

Grant Year: 3

Institution: University of California, Santa Cruz

CG Review Date: 2024-12-30

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Approved By: Erin Marnocha

Application ID: L22CR4529

Project Title: Coastal Wetland Restoration a Nature Based Decarbonization Multi-Benefit
Climate Mitigation Solution

**Award Amount
Modification:**

Progress Details

Progress Report Abstract

Wetlands can store large amounts carbon in their soil and provide multiple other benefits to people and biodiversity. Wetland restoration projects can serve to remove CO₂ from the atmosphere, clean water, protect coasts, used for recreation, and provide habitat organisms. This project aims to inform coastal wetland restoration design that allows us to maximize these benefits and ensure environmental justice. The project includes natural science studies to identify the processes that control carbon dynamics in these systems, the governance and environmental justice aspects of wetland restoration, and the economic value of the services wetlands provide.

We continue to monitor a diverse set of wetland sites in California measuring gases, water, soil, microbial activity and vegetation properties. We use cutting edge models including AI watershed and process-based models to better understand the processes that control carbon dynamics in these complex systems to predict conditions that facilitate net ecosystem carbon removal and how climate change will impact these processes. We are moving steadily towards our goal to create an accessible tool that will allow managers to identify and prioritize target areas for wetland conservation and restoration for multiple co-benefits and assess the benefits of these systems to people and nature (including monetary value). We also communicate our work to diverse stakeholders to facilitate decision making and increase climate literacy. We maintain a project website with updates (<https://wetlands.ucsc.edu/outputs.html>)

The major challenge we are facing stems from the significant variability between wetlands and the need to integrate data from all these sites and over different temporal and spatial scales. However, our team has gained recognition and is now involved in multiple national and international efforts focused on climate mitigation and coastal resilience; the project supported multiple student thesis and postdoctoral projects. We are working to achieve the project goals, although we need more time due to delays at the start of the project and some technical challenges encountered. We plan to continue towards better understanding of wetlands and their role in climate mitigation and the pathways towards management and governance of these complex systems to better the people and wildlife

Narrative Report of Progress

This research project aims to determine the potential of C sequestration and economic value of wetlands restoration in CA. We elucidate processes that control C dynamics in wetlands and integrate environmental justice considerations, policy, and governance approaches to develop a framework and guidelines for incorporating coastal wetland restoration/conservation into long-term adaptation and development plans.

Carbon Dynamics – At all the wetland sites we are continuously monitoring C fluxes and pools and focusing on understanding controls on carbon burial and GHG emissions. At Elkhorn Slough we are collecting flux data from the five eddy covariance towers representing diverse settings (restored, pristine, diked, eutrophic and agriculture). This year we created an app to streamline data uploading, quality, gap filling and to calculate fluxes. We now have data from all five sites although due to high winds our Yampah tower got damaged and needed substantial repair. This year we are hoping to establish continues remote data downloading and monitoring that will alert us if there are problems in the field. Our data has been submitted to the AmeriFlux network. Hester Marsh received special acknowledgement being 500th site to add data to the network (<https://paytanlab.ucsc.edu/2024/12/04/hester-marsh-ameriflux-networks-500th-site/>). We installed automatic water collection systems and wells to monitor carbon and nutrients export (lateral flux) and we are measuring all C species on multiple timescales, which has not been done at any wetland site in the world. Fluxes are being calculated based on natural isotope tracers and water exchange calculations. A metanalysis of lateral fluxes from wetlands is being conducted and will be submitted to publication soon. We have also collected sediments seasonally and samples are being processed for soil, porewater and dissolved gases. The reactive transport model development is moving along and will help determine the biogeochemical processes controlling C preservation. Soil samples were collected for microbial analyses and have been processed in collaboration with LLNL and LANL staff. We focused on identifying and comparing active microbial consortia within pristine versus restored wetland sediments to identify important members in C cycling and sequestration. DNA extractions and quantitative stable isotope probing will be used to determine microbial activity. The project was highlighted in the Mercury News. At Edan Landing we have continued to collect eddy covariance data as well as lateral flux data. We developed a model that can calculate all fluxes including lateral exchange which could be applied at other sites as well. We are working on C balance and upscaling at this site. Gas chambers have been used and the first assessment of GHG fluxes from pickleweed. Samples for microbiology have been collected and in the coming year we hope to gain new insight into the microbial community using these new data and how they regulate the exchange of GHGs and lateral flow of carbon. In the Delta eddy covariance GHG flux measurements continue at the 5 tidal and non-tidal wetland sites. All data are regularly uploaded to Ameriflux for public use. This year we explored the potential of using a non-parametric statistical method called Alternating Conditional Expectations, ACE, to quantify functional relationships in biogeosciences. We conducted soil and gas chamber campaigns to investigate microbial processes, trace metal abundance and how these relate trace gas fluxes of N₂O, CH₄, and CO₂. Our team is conducting a multi-site synthesis to compare several different tidal wetlands across California and more globally. And members from our team contributed to publication focusing on measuring carbon pools and fluxes, drivers and quantification of methane fluxes, nature-based climate

solutions, coastal wetland restoration as a nature-based climate solution.

Ecosystem Services and Carbon Economics - The team at UCSB is working on an economic model of wetlands restoration. We want to answer how, when, and where should investment in restoration be made to optimally mitigate flooding risks? In the past year, we made a methodological breakthrough on this project. We discovered that we could develop an optimal control model of wetlands restoration and obtain an explicit solution to the model, while retaining necessary realism and complexity. We also made significant progress in developing an application of the model to Huntington Beach, California. The application includes projected sea-level rise and uncertainty over flooding severity and leverages real estate and oceanographic data combined with models of storm surge to evaluate the costs and benefits of investments in wetlands restoration. We have a manuscript in progress ("Natural Climate Solutions: Optimal Restoration of Wetlands to Mitigate Damages from Sea-Level Rise.") that was presented at the World Congress on Natural Resource Modeling. We had originally planned to evaluate additional ecosystem services that can be generated by restoration projects designed to address flooding risk. Given the breakthrough described above, we have decided to focus our attention on understanding the flood mitigation benefits of wetlands. We show that wetlands restoration should continue to the point at which the marginal cost of restoration equals the marginal benefit of establishing a new wetlands patch. Over the next year, we will continue developing the application, finalizing our manuscript, and submitting it to a journal. At UCSC a postdoctoral fellow has been working on creating a transferable, practical tool that could be used for the quantitative valuation of costs and benefits of ecosystem services related to restoration and protection of coastal wetlands. This work will provide a framework and rubric that could be used consistently throughout the state and beyond and serve as a tool for selecting and prioritizing wetland restoration and conservation project sites based on multiple benefits and the stakeholders. We integrated methodologies that capture the economic, ecological, and social dimensions of ecosystem services. In the next year this tool will be tested and used in representative wetland sites. Our goal is to facilitate the creation of an online tool that will be available for scientists, project managers, state government, and NGOs to use for assessing the costs and benefits of wetland nature-based climate solutions and integrate the tool into EcoAtlas. At UCB this year we focused on assessing the risks of the combination of land sinking and water rising on failure of levees in the California Delta. We developed a model that describes the relative probability of failure of a given levee due to high flow events, storm surges, and earthquake liquefaction. The model suggests that full re-wetting could be a powerful strategy to protect the State Water Project for decades to come if carried out in the right locations. In addition, a collaboration was initiated with the Berkeley Carbon Trading Project where project team members are collaborating on writing an assessment of blue carbon accounting protocols, and how they are applied in practice by projects developers.

Governance & Environmental Justice - At UCD the research team is conducting qualitative and quantitative social science research on policy and governance of Bay-Delta wetland restoration. In year 3 of the project, the team has: 1) completed the first research component of an updated network analysis of wetland restoration project data with a draft manuscript reaching completion, 2) made significant progress on the second research component of project case studies and stakeholder interviews with 47 total interviews, coding of interviews, a draft manuscript, and plans for expanded analysis, and 3) developed a research design for reanalysis of existing project data and interviews for a third research study to be completed next year. This analysis was presented at the Bay-Delta Science Conference and awarded "Best Student Oral Presentation". The paper is in final preparation stages to be submitted for peer review. For the upcoming year, we will continue conducting interviews for the three new project case studies and analyze the new data that is collected, development of a new coding scheme for interviews around ecosystem services and barriers to restoration projects. Reanalysis of the EcoAtlas project data will be finished and 3 papers submitted. In addition, Kyra (PhD student) will also be applying for a post-doctoral fellowship to expand the work to the central coast of California. At UCI the team published an analysis in Landscape and Urban Planning. The article, "When mitigation is not "just mitigation": Defining (and diffusing) tensions between climate mitigation, adaptation, and justice". The article assesses wetlands conservation for carbon sequestration in California through an environmental justice lens and contributes to a critical discussion of just mitigation in the state. The StoryMap underwent significant revisions and continues to be updated. We also continued its work on a network analysis of restoration projects in the South Coast Basin. In the upcoming year, we will further develop the StoryMap, An Introduction to Wetlands and Environmental Justice. This will include experiential data from additional wetland sites in Southern California, as well as an expanded conversation on blue carbon sequestration in coastal wetlands for Californians who are new to this concept. At UCSC the accomplishments from the past year include progress on four major deliverables from the grant. The first was a review on "Environmental Justice of Coastal Hazards" and preliminary findings were presented at Society of Applied Anthropology conference, and the complete work will be presented at the Society of Applied Anthropology conference. The research is currently in its second round of reviews at the journal Climatic Change. The second major deliverable is work on "Operationalizing Equity in Nature-Based Coastal Adaptation: Assessing Practitioner Perspectives from the San Francisco Bay, California". This work is currently under review at the journal Nature-Based Solutions. The third is a project, entitled "Turning Finance on its Head: Ecosystem Service Valuation and the Question of Historical Justice." During the past year, our team completed drafting, presented findings at the Finance and Society Annual Conference, implemented feedback from the first reviewers and submitted the work for publication. The fourth deliverable is a project entitled "Evaluating Access to Coastal Wetlands in California." To date, students have compiled a spatial dataset of all parks where the public may access coastal wetlands, and they are currently completing work to manually populate additional amenities data in the dataset. These

data will be combined with coastal hazard data to understand future impacts to wetland-related protected areas and potential loss of amenities and ecosystem services.

Climate Modeling - The overall goal of the modeling team is to perform comprehensive modeling experiments using both the machine learning models and process-based model (ATS) to explore the effects of various coastal wetland restoration and land use strategies on net carbon sequestration. We integrate observational data to develop, parameterize, upscale, and validate these models, enabling us to predict greenhouse gas fluxes under different land-use scenarios. Over the past year, we have successfully developed a machine learning model to forecast carbon sequestration and methane emissions from non-tidal wetlands. We used a deep learning framework (LSTM) utilizing data from eddy covariance flux tower sites along with in situ and remote sensing datasets. The work has been presented at the Bay-Delta conference (Brereton et al., "The Regional Carbon and Climate Analytics Tool (RCCAT): A Deep-Learning Model to Predict Carbon Sequestration Potential and Greenhouse Gas Emissions." and the paper has been submitted to Geoscientific Model development. The process based ATS model was initiated for Elkhorn Slough to specifically compare the effect of wetland restoration on watershed hydrology and how this would change as sea level rises by comparing the Yampah and Hester settings. Preliminary results were presented at the Bay-Delta conference (Xu et al., "Interaction between Coastal Wetland Restoration and Hydrological Processes." This presentation explored the interactions between coastal wetland restoration initiatives and regional hydrological processes and a paper is being prepared for submission. Over the next year, we plan to continue our efforts to upscale the model regionally across the bay-delta system, aiming for a more comprehensive understanding of carbon dynamics at a larger spatial scale. Our focus will be on developing and comparing changes in carbon exchanges across different land-use scenarios. Additionally, we will couple a carbon biogeochemistry process model (PFLOTRN) to the watershed ATS model to assess impacts of climate change on carbon dynamics in wetland.

Key Personnel

Key Personnel

Annual Progress Report - L22CR4529 - Paytan - Coastal Wetland Restoration a Nature Based Decarbonization Multi-Benefit Climate Mitigation Solution

Last Name	First Name	Email	Degrees	Title	Department	Institution	Role on Project	% Effort	Institution Type	Out of State Effort?	No Longer on Project	Status	Updated
Paytan	Adina	apaytan@ucsc.edu	Ph.D	Researcher	IMS	UCSC	Applicant Principal Investigator		Academic/Research Institution	- Select One-		Submitted - Unlocked	2024-12-27 05:51
Arnold	Gwen	gbarnold@ucdavis.edu	Ph.D	Assistant Prof.	Environmental Science & Policy	UCD	Co-Principal Investigator		Academic/Research Institution			Submitted - Unlocked	2023-05-23 02:51
Zilberman	David	zilber11@berkeley.edu	Ph.D	Prof.	Agricultural and Resource Economics	UCB	Co-Principal Investigator		Academic/Research Institution			Submitted - Unlocked	2023-05-23 02:51
Platinga	Andrew	plantinga@bren.ucsb.edu	Ph.D	Prof.	Bren School of Environmental Science and Management	UCSB	Co-Principal Investigator		Academic/Research Institution			Submitted - Unlocked	2023-05-23 02:51
Matthew	Richard	rmatthew@uci.edu	Ph.D	Prof.	Urban Planning and Public Policy, and Political Science	UCI	Co-Principal Investigator		Academic/Research Institution			Submitted - Unlocked	2023-05-23 02:51

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Paytan - Coastal Wetland Restoration a
Nature Based Decarbonization Multi-Benefit
Climate Mitigation Solution

Pett- Ridge	Jen- nifer	pettrid ge2@ll nl.gov	Ph.D	Grou p Lead er	Environmen tal Isotope Systems	LLNL	Co- Princip al Investi gator	Government		Sub mitte d - Unloc ked	2023 -05-2 3 02:51
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Moulton	John	moulton@lanl.gov	Ph.D	Research Scientist	Applied Mathematics and Plasma Physics Group	LANL	Co-Investigator	Government	Submitted - Unlocked	2023-05-23 02:51
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Richards on	Christina	cmrichar@ucsc.edu	Ph.D	Post Doc	Earth and Planetary Science	UC SC	Co-Investigator	Academic/Research Institution	Submitted - Unlocked	2023-05-23 02:51
Pit	Susan	supit@ucsc.edu	M.S	Graduate Student	Earth and Planetary Science	UC SC	Trainee	Academic/Research Institution	Submitted - Unlocked	2023-05-23 02:51
Peasall	Grace	gpearsal@ucsc.edu	B.S	Graduate Student	Earth and Planetary Science	UC SC	Trainee	Academic/Research Institution	Submitted - Unlocked	2023-05-23 02:51
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Mendez	Michael	mamende6@uci.edu	Ph.D	Assistant Prof.	Urban Planning and Public Policy, and Political Science	UCI	Co-Investigator	Academic/Research Institution	- Select One- This person is no longer with the project.	Submitted - Unlocked	2023-05-23 02:51
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Publications

List all Publications

Add

Pu bli cat ion Ty pe	Publication Title	Ident ifier	Authors	Pu bli cat ion Ye ar	Pu blic atio n Sta tus	Sta tus
Ot her	Performance of Restored Tidal and Nontidal Wetlands on the Exchange of Carbon	AGU Abstract	Ariane Arias Ortiz, Robert Shortt, Tianxin Wang, Kaniska Mallick, Daphne J. Szutu, Joseph G Verfaillie and Dennis D Baldocchi	2022	Published	Su bm itte d - Unl ock ed
Ot her	The Human Story of Wetlands		Stephanie Martinez	2023	Published	Su bm itte d - Unl ock ed

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Journal Article	Practical guide to measuring wetland carbon pools and fluxes.	Bansal, S., Creed, I.F., Tangen, B.A., Bridgham, S.D., Desai, A.R., Krauss, K.W., Neubauer, S.C., Noe, G.B., Rosenberry, D.O., Trettin, C., Wickland, K.P., Allen, S.T., Arias-Ortiz, A., Armitage, A.R., Baldocchi, D., Banerjee, K., Bastviken, D., Berg, P., Bogard, M., Chow, A.T., Conner, W.H., Craft, C., Creamer, C., DelSontro, T., Duberstein, J.A., Eagle, M., Fennessy, M.S., Finkelstein, S.A., Göckede, M., Grunwald, S., Halabisky, M., Herbert, E., Jahangir, M.M.R., Johnson, O.F., Jones, M.C., Kelleway, J.J., Knox, S., Kroeger, K.D., Kuehn, K.A., Lobb, D., Loder, A.L., Ma, S., Maher, D.T., McNicol, G., Meier, J., Middleton, B.A., Mills, C., Mistry, P., Mitra, A., Mobilian, C., Nahlik, A.M., Newman, S., O'Connell, J.L., Oikawa, P., Post van der Burg, M., Schutte, C.A., Song, C., Stagg, C.L., Turner, J., Vargas, R., Waldrop, M.P., Wallin, M.B., Wang, Z.A., Ward, E.J., Willard, D.A., Yarwood, S., and Zhu, X.	2023	Published	Submitted - Unlocked
Journal Article	On the Relationship Between Aquatic CO2 Concentration and Ecosystem Fluxes in Some of the World's Key Wetland Types	Richardson, J. L., Desai, Ankur R., Thom, Jonathan, Lindgren, Kim, Laudon, Hjalmar, Peichl, Matthias, Nilsson, Mats, Campeau, Audrey, Järveoja, Järvi, Hawman, Peter, Mishra, Deepak R., Smith, Dontrece, D'Acunha, Brenda, Knox, Sara H., Ng, Darian, Johnson, Mark S., Blackstock, Joshua, Malone, Sparkle L., Oberbauer, Steve F., Detto, Matteo, Wickland, Kimberly P., Forbrich, Inke, Weston, Nathaniel, Hung, Jacqueline K. Y., Edgar, Colin, Euskirchen, Eugenie S., Bret-Harte Sydonia, Dobkowski, Jason, Kling, George, Kane, Evan S., Badiou, Pascal, Bogard, Matthew, Bohrer, Gil, O'Halloran, Thomas, Ritson, Jonny, Arias-Ortiz, Ariane, Baldocchi, Dennis, Oikawa, Patty, Shahan, Julie, Matsumura, Maiyah	2023	Published	Submitted - Unlocked

