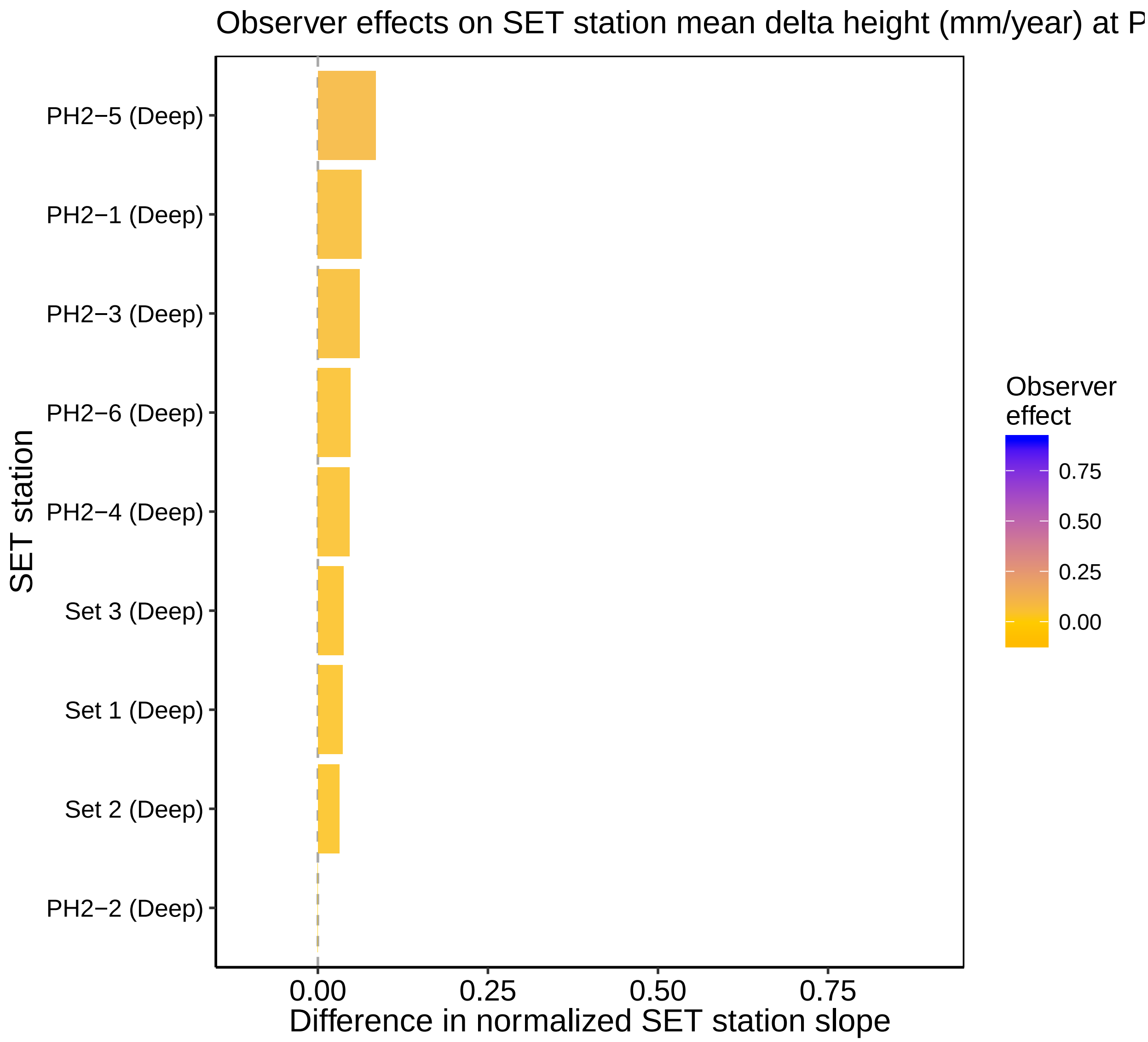


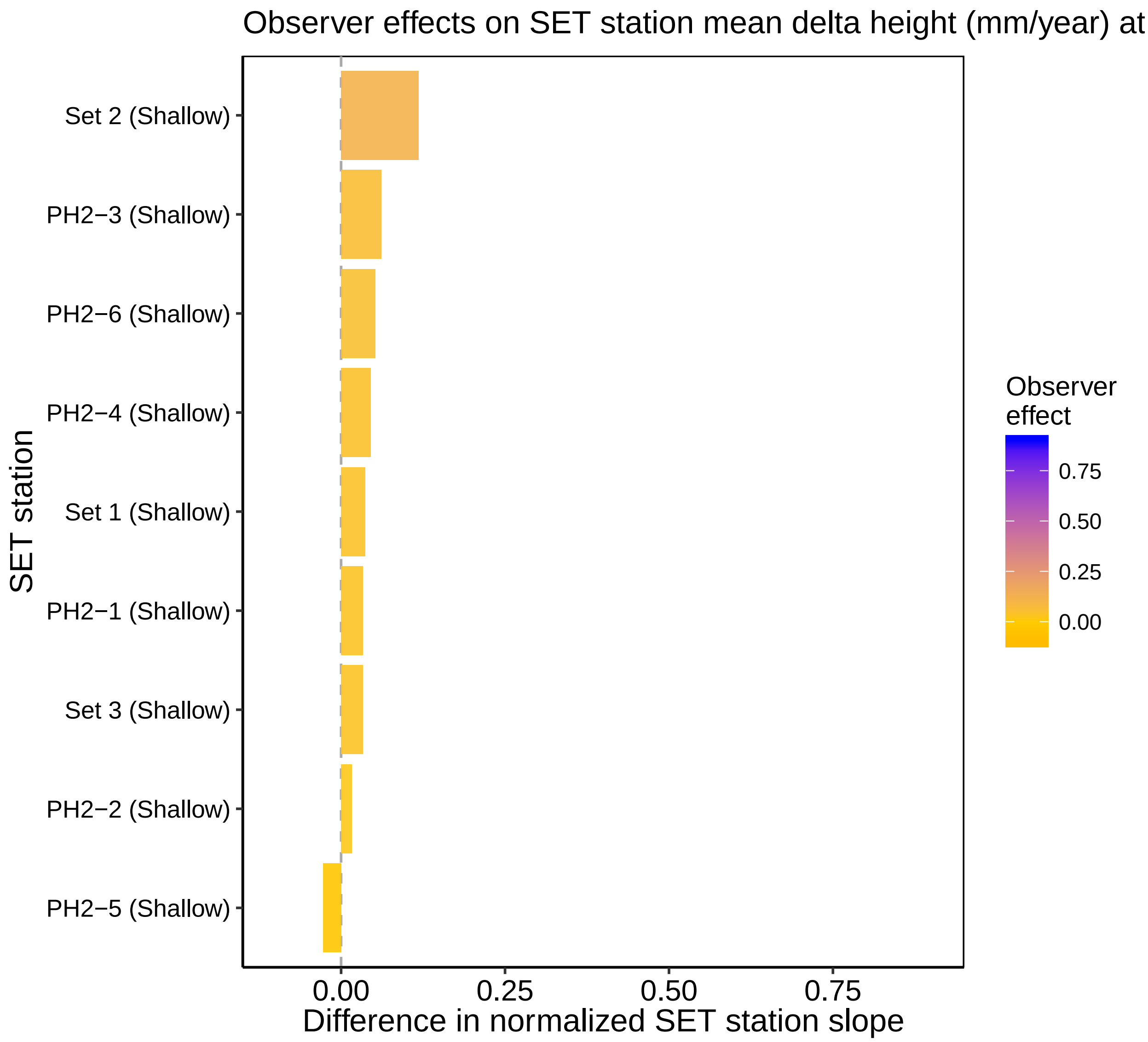
Observer effects on SET station mean delta height (mm/year) at WRT
SET station
SP2
SP1
WNU2
WNU1
SP3
WWU1
WWU2
WWU3
WEU3
WEU2
WEU1
WNU3
0.00
0.25
0.50
0.75
Difference in normalized SET station slope
Observer effect
0.75
0.50
0.25
0.00


Observer effects on SET station mean delta heigh
AT&T SMI 08
AT&T SMI 09
AT&T SMI 07
Mill Crk−Cedar Run SET Purple 01
AT&T Control SET 02
Mill Crk−Cedar Run SET Purple 03
AT&T Treatment SET 06
AT&T Control SET 01
Mill Crk−Cedar Run SET Purple 02
West Creek SET 02
AT&T Treatment SET 04
AT&T Treatment SET 05
Motts−Mull. Wild SET 02
AT&T Control SET 03
Motts−Mull. Wild SET 03
West Creek SET 01
Simpkins*
West Creek SET 03
LB−surf 2*
LB−surf 1*
SET station
0.00
0.25
0.50
0.75
Difference in normalized SET station slope
Observer
effect
0.75
0.50
0.25
0.00