Journal Article	Methane Fluxes in Tidal Marshes of the Contiguous United States: A Synthesis of Fluxes and Analysis of Predictor Variables	Aries-Ortiz et al	2023	Published	Submitted - Unlocked
Journal Article	Alternating Conditional Expectations: A Non-Parametric Statistical Method to Interpret Long-term Greenhouse Gas Flux Measurements over Natural Ecosystems	Baldocchi and Aries-Ortiz	2024	Published	Submitted - Unlocked
Other	B54A-06Carbon Biogeochemical Cycling in Tidal Wetlands: Exploring Lateral Carbon Exchange and Sequestration Potential	Ariane Arias Ortiz, Daphne J. Szutu, Joseph G Verfaillie, Tianxin Wang, Robert Shortt, Adina Paytan and Dennis D Baldocchi	2023	Published	Submitted - Unlocked
Other	GC51L-0762Dynamic Methane Emission Responses to Wetland Restoration	Kyle B Delwiche, Maoya Bassiouni, Dennis D Baldocchi, and Trevor F Keenan, L	2023	Published	Submitted - Unlocked

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Other	Pixel-Wise Footprint Analysis of GPP Using High- Resolution NDVI/NIRv Data	Robert Shortt, Dennis Baldocchi, Joseph Verfaillie	20 23	Pub lish ed	Su bm itte d - Unl ock ed
Other	B51E-1811 Carbon and Nitrogen content and Stable isotope analysis for Elkhorn Slough sediments	Valeria Galindo-Eguiarte, Susan M Pit, Ariane Arias Ortiz, Adina Paytan	20 23	Pub lish ed	Su bm itte d - Unl ock ed
Other	EP33D-2145 Investigate the Impacts of Coastal Wetland Restoration on Surface and Subsurface Hydrology and Freshwater- saltwater Interaction	Yi Xu, Yu Zhang, John D Moulton, Adina Paytan	20 23	Pub lish ed	Su bm itte d - Unl ock ed
Other	H31U-1775 In situ, continuous monitoring of agricultural drainage waters captures dynamic temporal and spatial patterns that provide insights into land use impacts	Christina Richardson, Tamara E.C. Kraus, Adina Paytan, Hieu Ly, Kyle Nakatsuka, Balthasar Von Hoyningen Huene, James L Orlando and Joseph Fackrell	20 23	Pub lish ed	Su bm itte d - Unl ock ed

Ot her	B54A-06 Carbon Biogeochemical Cycling in Tidal Wetlands: Exploring Lateral Carbon Exchange and Sequestration Potential	Ariane Arias Ortiz, Daphne J. Szutu, Joseph G Verfaillie, Tianxin Wang, Robert Shortt, Adina Paytan and Dennis D Baldocchi	20 23	Pub lish ed	Su bm itte d - Unl ock ed
Ot her	ED07-07 Monitoring of lateral carbon export in tidal wetlands - Examples from Elkhorn Slough	Ria Agrawal, Jacqueline Jabuka, Ariane Arias Ortiz and Adina Paytan	20 23	Pub lish ed	Su bm itte d - Unl ock ed
Ot her	INV11C-12 Using Authentic Local Climate Data in Teaching – Co- creating Student Climate Learning Experiences	Adina Paytan, Sarah Pedemonte and Emily L Weiss	20 23	Pub lish ed	Su bm itte d - Unl ock ed
Ot her	GC51L-0765 Evaluating Coastal Wetland Carbon Sequestration Potential: An Ecosystem Modelling Study	Ashley Brereton ^{1,2} , Zelalem A Mekonnen ³ , Bhavna Arora ⁴ , Dennis D Baldocchi ⁵ , John D Moulton ⁶ , Patty Y Oikawa ⁷ , Lisamarie Windham-Myers ⁸ , Yi Xu ^{9,10} , Yu Zhang ¹¹ and Adina Paytan	20 23	Pub lish ed	Su bm itte d - Unl ock ed

Journal Article	When mitigation is not “just mitigation”: Defining (and diffusing) tensions between climate mitigation, adaptation, and justice	10.1016/j.landurbpl.2024.105081	Jessica Debats Garrison and Stephanie Martinez	2024	Published	Submitted - Unlocked
Journal Article	When and where can coastal wetland restoration increase carbon sequestration as a natural climate solution?	doi.org/10.1017/cft.2024.14	Scott F Jones, Ariane Arias-Ortiz, Dennis Baldocchi, Meagan Eagle, Daniel A Friess, Catrina Gore, Greg Noe, Stefanie Nolte, Patty Oikawa, Adina Paytan, Jacqueline L Raw, Brian J Roberts, Kerrylee Rogers, Charles Schutte, Camille L Stagg, Karen M Thorne, Eric J Ward, Lisamarie Windham-Myers, Erik S Yando	2024	Published	Submitted - Unlocked
Journal Article	Methane fluxes in tidal marshes of the conterminous United States	10.1111/gcb.17462	Ariane Arias-Ortiz, Jaxine Wolfe, Scott D Bridgham, Sara Knox, Gavin McNicol, Brian A Needelman, Julie Shahan, Ellen J Stuart-Haëntjens, Lisamarie Windham-Myers, Patty Y Oikawa, Dennis D Baldocchi, Joshua S Caplan, Margaret Capooci, Kenneth M Czapla, R Kyle Derby, Heida L Diefenderfer, Inke Forbrich, Gina Groseclose, Jason K Keller, Cheryl Kelley, Amr E Keshta, Helena S Kleiner, Ken W Krauss, Robert R Lane, Sarah Mack, Serena Moseman-Valtierra, Thomas J Mozdzer, Peter Mueller, Scott C Neubauer, Genevieve Noyce, Karina VR Schäfer, Rebecca Sanders-DeMott, Charles A Schutte, Rodrigo Vargas, Nathaniel B Weston, Benjamin Wilson, J Patrick Megonigal, James R Holmquist	2024	Published	Submitted - Unlocked
Journal Article	We need a solid scientific basis for nature-based climate solutions in the United States	10.1073/pnas.2318505121	Novick, K. A., Keenan, TF, Anderegg, WRL, Normile, CP, Runkle, BRK, Oldfield, EE, Shrestha, G, Baldocchi, DD, Evans, ME, Randerson, JT, Sanderman, J. Torn, MS, Trugman, AT, Williams, CA	2024	Published	Submitted - Unlocked

Journal Article	Alternating Conditional Expectations: Introducing A non-parametric statistical method to interpret long-term greenhouse gas flux measurements over semi-arid and wetland ecosystems		DD Baldocchi, A Arias Ortiz	2024	Published	Submitted - Unlocked
Journal Article	Multiple microbial guilds mediate soil methane cycling along a wetland salinity gradient	10.1128/ms.00936-23	Wyatt H Hartman, Clifton P Bueno de Mesquita, Susanna M Theroux, Connor Morgan-Lang, Dennis D Baldocchi, Susannah G Tringe	2024	Published	Submitted - Unlocked
Journal Article	On the Relationship Between Aquatic CO2 Concentration and Ecosystem Fluxes in Some of the World's Key Wetland Types		Jessica L Richardson, Ankur R Desai, Jonathan Thom, Kim Lindgren, Hjalmar Laudon, Matthias Peichl, Mats Nilsson, Audrey Campeau, Järvi Järveoja, Peter Hawman, Deepak R Mishra, Dontrece Smith, Brenda D'Acunha, Sara H Knox, Darian Ng, Mark S Johnson, Joshua Blackstock, Sparkle L Malone, Steve F Oberbauer, Matteo Detto, Kimberly P Wickland, Inke Forbrich, Nathaniel Weston, Jacqueline KY Hung, Colin Edgar, Eugenie S Euskirchen, Sydonia Bret-Harte, Jason Dobkowski, George Kling, Evan S Kane, Pascal Badiou, Matthew Bogard, Gil Bohrer, Thomas O'Halloran, Jonny Ritson, Ariane Arias-Ortiz, Dennis Baldocchi, Patty Oikawa, Julie Shahan, Maiyah Matsumura	2024	Published	Submitted - Unlocked

Journal Article	Controls on spatial variation in porewater methane concentrations across United States tidal wetlands	https://doi.org/10.1016/j.scitotenv.2024.177290	Erika L Koontz, Sarah M Parker, Alice E Stearns, Brian J Roberts, Caitlin M Young, Lisamarie Windham-Myers, Patricia Y Oikawa, J Patrick Megonigal, Genevieve L Noyce, Edward J Buskey, R Kyle Derby, Robert P Dunn, Matthew C Ferner, Julie L Krask, Christina M Marconi, Kelley B Savage, Julie Shahan, Amanda C Spivak, Kari A St Laurent, Jacob M Argueta, Steven J Baird, Kathryn M Beheshti, Laura C Crane, Kimberly A Cressman, Jeffrey A Crooks, Sarah H Fernald, Jason A Garwood, Jason S Goldstein, Thomas M Grothues, Andrea Habeck, Scott B Lerberg, Samantha B Lucas, Pamela Marcum, Christopher R Peter, Scott W Phipps, Kenneth B Raposa, Andre S Rovai, Shon S Schooler, Robert R Twilley, Megan C Tyrrell, Kellie A Uyeda, Sophie H Wulfin, Jacob T Aman, Amanda Giacchetti, Shelby N Cross-Johnson, James R Holmquist	2024	Published	Submitted - Unlocked
Journal Article	A new coupled biogeochemical modeling approach provides accurate predictions of methane and carbon dioxide fluxes across diverse tidal wetlands	10.1029/2023JG007943	PY Oikawa, D Sihi, I Forbrich, E Fluett-Chouinard, M Najarro, O Thomas, J Shahan, A Arias-Ortiz, S Russell, SH Knox, G McNicol, J Wolfe, L Windham-Myers, E Stuart-Haentjens, SD Bridgham, B Needelman, R Vargas, K Schäfer, EJ Ward, P Megonigal, J Holmquist	2024	Published	Submitted - Unlocked
Other	A Comparative Analysis of Dissolved Inorganic Carbon Fluxes in Tidal Marshes of the San Francisco Bay Delta	Jessica Silberman		2024	Published	Submitted - Unlocked

Other	Building Resilience to Coastal Hazards: An Analysis of Decision-Making and Environmental Justice on Changing Coasts		Amanda Daria Stoltz	2024	Published	Submitted - Unlocked
Journal Article	Environmental Justice of Coastal Hazards: A Systematic Literature Review	https://doi.org/10.21203/rs.3.rs-4331822/v1	Amanda Daria Stoltz, Olivia M Won, Emma KC Gee, Katherine L Seto	2024	In Review	Submitted - Unlocked
Other	Detecting and Predicting Hot Moments of Methane Emissions from Coastal Wetlands		Pearsall Grace	2024	Published	Submitted - Unlocked
Journal Article	How to pay for ecosystem services	10.1002/fee.2680	Andrew J Plantinga, Katherine Millage, Erin O'Reilly, Tamaki Bieri, Nick Holmes, Jono Wilson, Darcy Bradley	2024	Published	Submitted - Unlocked

Jo urn al Art icle	A market for 30x30 in the ocean	DOI: 10.11 26/s cienc e.adl 4019	Juan Carlos Villaseñor-Derbez, Christopher Costello, Andrew J Plantinga	20 24	Pub lish ed	Su bm itte d - Unl ock ed
Jo urn al Art icle	Toward improved sediment management and coastal resilience through efficient permitting in California		KA Goodrich, N Ulibarri, R Matthew, ED Stein, M Brand, BF Sanders	20 24	Pub lish ed	Su bm itte d - Unl ock ed
Jo urn al Art icle	Net Fluxes of Broadband Shortwave and Photosynthetical ly Active Radiation Complement NDVI and Near Infrared Reflectance of Vegetation to explain Gross Photosynthesis Variability Across Ecosystems and Climate		Kanishka Mallick, Joseph Verfaillie, Tianxin Wang, Ariane Arias Ortiz, Daphne Szutu, Koong Yi, Yanghui Kang, Robert Shortt, Tian Hu, Mauro Sulis, Zoltan Szantoi, Gilles Boulet, Joshua B Fisher, Dennis Baldocchi	20 24	Pub lish ed	Su bm itte d - Unl ock ed

Patents and Licenses

List all Patents

Nothing to Report

Human Subjects Use

Assurance Status	IRB Approval Date	IRB Expiration Date	Assurance Number	Status
Exempt	2022-05-04	2025-04-14	1781342	Approved

Leveraged Funding

List all Leveraged Funding

Add

Achievement Type	Total Amount	Funding Organization	Year Received	Status
Leveraged Grant	\$406,100	NSF	2022	Submitted - Unlocked
Leveraged Grant	\$184,760	NSF	2021	Submitted - Unlocked
Leveraged Grant	\$499,826	UCSC	2023	Submitted - Unlocked
Leveraged Grant	\$221,020	Sea Grant	2025	Submitted - Unlocked
Leveraged Grant	\$220,000	NSF	2024	Draft

Signature

Funding Acknowledgement

As Principal Investigator of this grant, I affirm that I have ensured all publications, licenses, patents and patent applications, or other products produced or supported by this grant acknowledge the funding sponsorship of this grant program by name and by grant ID number. Publications, licenses, patents, or other products issued after grant closure must also comply with these requirements. Funding acknowledgement language appears in the RGPO Grants Administration Manual and/or the grant agreement.

Open Access Compliance

As Principal Investigator of this grant, I affirm that I have ensured all publications supported by this grant comply with RGPO, University of California, and State of California "Open Access" policies. Publications issued after grant closure must also comply with these requirements. Please reference the RGPO Grants Administration Manual and/or your grant agreement for these requirements.

Principal Investigator Signature

I certify that the statements herein are true, complete and accurate to the best of my knowledge. I am aware that any false, fictitious, or fraudulent statements or claims may subject me to criminal, civil, or administrative penalties. I agree to accept responsibility for the scientific conduct of the project and to provide the required progress reports if a grant is awarded as a result of this application.

Applicant Electronic Signature (Type in your full legal name)

Adina Paytan

Date

12/27/2024

C&G Officer Signature

I certify that the statements herein are true, complete and accurate to the best of my knowledge. I am aware that any false, fictitious, or fraudulent statements or claims may subject me to criminal, civil, or administrative penalties. I agree to accept responsibility for the scientific conduct of the project and to provide the required progress reports if a grant is awarded as a result of this application.

C&G Officer Electronic Signature (Type in your full legal name)

Nick Theodosis

Date

12/30/2024

C&G Officer Comments

Submitted By: Betsy QuayleNicholas TheodosisVicky BenderJames McAtee

Natural Climate Solutions: Optimal Restoration of Wetlands to Mitigate Damages from Sea-Level Rise

Jonah Danziger

June 6, 2024

Background Climate Change

- ▶ Global temperatures increasing on average causing more severe and frequent natural disasters
- ▶ The result is both people and infrastructure are at risk
- ▶ Increased temperatures and sea-ice melt lead to sea-level rise
- ▶ This leads to property destruction and displacement

Motivation

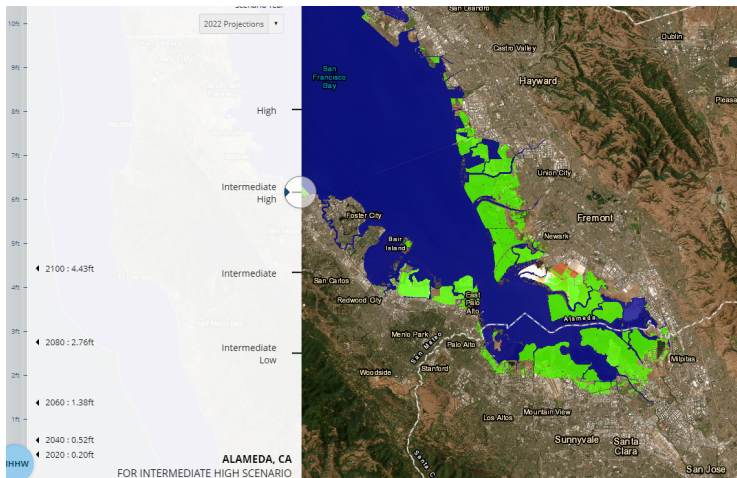


Figure: Sea-level as of 2022
Sources: NOAA

Motivation

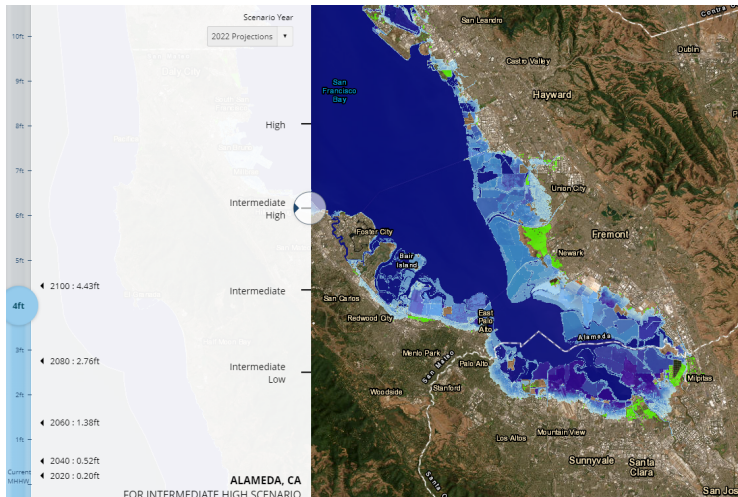


Figure: Sea-level as of 2090
Sources:NOAA

Background - Wetland Ecosystem Services

1. Wetlands protect coastal areas from waves by disrupting the waves energy([Narayan et al., 2016], [Barbier et al., 2008], [Arkema et al., 2013])
2. Act as a barrier against sea level rise, and grow with water depth unlike man-made structures ([Cahoon et al., 2006] [Kirwan and Megonigal, 2013])
3. Carbon sequestration and vital fishery habitat

Question and Contributions

Question : What is the optimal choice of wetland restoration considering future damages from sea-level rise?

Contributions:

1. The first optimal control model of wetlands restoration
2. A vintage capital theory approach to modeling natural resources
3. New insights on how natural climate solutions can contribute to climate change adaptation

Where we are going

- ▶ Optimal Control Model
- ▶ Set-up and Solutions
- ▶ Simulation
- ▶ Next Steps

Model-Planners Problem

$$\begin{aligned} \max_{y(t)} & - \int_0^T e^{-rt} \left[\int_0^t p(t)(\bar{x} - x(t, \alpha)) d\alpha + C(y(t)) \right] dt \quad \text{s.t.} \\ \frac{\partial x(t, \alpha)}{\partial \alpha} &= x(t, \alpha) f(\alpha) \quad \alpha \in [0, t] \quad x(t, 0) = y(t) \quad \lambda(T, \alpha) = 0 \end{aligned}$$

Control: $y(t)$ the amount of wetland to plant

State: $x(t, \alpha)$ The amount of wetland mass in time t at age α

The outer integral with respect to time

$$\max_{y(t)} - \int_0^T e^{-rt} \left[\int_0^t p(t)(\bar{x} - x(t, \alpha)) d\alpha + C(y(t)) \right] dt \quad \text{s.t.}$$
$$\frac{\partial x(t, \alpha)}{\partial \alpha} = x(t, \alpha) f(\alpha) \quad \alpha \in [0, t] \quad x(t, 0) = y(t) \quad \lambda(T, \alpha) = 0$$

- ▶ r is the interest rate
- ▶ A definite integral with T as the final period
- ▶ All the values inside actually take a negative value so the maximize is to reduce damages and costs together

Damage Function

$$\max_{y(t)} - \int_0^T e^{-rt} \left[\int_0^t p(t)(\bar{x} - x(t, \alpha)) d\alpha + C(y(t)) \right] dt \quad \text{s.t.}$$
$$\frac{\partial x(t, \alpha)}{\partial \alpha} = x(t, \alpha) f(\alpha) \quad \alpha \in [0, t] \quad x(t, 0) = y(t) \quad \lambda(T, \alpha) = 0$$

$p(t)$: per unit damages of unrestored wetlands which grows over time rather than staying constant

$(\bar{x} - x(t, \alpha))$: Gap between potential wetlands and restored wetlands

Cost Function

$$\max_{y(t)} - \int_0^T e^{-rt} \left[\int_0^t p(t)(\bar{x} - x(t, \alpha)) d\alpha + C(y(t)) \right] dt \quad \text{s.t.}$$

$$\frac{\partial x(t, \alpha)}{\partial \alpha} = x(t, \alpha) f(\alpha) \quad \alpha \in [0, t] \quad x(t, 0) = y(t) \quad \lambda(T, \alpha) = 0$$

$C(y(t))$: The cost of planting amount $y(t)$

Constraints

$$\max_{y(t)} - \int_0^T e^{-rt} \left[\int_0^t p(t)(\bar{x} - x(t, \alpha)) d\alpha + C(y(t)) \right] dt \quad \text{s.t.}$$

$$\frac{\partial x(t, \alpha)}{\partial \alpha} = x(t, \alpha) f(\alpha) \quad \alpha \in [0, t] \quad x(t, 0) = y(t) \quad \lambda(T, \alpha) = 0$$

$\frac{\partial x(t, \alpha)}{\partial \alpha}$: the mass of wetland at time t that is age α grows by $f(\alpha)$.

An atypical equation of motion reflects the age structure

$f(\alpha)$: the growth rate of wetland of age α

$x(t, 0)$: New wetlands in time t

Hamiltonian Set-Up

We have both the current value and the boundary Hamiltonian because our state has an age structure, but our control does not.

Current Value Hamiltonian

$$\tilde{H}(x, y, \lambda) = -p(t)(\bar{x} - x(t)) + \lambda(\alpha, t)f(\alpha)x(\alpha, t) \quad (1)$$

Boundary Hamiltonian

$$H_0 = -C(y(t)) + \lambda(0, t)y(t) \quad (2)$$

First Order Conditions & Adjoint Equations

$$\frac{\partial \tilde{H}}{\partial y} = 0 \quad \text{FOC} \quad (3)$$

$$\frac{\partial \lambda}{\partial t} + \frac{\partial \lambda}{\partial \alpha} = r\lambda - \frac{\partial \tilde{H}}{\partial x} = -p(t) + \lambda(r - f(\alpha)) \quad (\text{adjoint equation}) \quad (4)$$

$$\frac{\partial H_0}{\partial y} = 0 = -C'(y(t)) + \lambda(t, 0) \quad \text{Boundary FOC} \quad (5)$$

Solutions

$$\lambda(t, \alpha) = \int_t^T e^{-r(s-t)} e^{\int_t^s f(\alpha + \rho - t) d\rho} p(s) ds \quad (6)$$

$$C'(y(t)) = \int_t^T e^{-r(s-t)} e^{\int_t^s f(\rho - t) d\rho} p(s) ds \quad (7)$$

$$x(t, \alpha) = y(t) e^{\int_0^\alpha f(\rho) d\rho} \quad (8)$$

Motivation

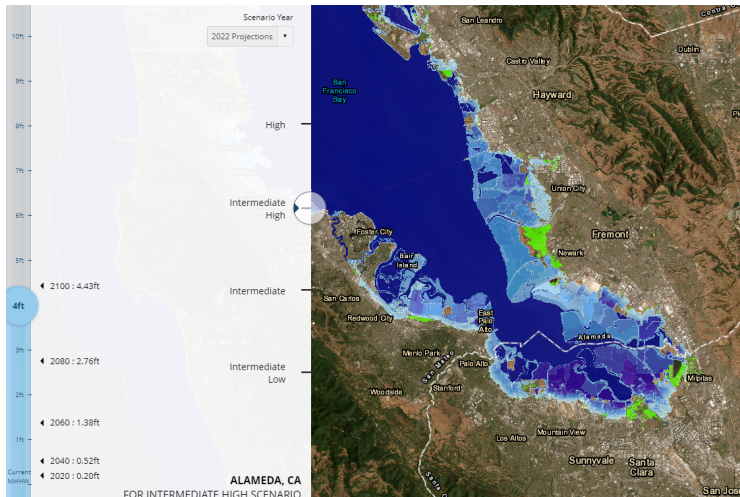


Figure: Sea-level as of 2090
 Sources:NOAA

Deterministic Simulation

1. Cost function estimated using data from Taillardat et al. [2020]
2. Estimate our damage function using NOAA sea-level estimates and Redfin real estate data
3. Use a typical growth function from literature

Deterministic Simulation

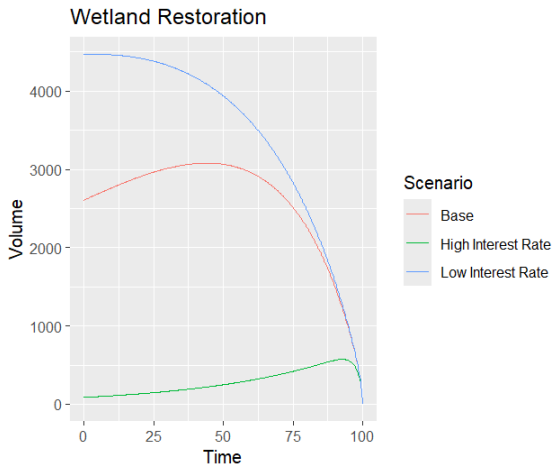


Figure: Wetland Simulations Over 100 Year period

Next Steps

1. Pin down the damage function and how wetlands reduce damages
2. Include uncertainty from storms and flooding
3. Begin writing the paper

Appendix

Method of Characteristics

$$\frac{\partial \lambda(\alpha, t)}{\partial t} * \frac{\partial t}{\partial s} + \frac{\partial \lambda(\alpha, t)}{\partial \alpha} * \frac{\partial \alpha}{\partial s} = \frac{\partial \lambda(\alpha, t)}{\partial s}$$

Then if we solve for ds for each part and set them equal we have

$$\frac{\partial t}{1} = \frac{\partial \alpha}{1} = \frac{\partial \lambda}{-p(t) + \lambda(r - f(\alpha))}$$

Frame Title

Now we can also recover $x(t, \alpha)$

$$\frac{\partial x(t, \alpha)}{\partial \alpha} = x(t, \alpha) f(\alpha)$$

$$\frac{\frac{\partial x(t, \alpha)}{\partial \alpha}}{x(t, \alpha)} = f(\alpha)$$

$$\ln(x(t, s))|_0^\alpha = \int_0^\alpha f(\rho) d\rho$$

$$\ln(x(t, \alpha)) - \ln(x(t, 0)) = \int_0^\alpha f(\rho) d\rho$$

$$\ln(x(t, \alpha)) = \ln(x(t, 0)) + \int_0^\alpha f(\rho) d\rho$$

$$x(t, \alpha) = x(t, 0) e^{\int_0^\alpha f(\rho) d\rho}$$

Deterministic Simulation

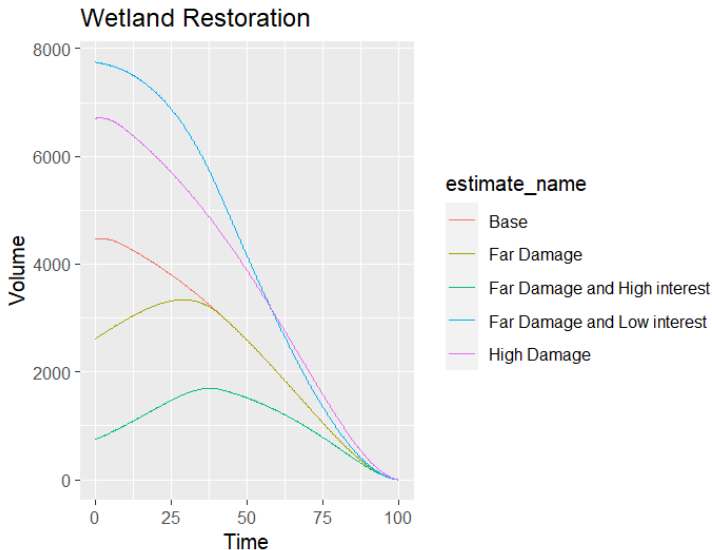


Figure: Wetland Simulations Over 100 Year period

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- Taillardat, P., Thompson, B. S., Garneau, M., Trottier, K., and
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wetlands and the cost-effectiveness of their restoration. *Interface
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Economics of Wetlands Protection



Prof. Galina Hale
Economics and Coastal
Science and Policy

KEY \$\$\$UE #1: who is to pay?

High capital cost
upfront

Costs are well-
defined and highly
concentrated

Pillar Point Harbor West Trail



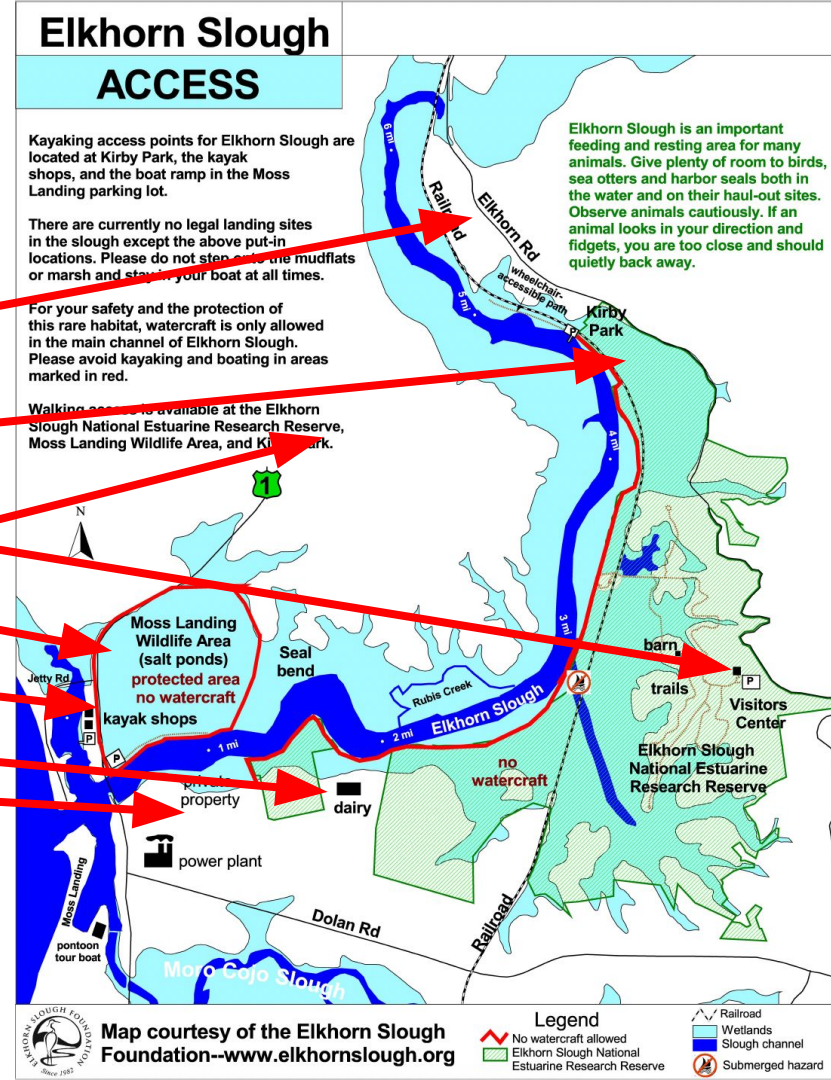
KEY \$\$\$UE: who is to pay?

Benefits are very dispersed

- Public infrastructure
- Community access
- Nature (ecosystem)
- Business
- Farming
- Private housing

.. and more ...

***Jobs: protected and created by the projects
- additional benefit to the community***







**This is a classic “free-rider” /
coordination problem**

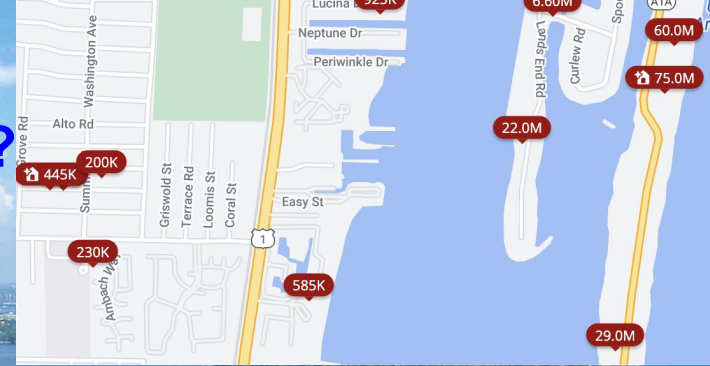
**Resulting in insufficient investment in
such projects**

KEY ISSUE #2: how to measure benefits?

Market values of assets at risk that NBS are protecting are

- Easy to observe, but
- Do not measure actual social benefits of NBS

E.g. costs of flood: relocation, rebuilding - higher costs for lower-income (=> lower market price) areas

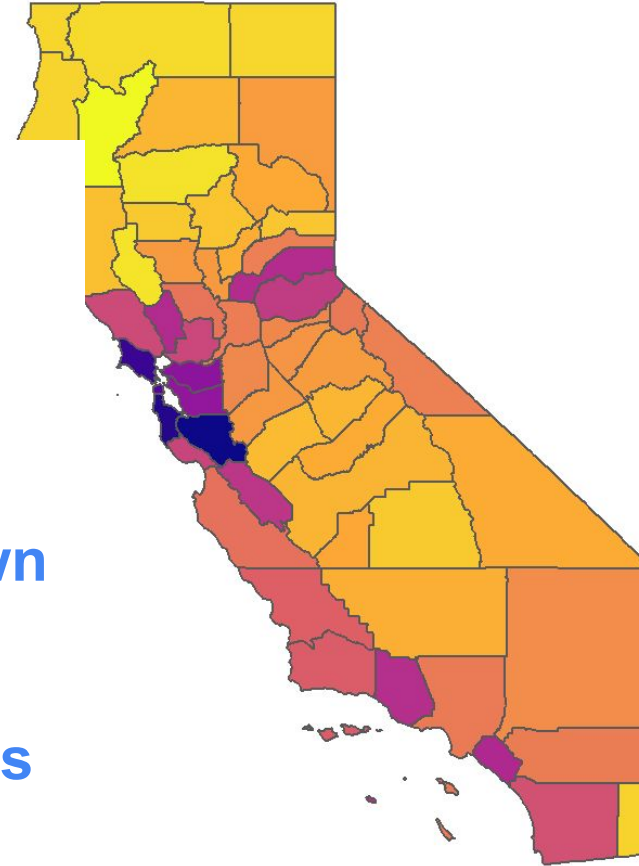




**We need a unified methodology of
measuring social benefits**

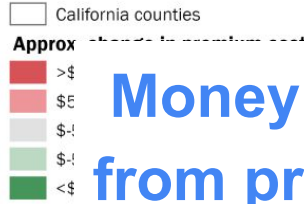
To all stakeholders

Median Income by County in California



Source: American Communities

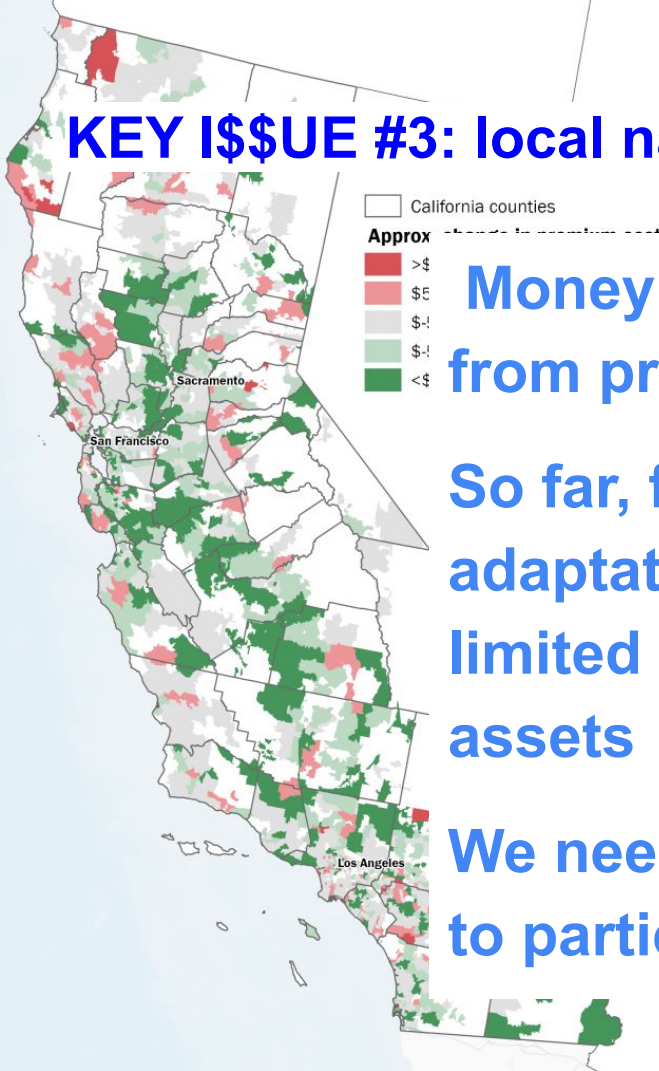
KEY ISSUE #3: local nature of the projects



Money location is different from project location

So far, financial institutions' adaptation investment is limited to protecting their own assets

We need financial institutions to participate more broadly



Carolina will provide details



Microbial Communities Driving Carbon Sequestration in Coastal Estuarine Wetlands



Leah Van Dyke



Research Plans:

I will study microbial processes in representative coastal wetlands using quantitative **Stable-Isotope Probing (qSIP)**, and genetic analysis to assess their role in net carbon sequestration.