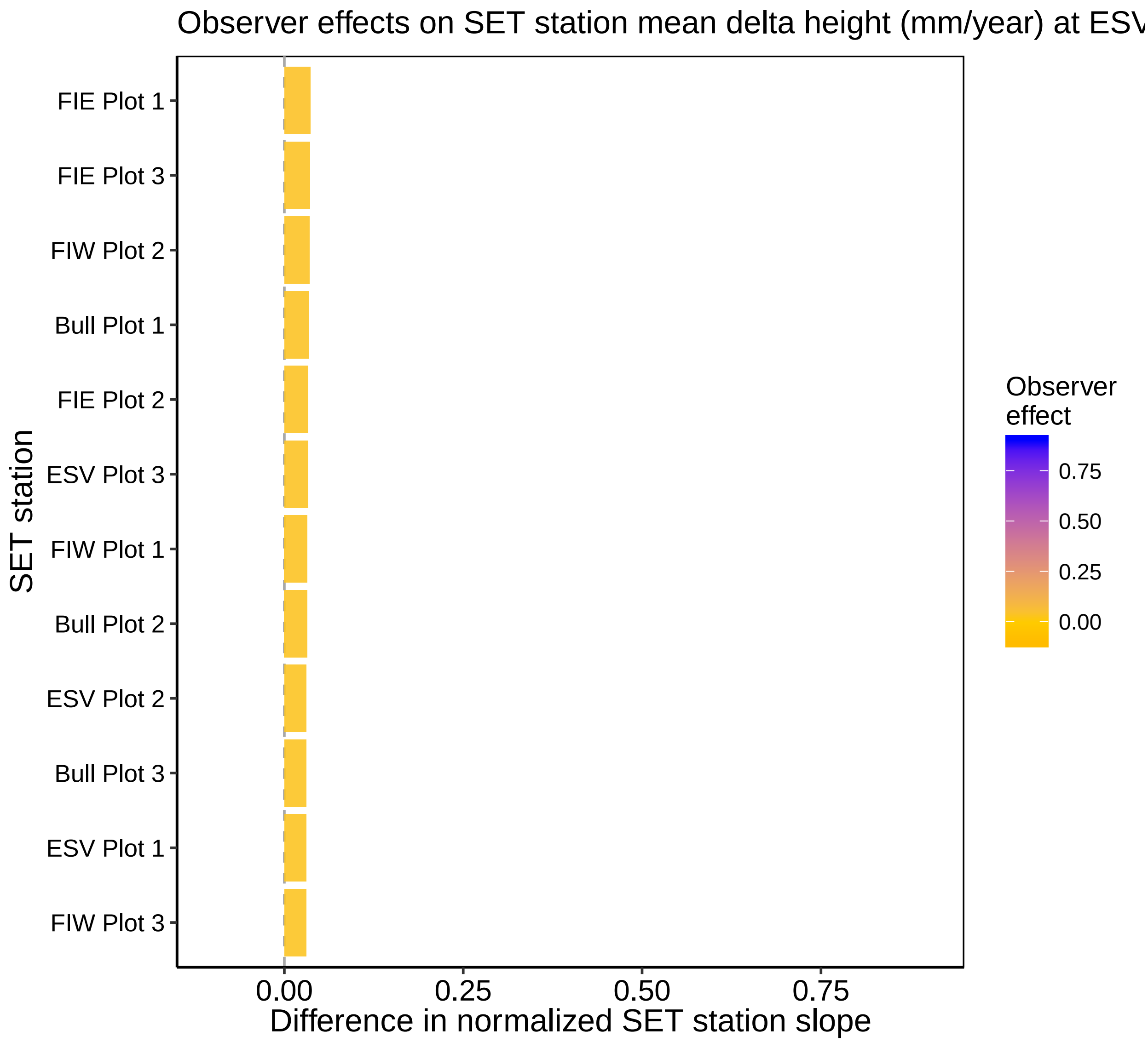


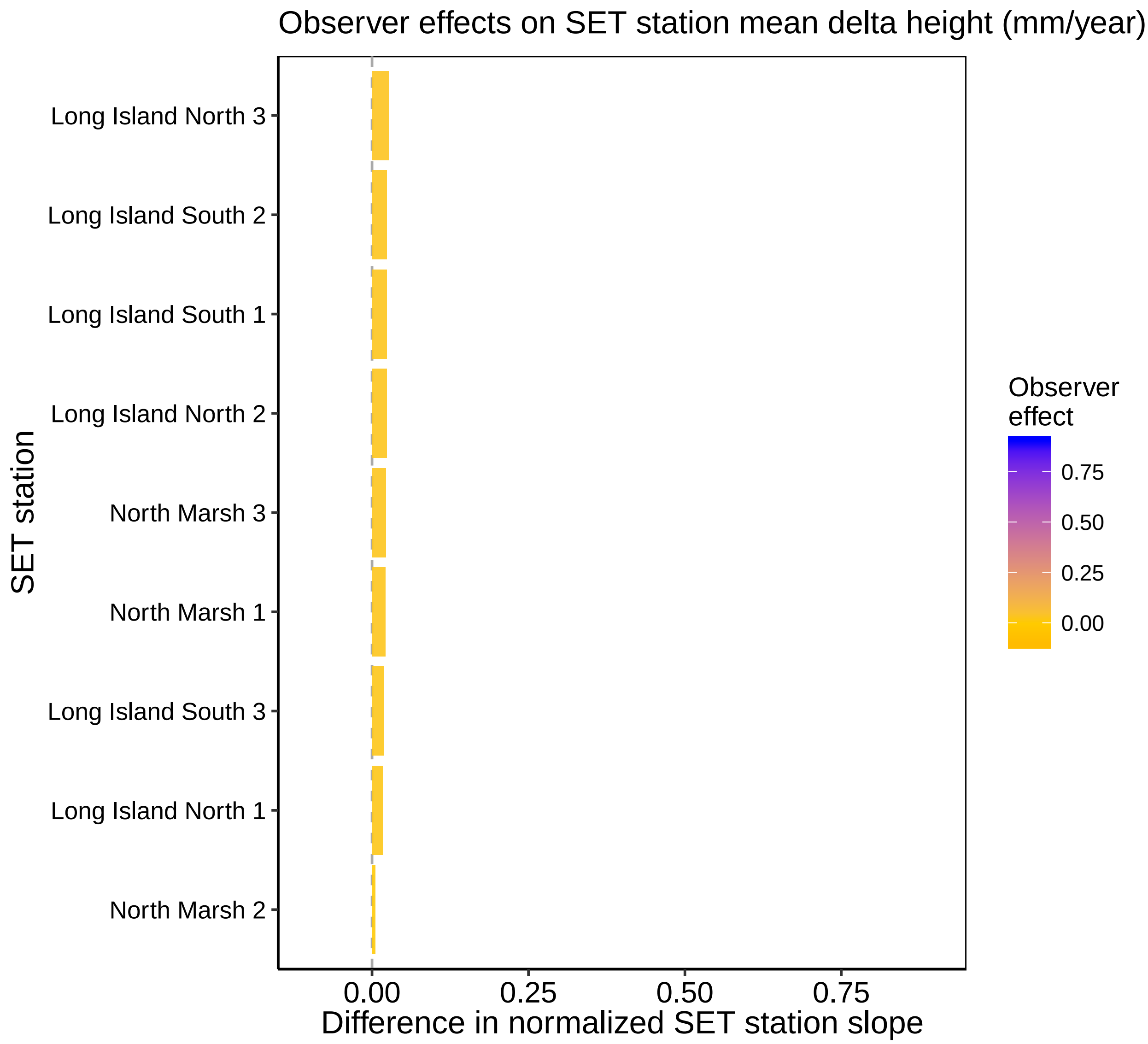
Observer effects on SET station mean delta height (mm/year) a
USGS_3_control
USGS_1_fertilized
USGS_2_control
USGS_4_fertilized
SET01_BHIN
SET02_Kent
SET03_Kent
SET03_AF
SB03
SB01
SET03_GI
SET01_AF
SET02_GI
SB02
SET01_Kent
SET01_GI
Set01−BHIS
SET station
0.00
0.25
0.50
0.75
Difference in normalized SET station slope
Observer
effect
0.75
0.50
0.25
0.00


Observer effects on SET station mean delta height (mm/year) at P
SET station
PH2−5 (Deep)
PH2−1 (Deep)
PH2−3 (Deep)
PH2−6 (Deep)
PH2−4 (Deep)
Set 3 (Deep)
Set 1 (Deep)
Set 2 (Deep)
PH2−2 (Deep)
0.00
0.25
0.50
0.75
Difference in normalized SET station slope
Observer effect
0.75
0.50
0.25
0.00



Observer effects on SET station mean delta height (mm/year) at
SET station
Set 2 (Shallow)
PH2−3 (Shallow)
PH2−6 (Shallow)
PH2−4 (Shallow)
Set 1 (Shallow)
PH2−1 (Shallow)
Set 3 (Shallow)
PH2−2 (Shallow)
PH2−5 (Shallow)
0.00
0.25
0.50
0.75
Difference in normalized SET station slope
Observer effect
0.75
0.50
0.25
0.00


Observer effects on SET station mean delta height (mm/year) at ESV
FIE Plot 1
FIE Plot 3
FIW Plot 2
Bull Plot 1
FIE Plot 2
ESV Plot 3
FIW Plot 1
Bull Plot 2
ESV Plot 2
Bull Plot 3
ESV Plot 1
FIW Plot 3
SET station
0.00
0.25
0.50
0.75
Difference in normalized SET station slope
Observer effect
0.75
0.50
0.25
0.00



Observer effects on SET station mean delta height (mm/year)
Long Island North 3
Long Island South 2
Long Island South 1
Long Island North 2
North Marsh 3
North Marsh 1
Long Island South 3
Long Island North 1
North Marsh 2
SET station
0.00
0.25
0.50
0.75
Difference in normalized SET station slope
Observer effect
0.75
0.50
0.25
0.00