I plan to use **quantitative Stable-Isotope Probing (qSIP)**, in collaboration with **LLNL** to link specific microbial taxa with changes in carbon sequestration efficiency of wetland soils.

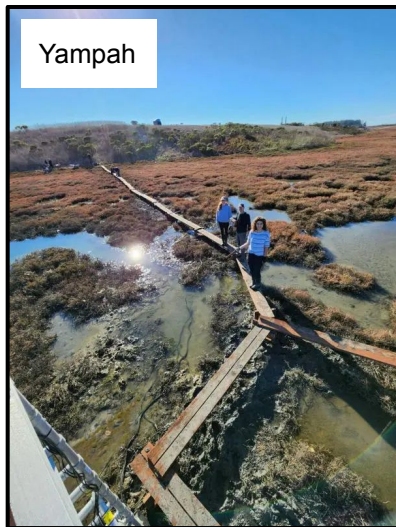
I will use **molecular genomics and microscopy approaches** to identify and characterize the specific microbial taxa driving carbon cycling through wetland soils in collaboration with Dr. Buck Hanson at **LANL**.

Samples will be taken from five representative wetland environments at the Elkhorn Slough National Estuarine Reserve with varying amounts of plant cover, tidal inundation, and soil properties (including pristine and restored sites) to better understand how differences in environmental conditions impact microbial community structure and function.

Hester



Yampah

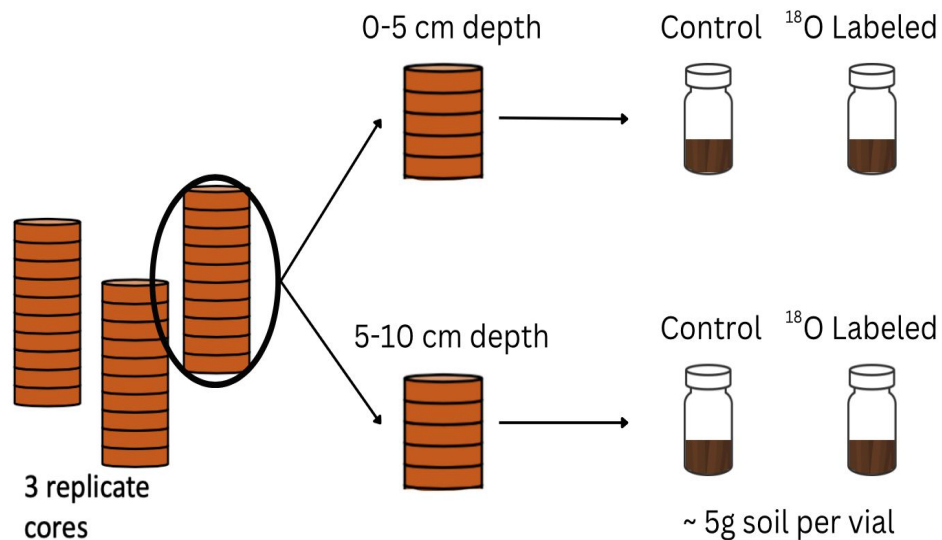
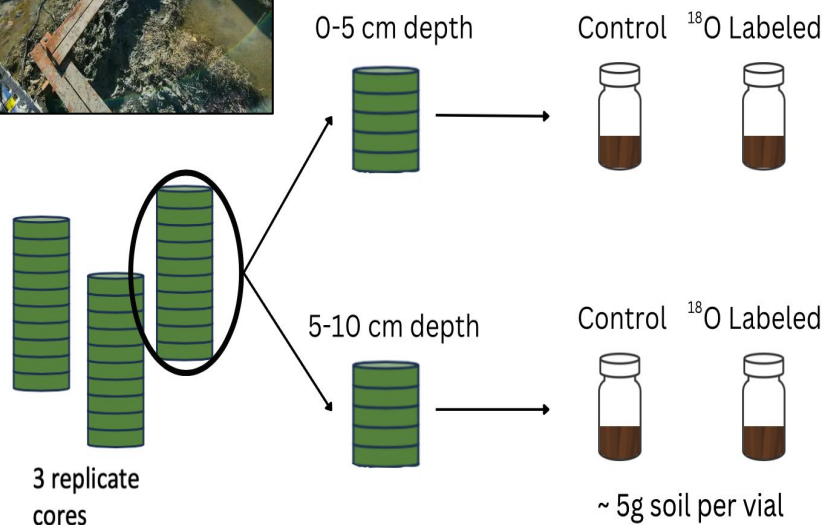


Yampah



Sampling Sites

Hester

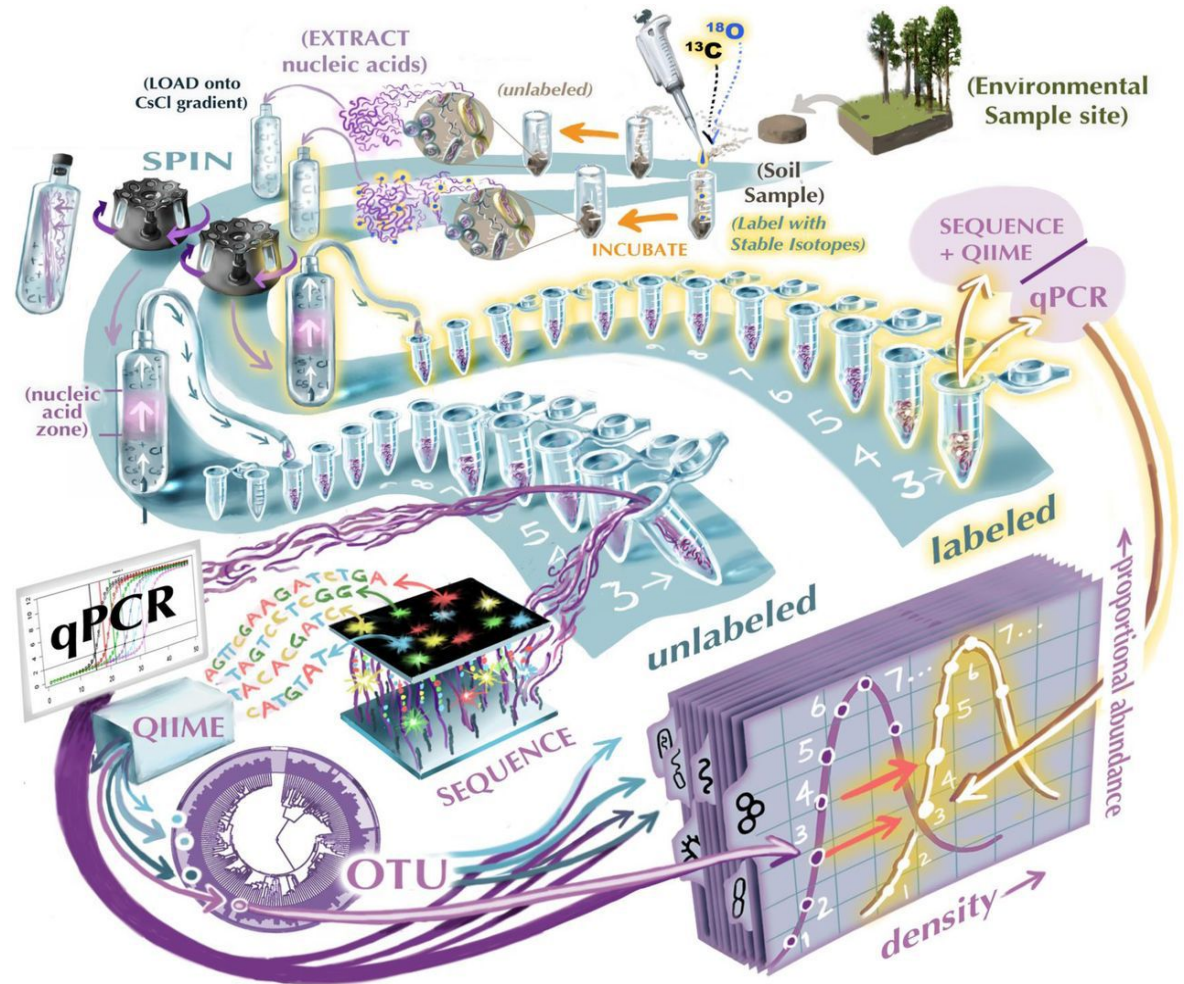


qSIP

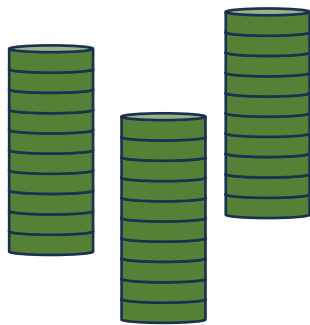
Sediment cores have been taken in the summer dry season, and I will be taking additional samples in the winter wet season from **Hester and Yampa**.

Samples were transferred to air-tight wheaton vial, and immediately processed in the laboratory at UCSC using **isotope spikes**.

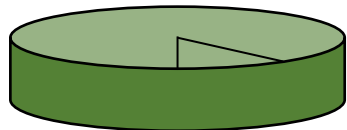
Samples of these sediment cores were supplemented with normal (control) or heavy isotope water H_2O^{18} (**qSIP**) and subjected to a DNA extraction technique that **factors in the weight of DNA and phylogenetic identity** as identified through the 16S rRNA.



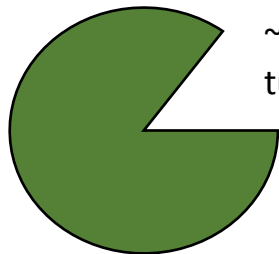
Yampah



3 replicate
cores



~10 sections per core
(or whatever seems
reasonable in the
field), section depth
should be consistent
or noted



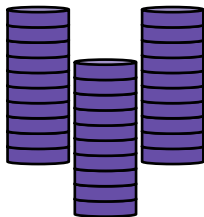
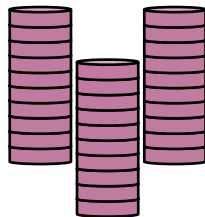
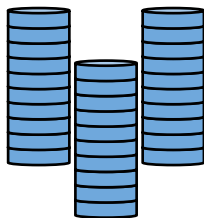
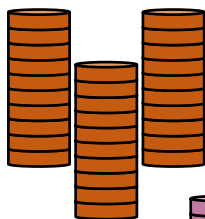
~1/8th or 1-2 g (or whatever fits in a 2 ml
tube)



Bring empty, pre-labeled tubes
Flash freeze sample in the field in lq. N₂
or if lq N₂ is not available, put on dry ice in the field,
or put on ice in the field, flash freeze when possible
Store @ -80C

Used for nucleic
acid analyses

Hester, North, Porter, and Castroville



Bring pre-labeled tubes containing 0.5 ml of 4% formaldehyde
Aliquot a small amount of sediment (~0.1 g or a cap full)
within 24 h, centrifuge (4C) to pellet.
remove sup., resuspend in 1 ml 1X PBS.
Centrifuge to pellet
remove sup.
resuspend in 0.5 ml 50% ethanol:1XPBS.
Store @ -20C

Used for microscopic
imaging

Research Plans:

I will study microbial processes in representative coastal wetlands using quantitative **Stable-Isotope Probing (qSIP)**, and genetic analysis to assess their role in net carbon sequestration.

I plan to use **quantitative Stable-Isotope Probing (qSIP)**, in collaboration with **LLNL** to link specific microbial taxa with changes in carbon sequestration efficiency of wetland soils.

I will use **molecular genomics and microscopy approaches** to identify and characterize the specific microbial taxa driving carbon cycling through wetland soils in collaboration with Dr. Buck Hanson at **LANL**.

Samples will be taken from five representative wetland environments at the Elkhorn Slough National Estuarine Reserve with varying amounts of plant cover, tidal inundation, and soil properties (including pristine and restored sites) to better understand how differences in environmental conditions impact microbial community structure and function.

Upcoming Work:

By identifying **which microbial taxa are most active in soils across representative sampling sites** of varying soil properties, vegetative cover, and pore saturation, I can better inform wetland restoration projects that aim to **maximize soil productivity** and **carbon sequestration abilities** in response to wetland loss and sea level rise.

This summer:

- I will be going to LANL from August to the End of September to analyze the recent summer dry season samples.
- I will be going to LLNL this summer to run the qSIP pipeline, and will soon learn how to use the necessary software to analyze the data.

Thank you!

Microbiology Results

Progress by microbiology team at LLNL in collaboration with the Paytan lab at UCSC has continued baseline characterizations of microbial communities at Elkhorn Slough. Microbes are the primary drivers of elemental fluxes and GHG dynamics and work is providing insights into how intact versus restored wetland sites (Yampah and Hester, respectively) align and diverge in terms of biomass composition of bacteria that predominantly catalyze GHG production and microalgae (or phytoplankton) that photosynthesize and thus may be considered a sink for CO₂. In 2022, we collected sediment cores and extracted DNA from the top 5 cm qSIP analyses, which reveals which microbes are active at high taxonomic resolution. A total of 242 samples, or fractions, were sent for sequencing and are currently being analyzed to identify the bacterial (16S amplicon sequences) and eukaryotic (18S, algal amplicon sequences) communities that comprise the intact and restored wetlands. Preliminary analyses of the bacteria data show differences in guanine-cytosine content of DNA within biomass fractions of the intact versus restored sites (Figure 1). We anticipate this differences becoming more pronounced as we assess the isotopic composition of the fractions and compare the relative abundances of 16S sequences.

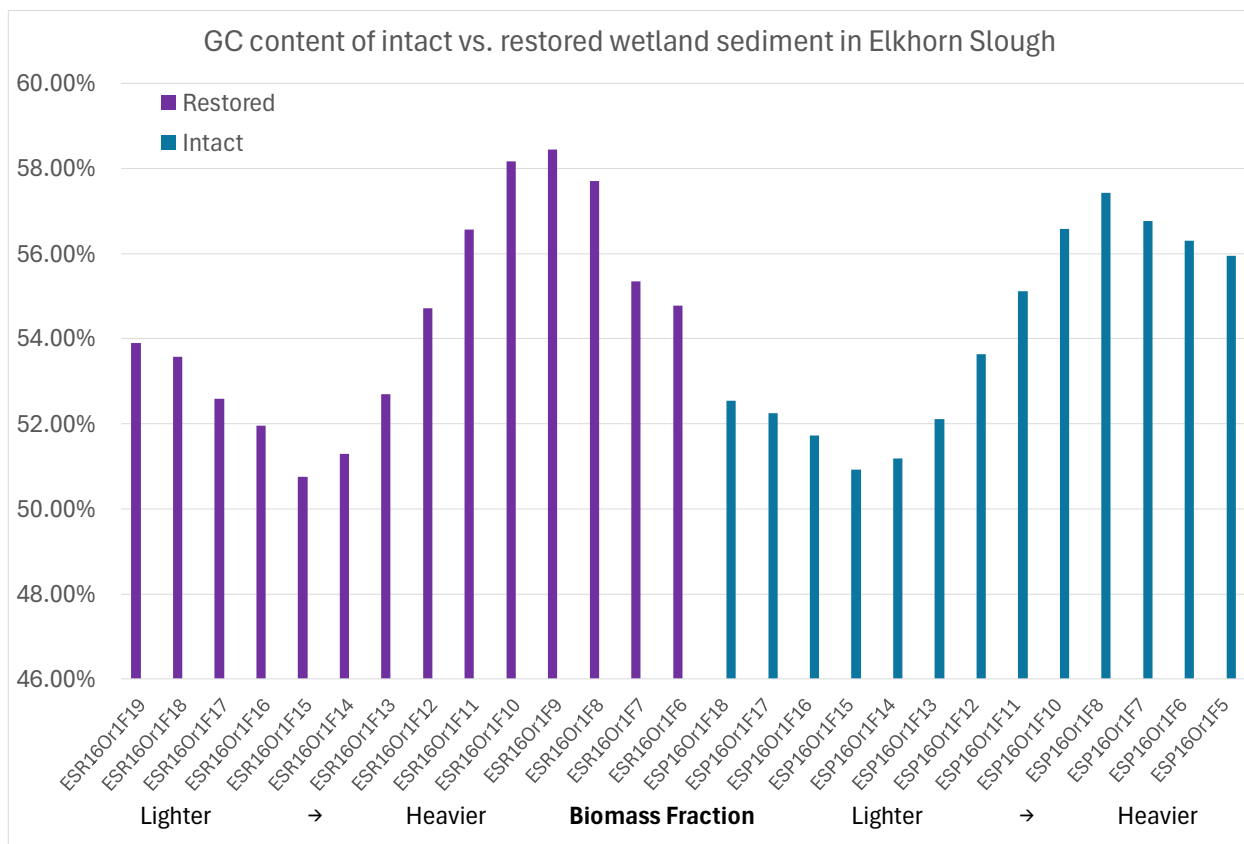


Figure 1. GC content differences observed between biomass fractions of the intact and restored wetland sites at Elkhorn Slough indicate that these microbial communities are significantly different from one another and are likely cycling organic matter differently.

In 2024, we sample these sites again and incubated the samples under light vs. no light to more accurately capture environmental photon flux and impacts on bacterial and phytoplankton activity and community composition. These samples are currently being processed, but we performed quantitative microscopy analyses of the samples for comparison to 2022. We found that phytoplankton had appeared in the restored sample, whereas there were none in 2022. This result is notable since it corroborates eddy covariance data showing CO₂ drawdown at Hester site. Meanwhile, the intact continued to exhibit high biomass of both bacteria and phytoplankton (Figure 2).

A continuing goal of the project will be to assess the degree to which phytoplankton presence and/or high microbial biomass represents a hallmark of a well-functioning wetland. In this vein, we will continue working with project colleagues to connect observations across spatial scales. The set of samples currently being extracted for DNA sequencing and microbial community analyses will be critical to this goal as we examine the influence of illumination on microbial metabolism and resulting GHG dynamics.

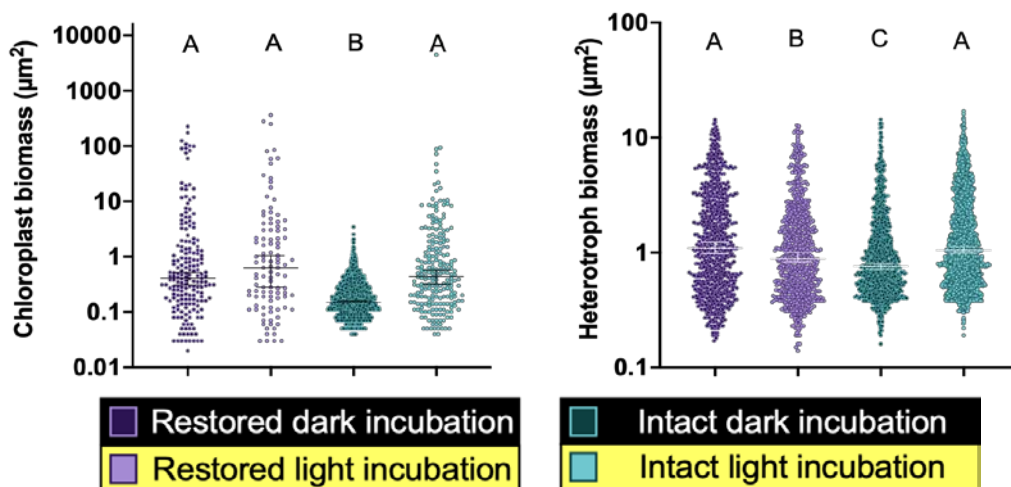
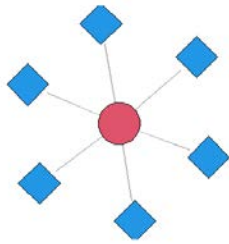


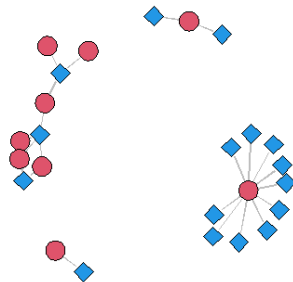
Figure 2. Microscopy revealed the appearance of phytoplankton in the restored site, which was not seen in 2022. Single-cell biomass of phytoplankton decreased in the light in both site. Bacterial heterotrophs biomass increased in darkness within the restored site while decreasing in the intact site.

Governance Results

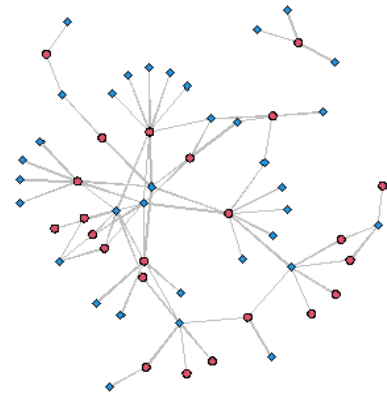
1. Figures of Updated Project-Organization Network Analysis (New TERGM Network Time Steps, Additional Analysis of Organization Degree)



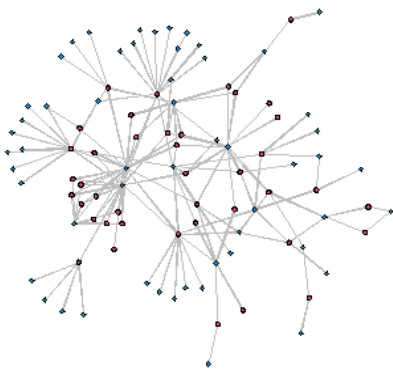
1982-1987



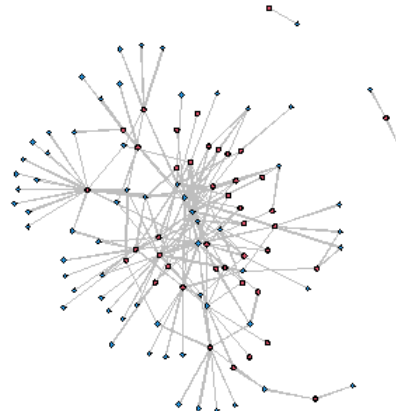
1988-1993



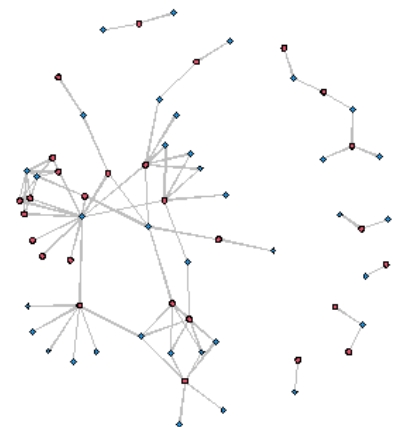
1994-1999



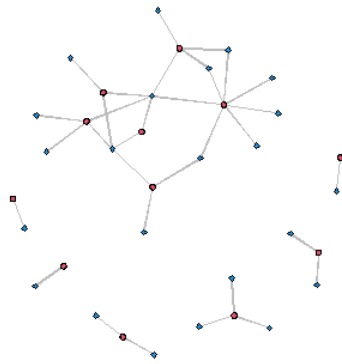
2000-2005



2006-2011



2012-2017



2018-2023

Figure shows the 7 time steps of the updated project-organization network used in current TERGM analysis (from new EcoAtlas data from June 2024)

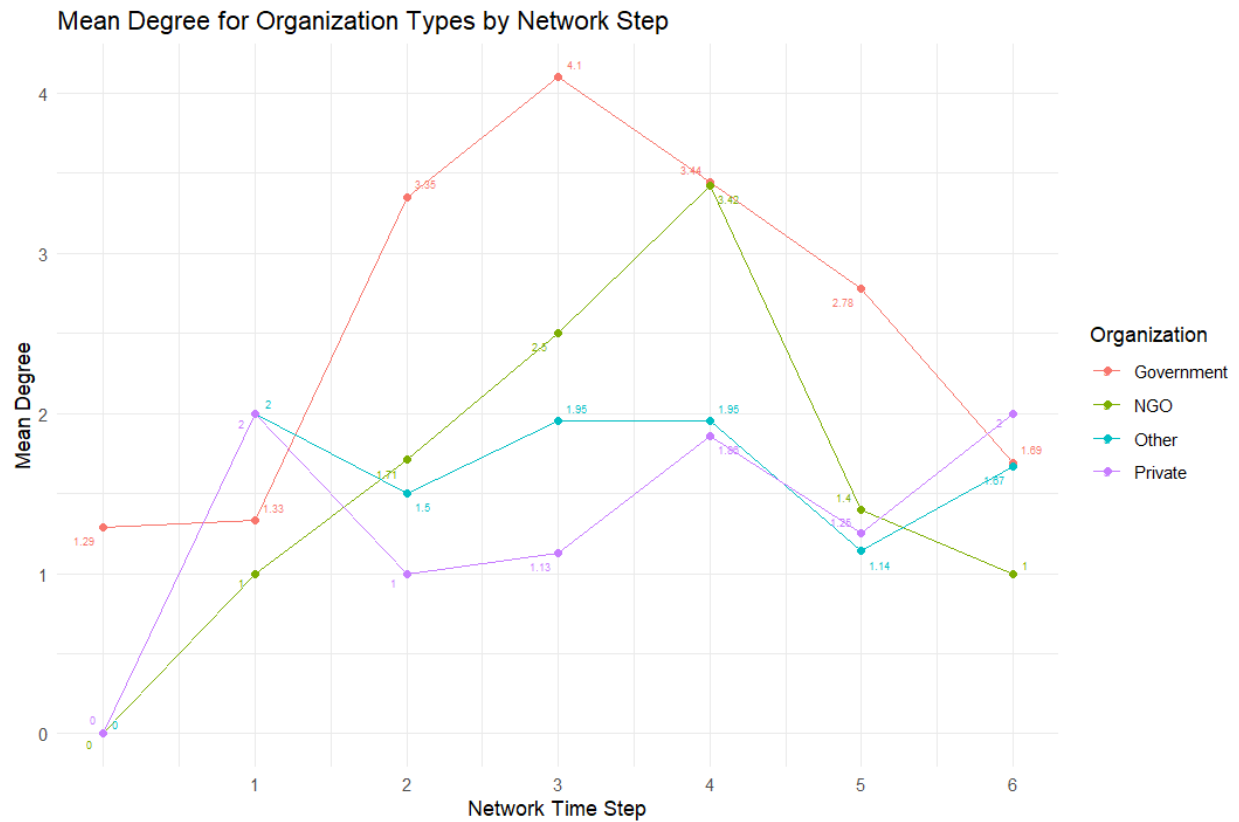


Figure shows the average degree for organizations of different types at each time step of the network used in TERGM analysis.

2. Figures of New Ecosystem Services Coding Analysis of EcoAtlas Project Descriptions (Totals of Coded Services, Correlations of Service Co-Occurrence within Projects)

Wetland Restoration Project Goals

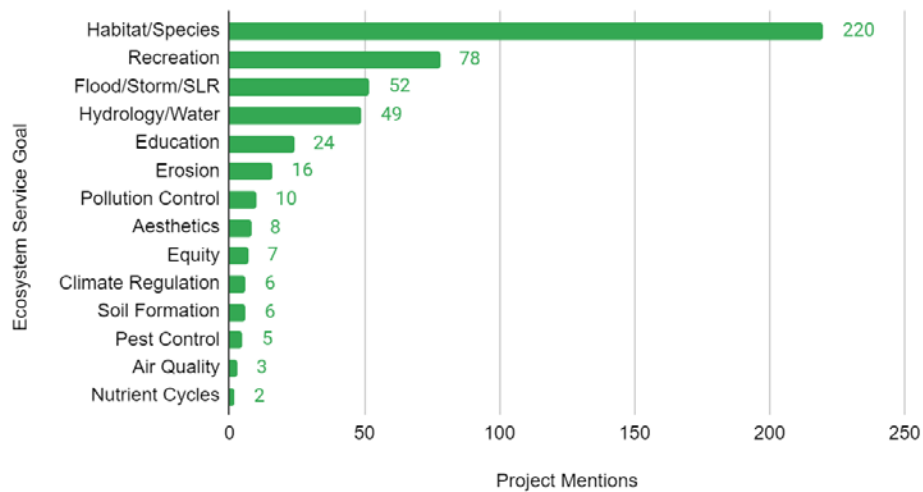


Figure shows results of ecosystem service mentions in the project descriptions of 225 Bay-Delta wetland restoration projects from the EcoAtlas database, ecosystem service categories originate from de Groot et al. (2018)

3. Completed Interviews As of November 5, 2024 (47 total)

Case Study	Total Interviews	Organization Type (Totals)	Roles (Totals)
Dutch Slough Tidal Marsh	5 (5)	State Government (2) Private Consultants (3)	Project Manager (2) Engineer (2) Planner (1)
Giacomini Wetlands	5 (5)	Federal Government (2) Private Consultant (2) Nonprofit (1)	Project Manager (2) Executive Director (1) Construction Manager (1) Hydrologist (1)
SAFER Bay	3 (4)	Regional Government (1) Nonprofit (2)	Community Engagement (2) Project Management (1) Director (1)
Sears Point	4 (4)	State Government (1) Federal Government (1) Nonprofit (2)	Designer/Engineer (1) Project Manager (2) Scientist (1)
Sherman Island	3 (3)	State Government (1) Regional Government (1) Education/Research (1)	Project Manager (1) Scientist (1) General Manager (1)
South Bay Salt Ponds	5 (5)	State Government (3) Regional Government (1) Science/Research (1)	Project Manager (4) Scientist (1)
Tule Red/ Suisun Marsh	4 (4)	State Government (2) Private Consultant (1) Regional Government (1)	Project Manager (2) Construction/Land Ownership (1) Land Stewardship (1)
Twitchell Island	4 (4)	State Government (2) Private Consultant (2)	Project Manager (2) Hydrologist (1) Engineer (1)
Additional Case Study: Elkhorn Slough	1 (2)	Nonprofit (1) State Government (1)	Executive Director (1) Scientist/Land Manager (1)
Regional Interviews	13 (14)	State Government (3) Nonprofit (2) Local/Regional Government (6) Partnership (2)	Director (3) Project Manager (5) Coordinator/Program Manager (3) Funding Manager (2) Politician (1)

4. Summary Figure of Barriers to Restoration from Initial Interview Analysis (42 interviews as of Spring 2024)

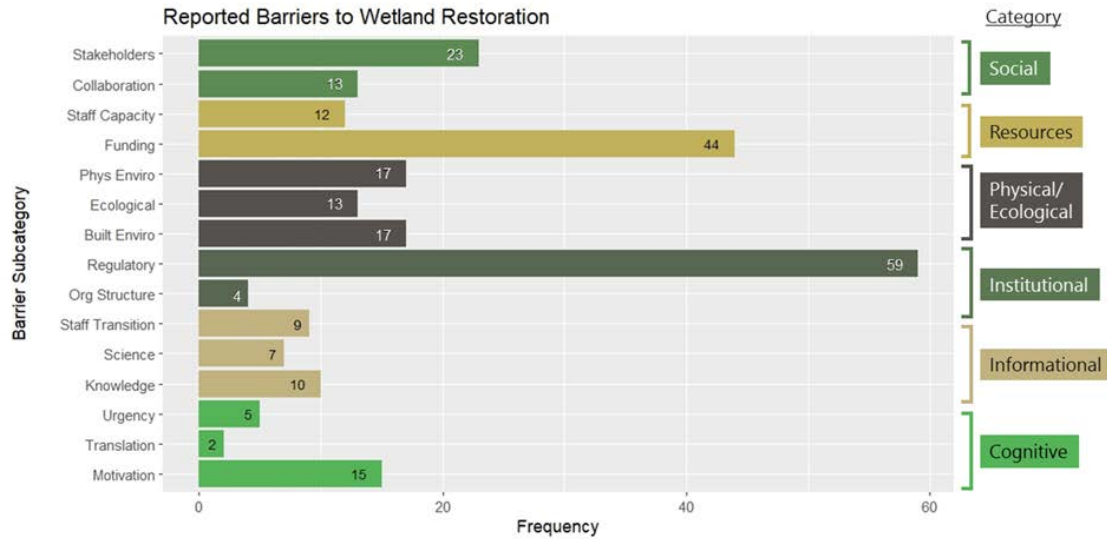


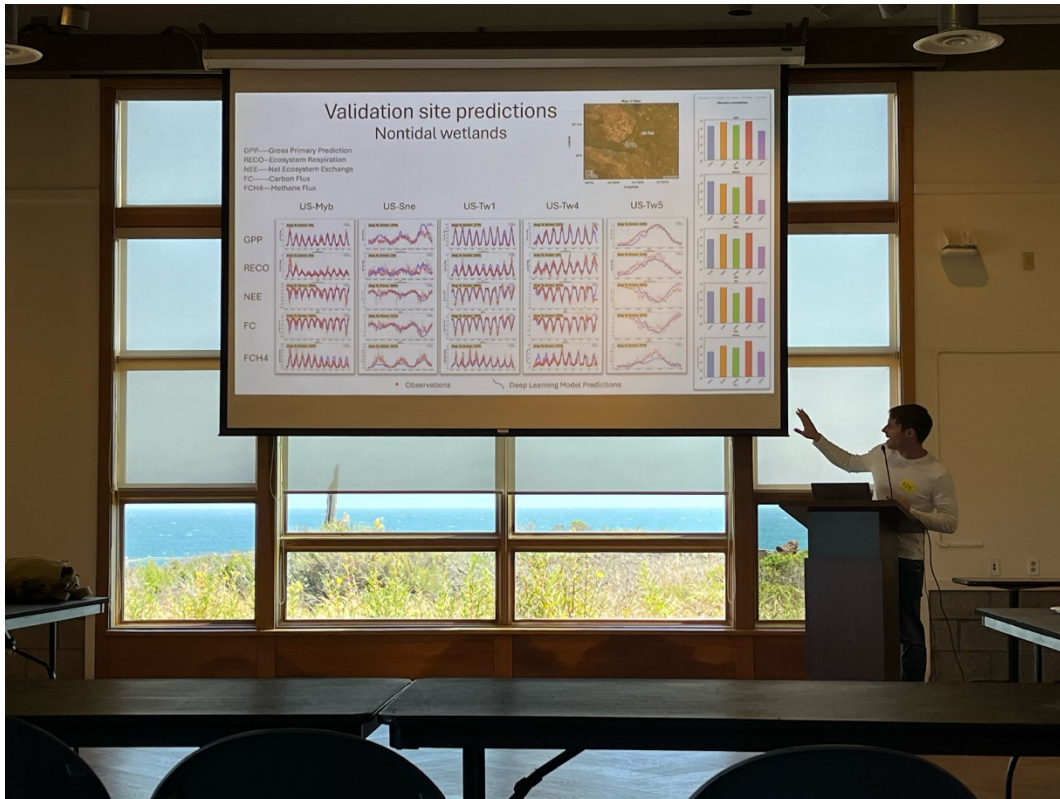
Figure shows mentions of different barriers to wetland restoration by the 42 interview participants as of Spring 2024, using categories developed from Biesbroek et al. 2014.

Annual Meeting June 2024 Schedule

Time	Activity/Presentation	Contacts	Location and Presentation Title
9:30am	Coffee and Scones	Adina	Seymour Center Santa Cruz
10:00 AM	EJ	Jessica Garrison	Defining (and diffusing) tensions between climate mitigation, adaptation, and justice
	Ecosystem Services	Katy Seto	Updates on work at UCSC
10:30 AM	Economics	Andrew Platinga	Natural Climate Solutions: Optimal Restoration of Wetlands to Mitigate Damages from Sea-Level Rise
	Economics	Robert Shortt	Levee Stability in the Delta with Changing Land Use
11:00 AM	Economics	Galina and Carolina	Wetland ecosystem services valuation in CA
	Carbon Markets	Barbara Haya	"Wetland Restoration Offsets: Summary of Existing Programs and Our Research Plan to Study Their Effectiveness
11:30 AM	Governance	Kyra, Mark, Gwen	"Governance in Bay-Delta Wetland Restoration: Understanding Collaboration, Investment, and Implementation".
12:00 AM	SCCWRP	Jan Walker	Monitoring for management: Leveraging regional efforts to assess estuarine condition
12:10 PM	CCWG	Ross and Kevin	Linking estuarine rapid condition assessments, marsh plain dynamics, and sediment carbon sequestration
12:20	SFEI	Dan Killam	The Nutrient-pH nexus: Building an estuarine acidification monitoring program in SF Bay
12:30	Lunch (work groups)		
1:30 PM	Delta	Dennis	The carbon balance in Delta wetlands
2:00 PM	Edan and Suisan	Jessica /Emilio/Patty	Carbon dynamics at Eden and Rush
2:30 PM	Elkhorn	Adina	Net Ecosystem Carbon Balance at Elkhorn Slough
3:00 PM	Modeling	Yi (Yu, David)	Investigate the impacts of coastal wetland restoration on the hydrologic processes in Elkhorn Slough watershed
	Upscaling using AI	Ash, Zelalem, Bhavna)	Modelling wetland carbon fluxes using a deep learning approach
3:30 PM	Microbiology	Buck/Ty/Rhona/Leah	Microbial processes in wetland soils
4:00 PM	Flash Talks	Students	Susan, Leah, Irene, Kim, Natalie, Aliya
4:30 PM	Drinks Exhibit Hall		
6:00 PM	Dinner	Copal	6:15 two tables
June 22, 9:30am	Field Trip	Adina	Ano Nuevo Elephant Seals tour

Annual Meeting June 2024 Photos







Presentations in Conferences by Group Members

Brereton, A., Arora, B., Mekonnen, Z., Riley, W., Xu, Y., Yuan, K., Zhang, Y., Paytan, A. "The Regional Carbon and Climate Analytics Tool (RCCAT): A Deep-Learning Model to Predict Carbon Sequestration Potential and Greenhouse Gas Emissions." This presentation discussed the development of RCCAT, a deep-learning model designed to predict the carbon sequestration potential and greenhouse gas emissions in the bay-delta region. 2024 Bay-Delta Science Conference in Sacramento

Xu, Y., Zhang, Y., Moulton, D., Mekonnen, Z., Arora, B., Paytan, A. "Interaction between Coastal Wetland Restoration and Hydrological Processes." This presentation explored the interactions between coastal wetland restoration initiatives and regional hydrological processes in the bay-delta. 2024 Bay-Delta Science Conference in Sacramento

[Ocean Negative Carbon Emission Approaches for Mitigating Climate Change: Mechanisms, Practices, and Governance II Oral](#) C Zhang, K Maiti, A Paytan AGU24

[Ecoengineering Approaches for Marine Carbon Dioxide Removal \(mCDR\): Strategies and Challenges](#) C Zhang, N Jiao, SJ Giovannoni, K Maiti, A Paytan, K Ramakrishna, ... AGU24

[Periodicity in Methane Emissions from a Restored Freshwater Wetland](#) R Shortt, DD Baldocchi, JG Verfaillie, DJ Szutu AGU24

[Methane Flux Heterogeneity and Driving Mechanisms in Wetland Ecosystems](#) I Okiti, A Arias-Ortiz, R Shortt, E Gamez, K Delwiche, C Wang, A Ahmadi, ... EGU24

[Coupled high-frequency sensor network explains nutrient transport and subsurface hydrologic interactions at the coastal-terrestrial interface](#) M Esqueda, E Grande, PY Oikawa AGU24

[PEPRMT-LF model development](#) KD Kroeger, PY Oikawa AGU24

[A Process-Based Modeling Approach to Estimating Net Ecosystem Carbon Balance in Tidal Wetlands](#) I Amitay, E Gamez, J Silberman, M Matsumura, J Shahan, ... AGU24

[The California Soil Carbon Accrual Project: Impacts on Carbon and Water Cycle](#) A Singh, J Knowles, P Oikawa, J Brimlow, GC Liles, S Matiassek, L Smith, ... ASA, CSSA, SSSA International Annual Meeting

[Methane Flux Heterogeneity and Driving Mechanisms in Wetland Ecosystems](#) I Okiti, A Arias-Ortiz, R Shortt, E Gamez, K Delwiche, C Wang, A Ahmadi, ... EGU24

Presentations by Gmoser-Daskalakis, K., Lubell, M., & Arnold, G

- "Collaboration for Wetland Restoration in the California Bay-Delta: A Historical Network Approach". Oral Presentation. UC Davis Graduate Group in Ecology Student Symposium. February 2, 2024.
- "Collaborative Wetland Restoration Implementation in the Bay and Delta: A Comparative Case Study Approach". Academic Poster Presentation. UC Davis Graduate Studies Interdisciplinary Research Exhibition. April 11, 2024.

- “Collaborative Wetland Restoration Implementation in the Bay and Delta: A Comparative Case Study Approach”. UC Davis Symposium on the Agricultural, Environmental and Human Sciences. May 1, 2024.
- “Collaborative Wetland Restoration Implementation in the Bay and Delta: A Comparative Case Study Approach”. State of the Estuary Conference. March 12-13, 2024.
- “Collaborative Barriers, Opportunities and Outcomes in Wetland Restoration: A Comparative Case Study Approach in the San Francisco Bay-Sacramento San Joaquin Delta”. Conference Paper Session. 81st Annual Midwest Political Science Association Conference. April 4, 2024.
- “Collaborative Barriers, Opportunities and Outcomes in Wetland Restoration: A Comparative Case Study Approach in the San Francisco Bay-Sacramento San Joaquin Delta”.
- “Collaborative Barriers, Opportunities and Outcomes in Wetland Restoration: A Comparative Case Study Approach in the San Francisco Bay-Sacramento San Joaquin Delta”. Conference Paper Session. Conference on Policy Process Research 2024. May 14-16, 2024.
- “Collaborative Barriers, Opportunities and Outcomes in Wetland Restoration: A Comparative Case Study Approach in the San Francisco Bay-Sacramento San Joaquin Delta”. Conference Paper Session. European Consortium on Political Research 2024. August 15, 2024.
- “Collaboration for Wetland Restoration in the California Bay-Delta: A Historical Network Approach”. Oral Presentation. Bay-Delta Science Conference. October 2, 2024.

[Modeling Marsh Migration on the US East Coast: Do the Goals of Scientists Align with the Needs of Coastal Decisionmakers?](#) A Stoltz, D Kotowicz, EE Lentz 2024 Ocean Sciences Meeting

[Large-Scale Carbon Dioxide Removal: Potentials, Considerations, and Challenges I](#) eLightning D Fairbanks, C Averill, J Pett-Ridge, A Mayer AGU24

[Testing the potential of ERW in California working lands: challenges and opportunities](#) R Schmidt, IP Montanez, A T O'Geen, S Whiteaker, N Sokol, J Pett-Ridge, AGU24

[Enhanced Weathering for Soil-Based Carbon Dioxide Removal: Potential and Challenges II](#) Oral J Pett-Ridge, D Maxbauer, IP Montanez, N Planavsky, E Milliken AGU24

[Who, Where and When: How Microbial Ecophysiology Shapes Persistence of Organic Carbon in Soil's Many Habitats](#) J Pett-Ridge, ASA, CSSA, SSSA International Annual Meeting

[Soil Organic Carbon Sequestration \(SOC\) Storage, Distribution, and Dynamics in Perennial Bioenergy Cropping Systems Compared to Corn](#) M Dolui, AC von Haden, J Mulcrone, K Estera-Molina, K McFarlane, ... ASA, CSSA, SSSA International Annual Meeting 2024



Dutch Slough and Other Wetlands: How We Can Influence GHG Fluxes

The UCB Biomet Lab

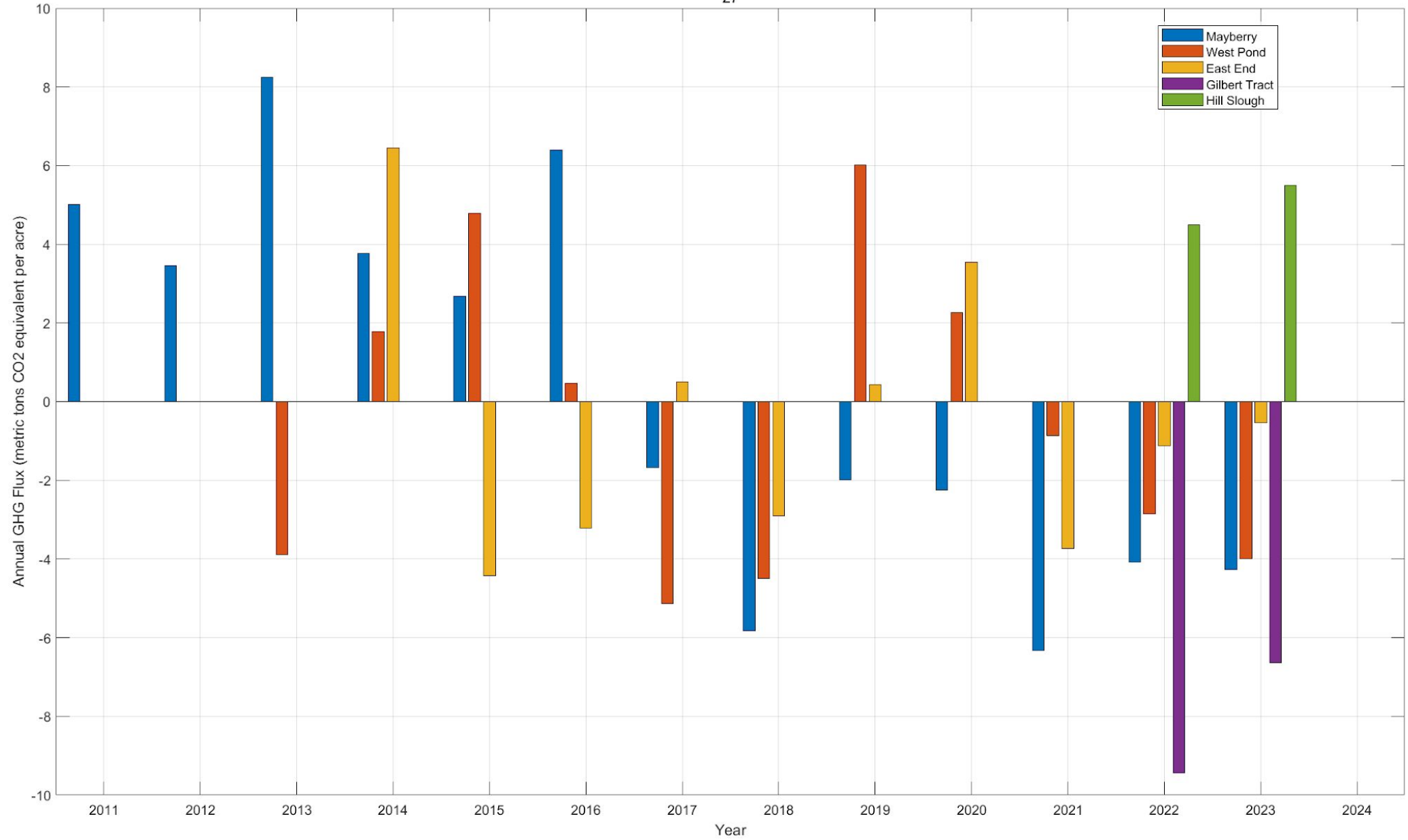


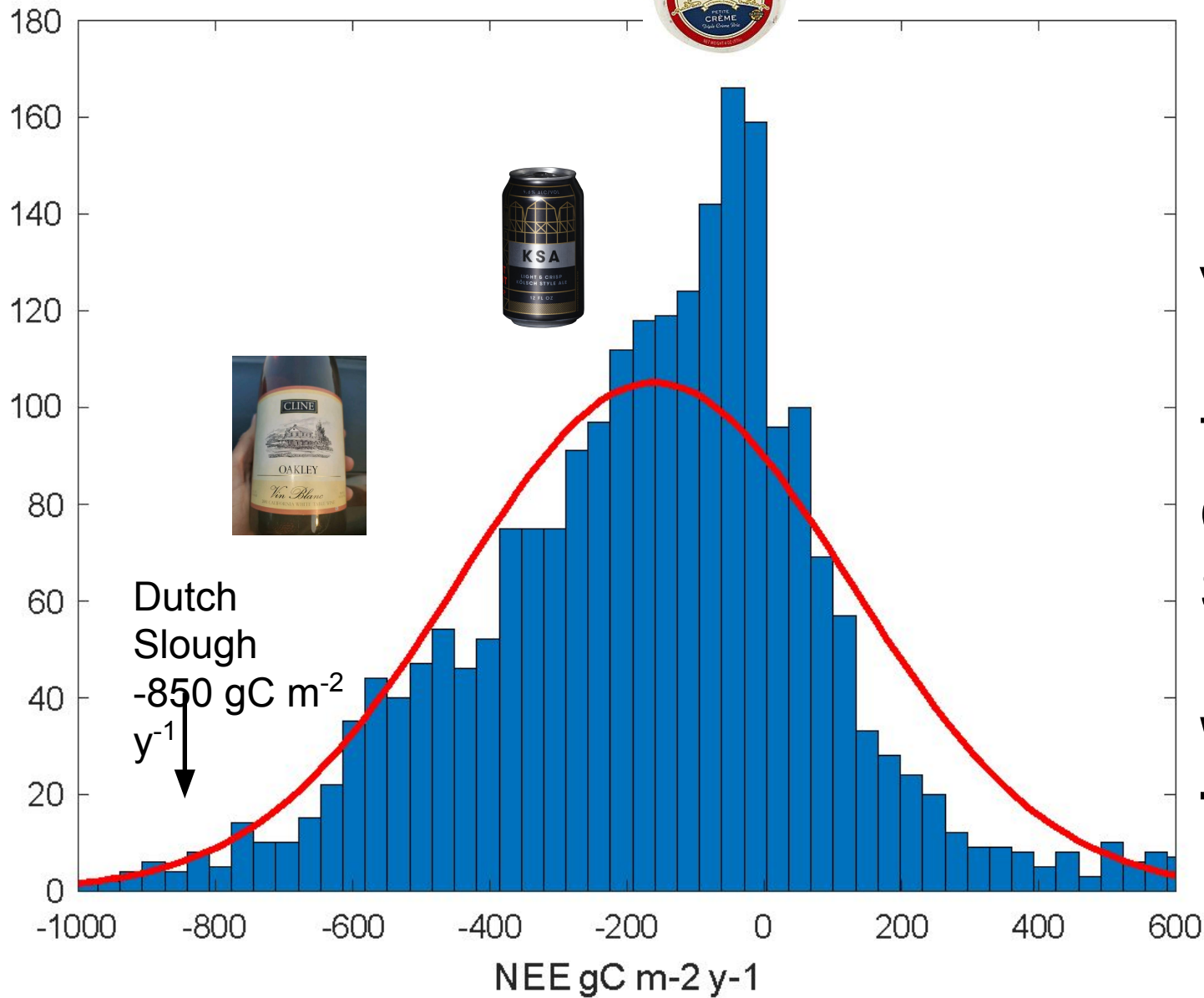
Why Optimize Wetland GHG Balance?

- Wetlands are a powerful climate adaptation tool with co-benefits
 - If being used to adapt, they should also be leveraged to mitigate
- Freshwater Wetlands have a tradeoff between CO₂ and CH₄
 - Reducing CH₄ emissions improves GHG balance
 - Increasing productivity and reducing soil respiration also accretes soil
- Wetlands bury CO₂ for a long time (1,000s of years)
 - Even with relatively large CH₄ contributions they are strong GHG sinks over decades to centuries.

Annual GHG Flux by Site

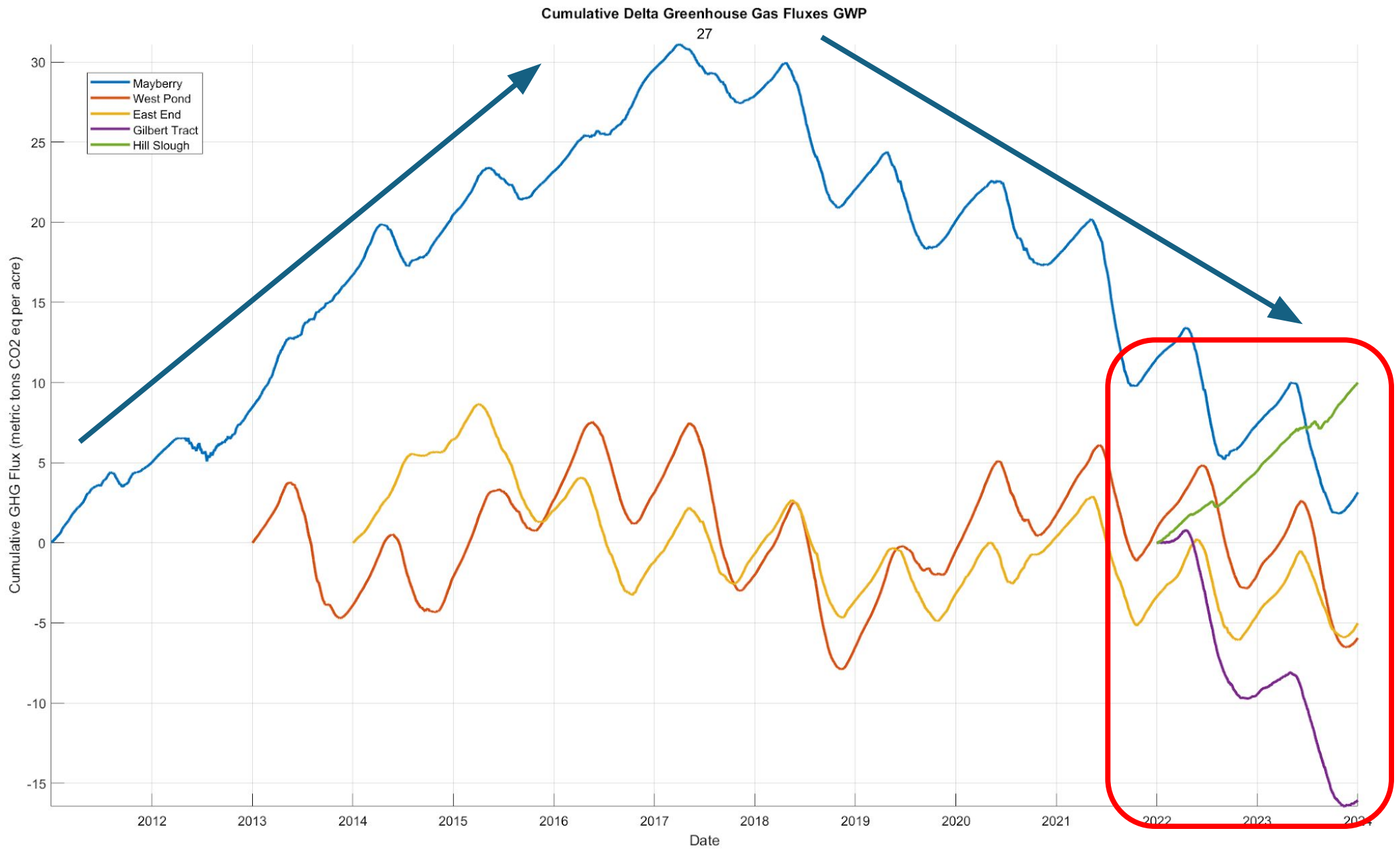
27





Histogram of Annual Net Ecosystem Carbon Exchange, World-Wide Via Fluxnet

The Magnitude of the Carbon Sink at Dutch Slough, a Tidal, Freshwater, Restored Wetland Is in the **Top 1 Percentile Worldwide**



How Can We Improve GHG Balance?

- **Remove Dead Biomass**

- Necromass blocks light, delays growing season onset, and increases respiration
- 2017 Caterpillar event at Mayberry provides a good analogue for litter removal

- **Actively Revegetate New Wetlands**

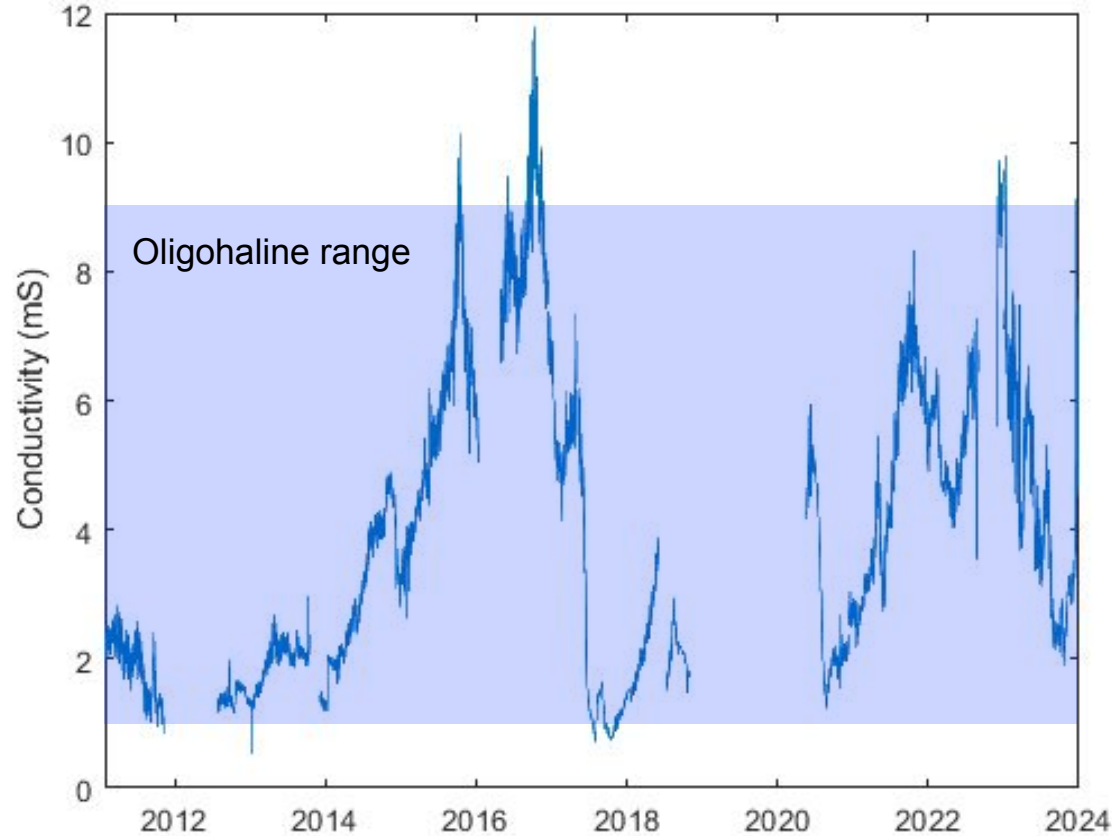
- Bare soil with sparse vegetation respire CO₂ readily and emits methane
- Aquatic plants such as Azolla may be surprisingly strong primary producers

- **Keep Water Tables High**

- A low water table allows peat to oxidize rapidly
- Aligning high water with midday at tidal sites may reduce methane emissions

Mayberry was Disturbed: High Salinity ☐

Caterpillars



- Oligohaline = ~1-9 mS/cm (0.5-5 ppt)

“Normal” year



July 19,
2021

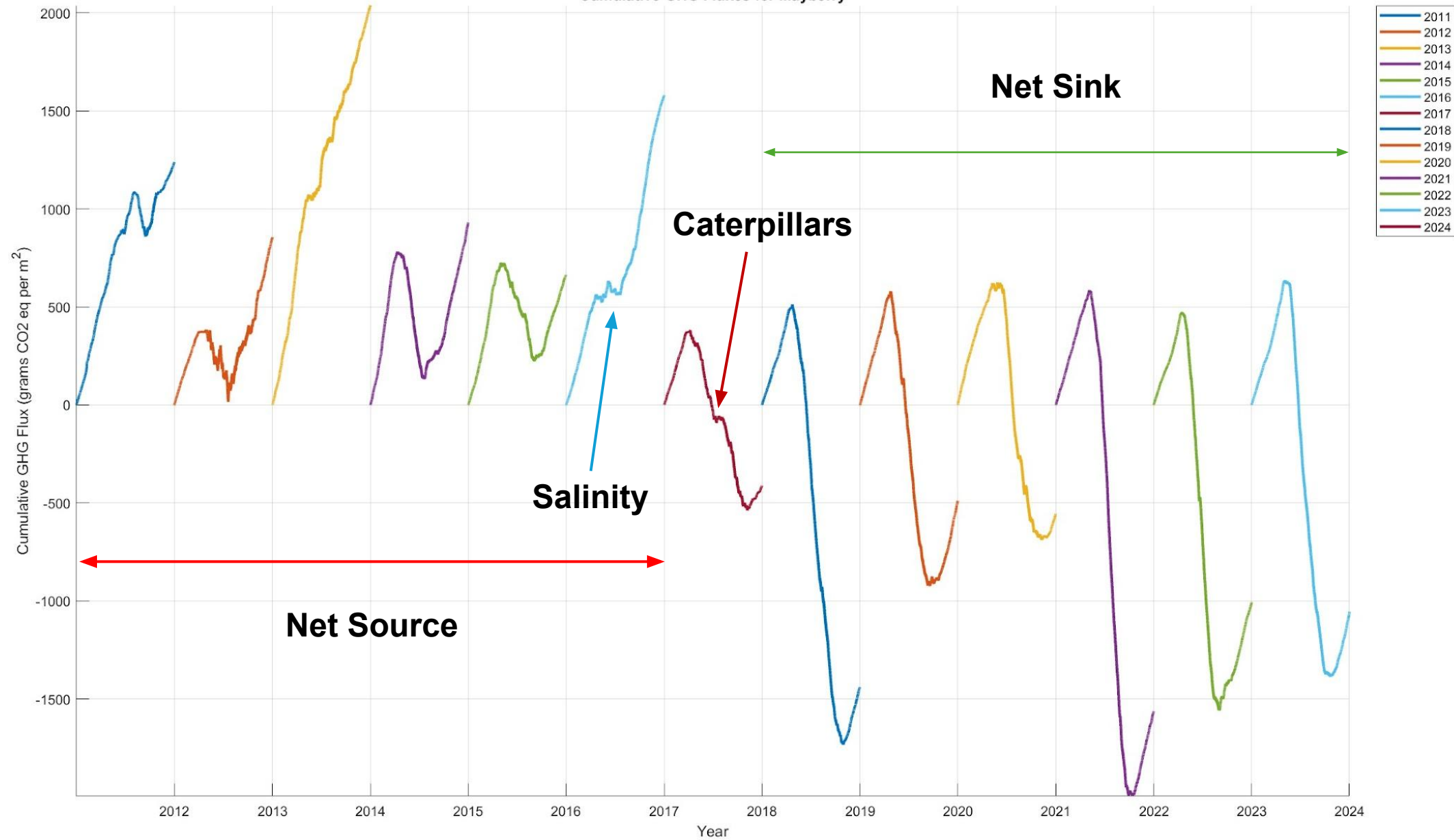


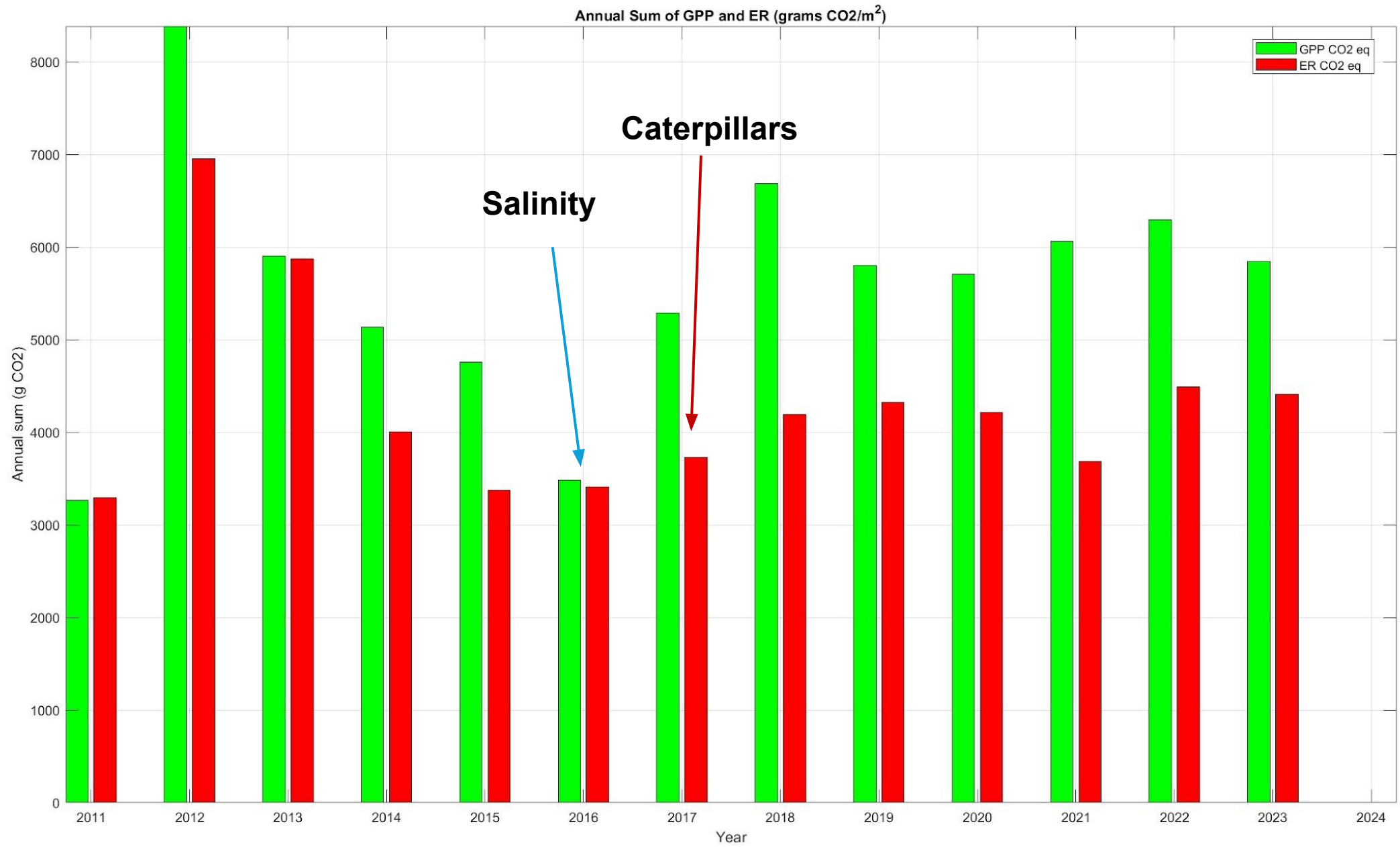
July 19,
2017

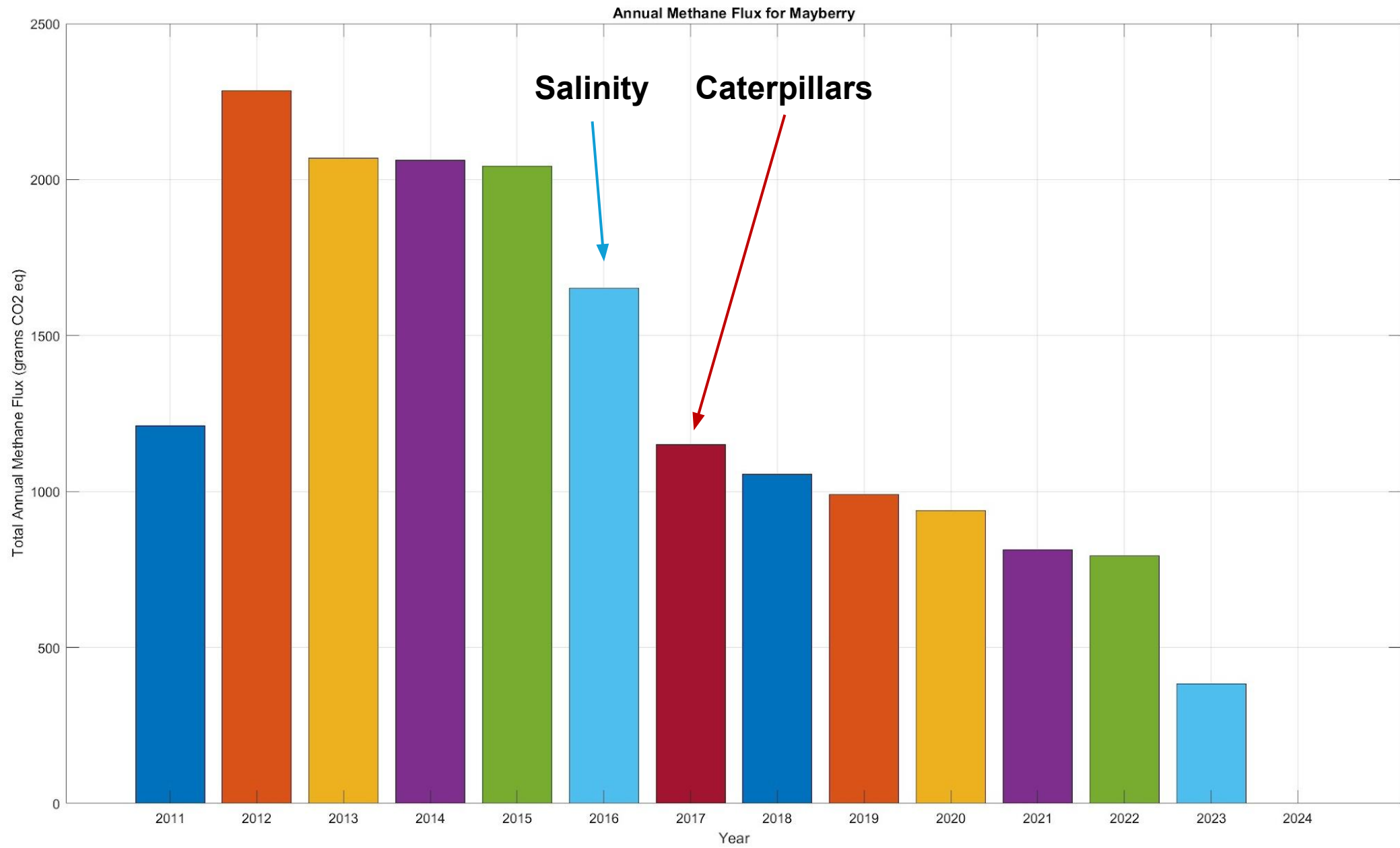


Caterpillar
year

Cumulative GHG Fluxes for Mayberry





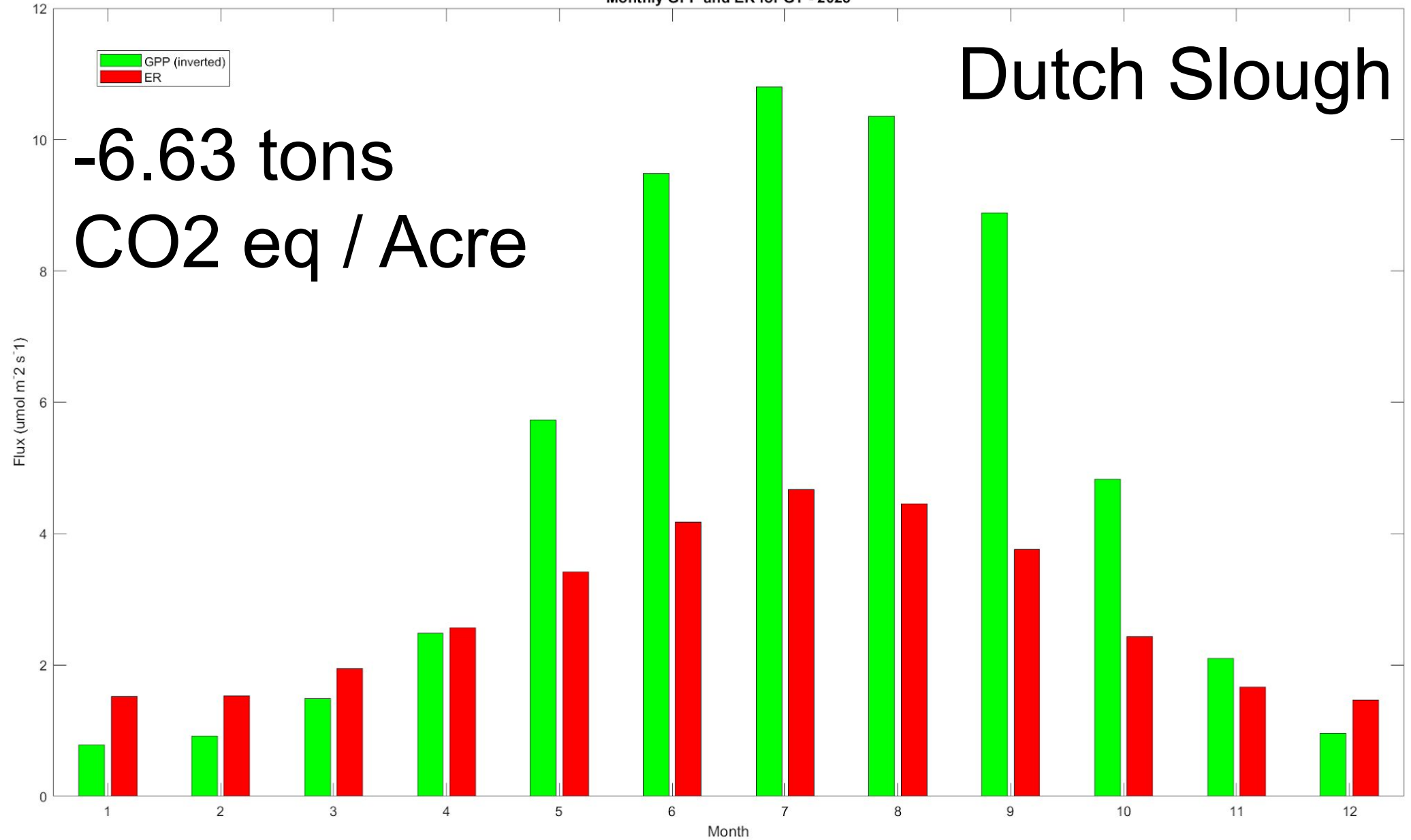


Revegetation: Hill Slough Vs Dutch Slough Three Years After Breach



Photo Credit: Mel Baldino, UCB

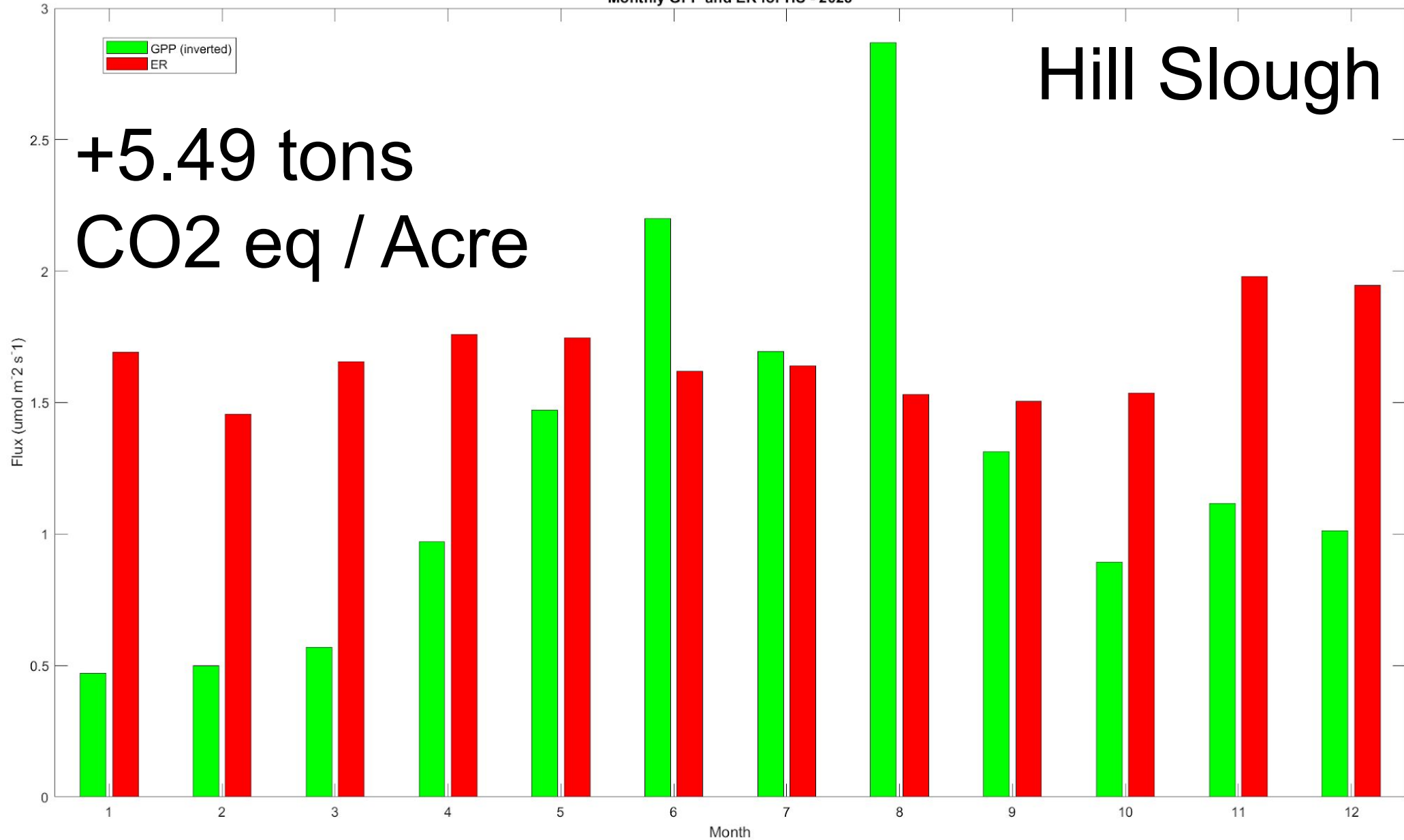
Monthly GPP and ER for GT - 2023



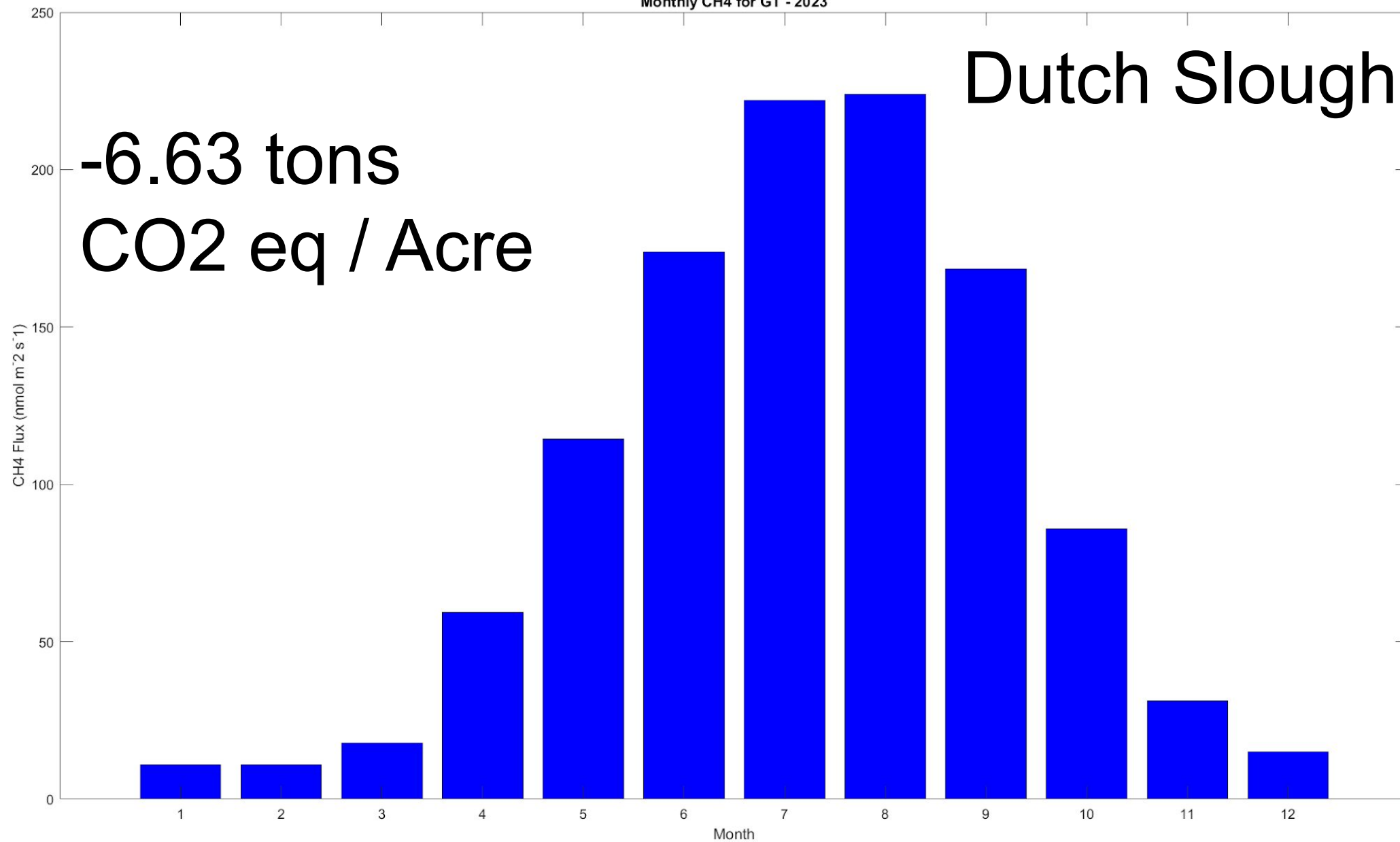
Monthly GPP and ER for HS - 2023

Hill Slough

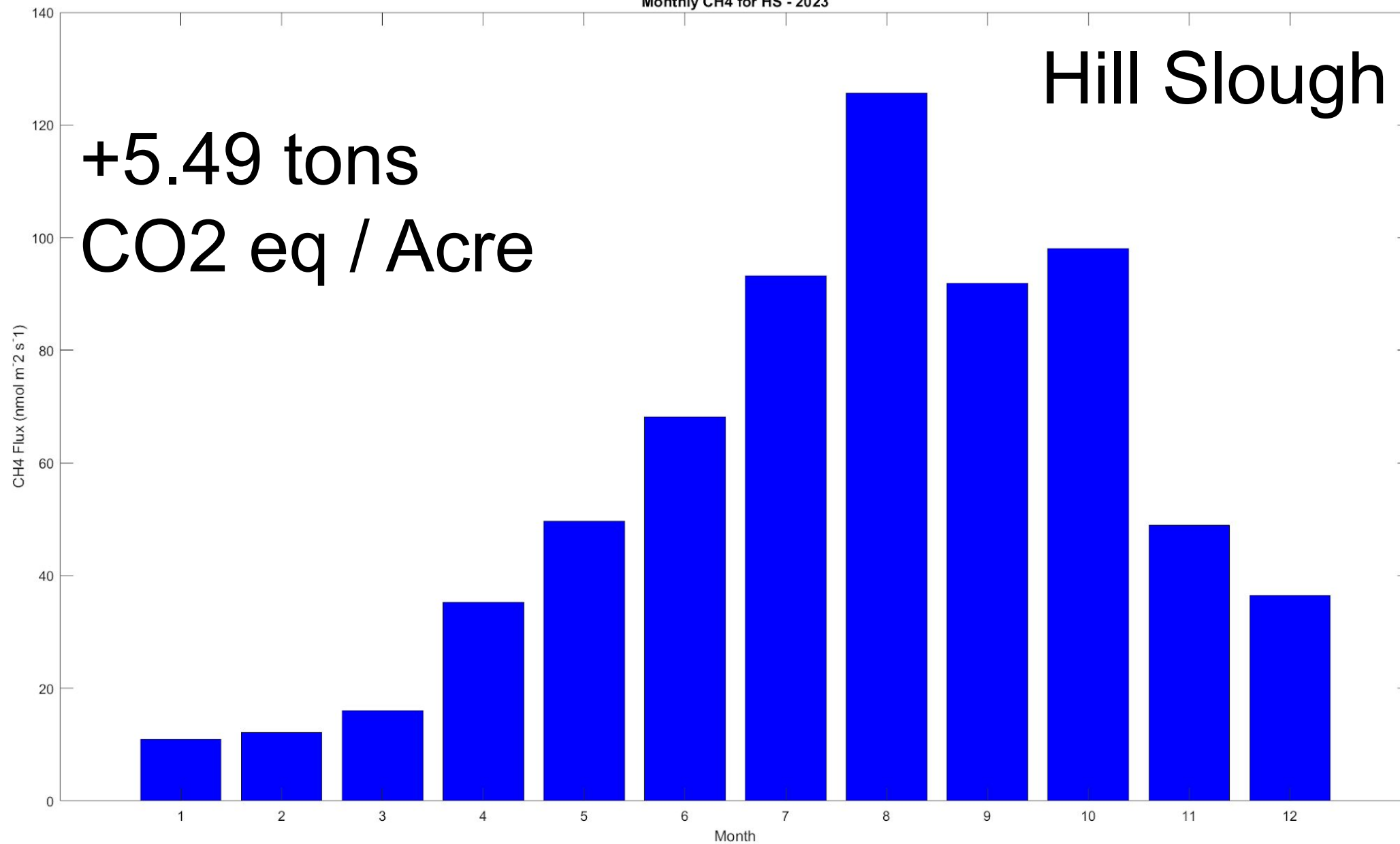
+5.49 tons
CO₂ eq / Acre



Monthly CH4 for GT - 2023



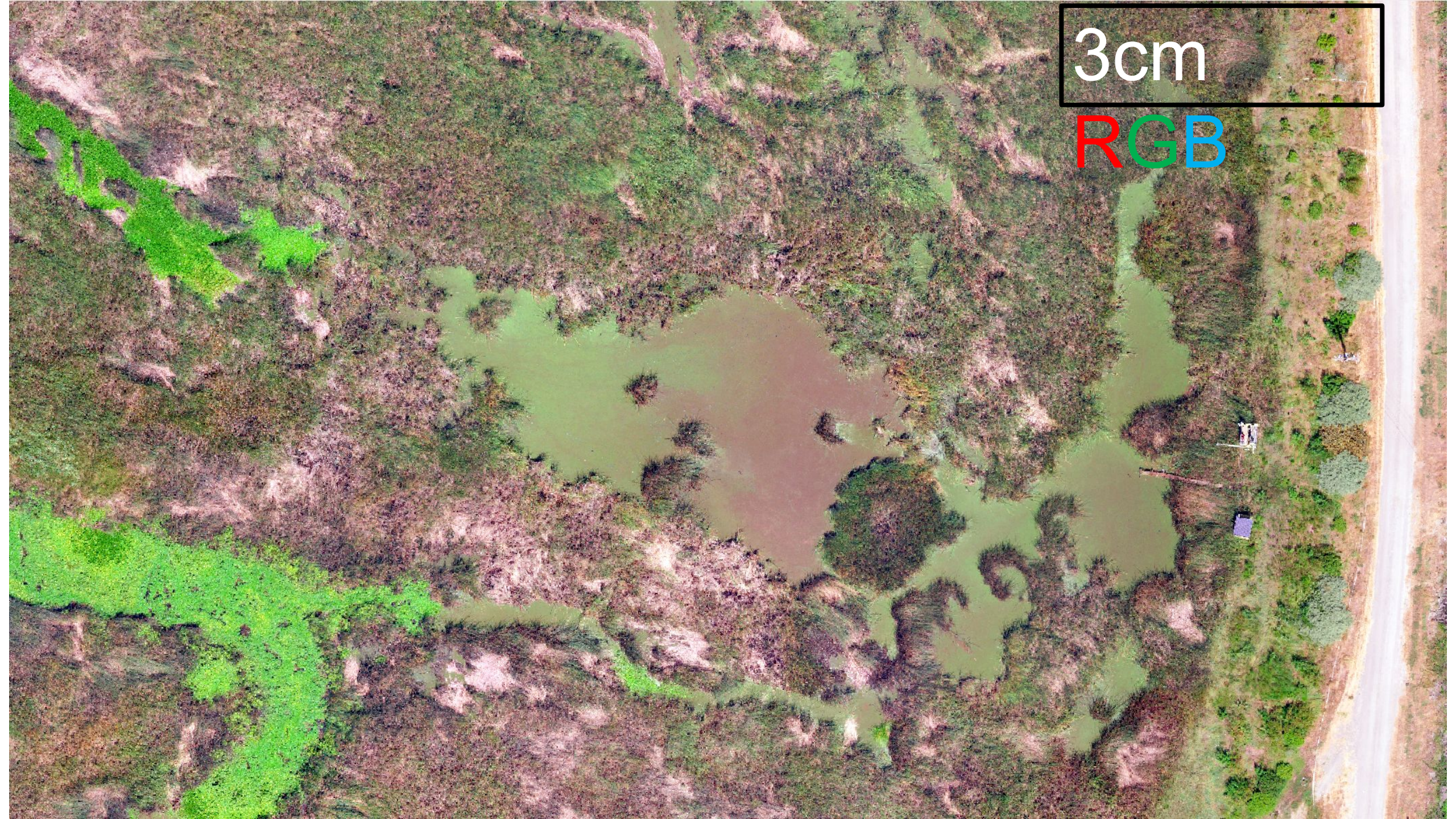
Monthly CH₄ for HS - 2023



Azolla May Support GPP

- Nitrogen Fixer
- Perennial Photosynthesizer
- Exists only in Channel Terminals

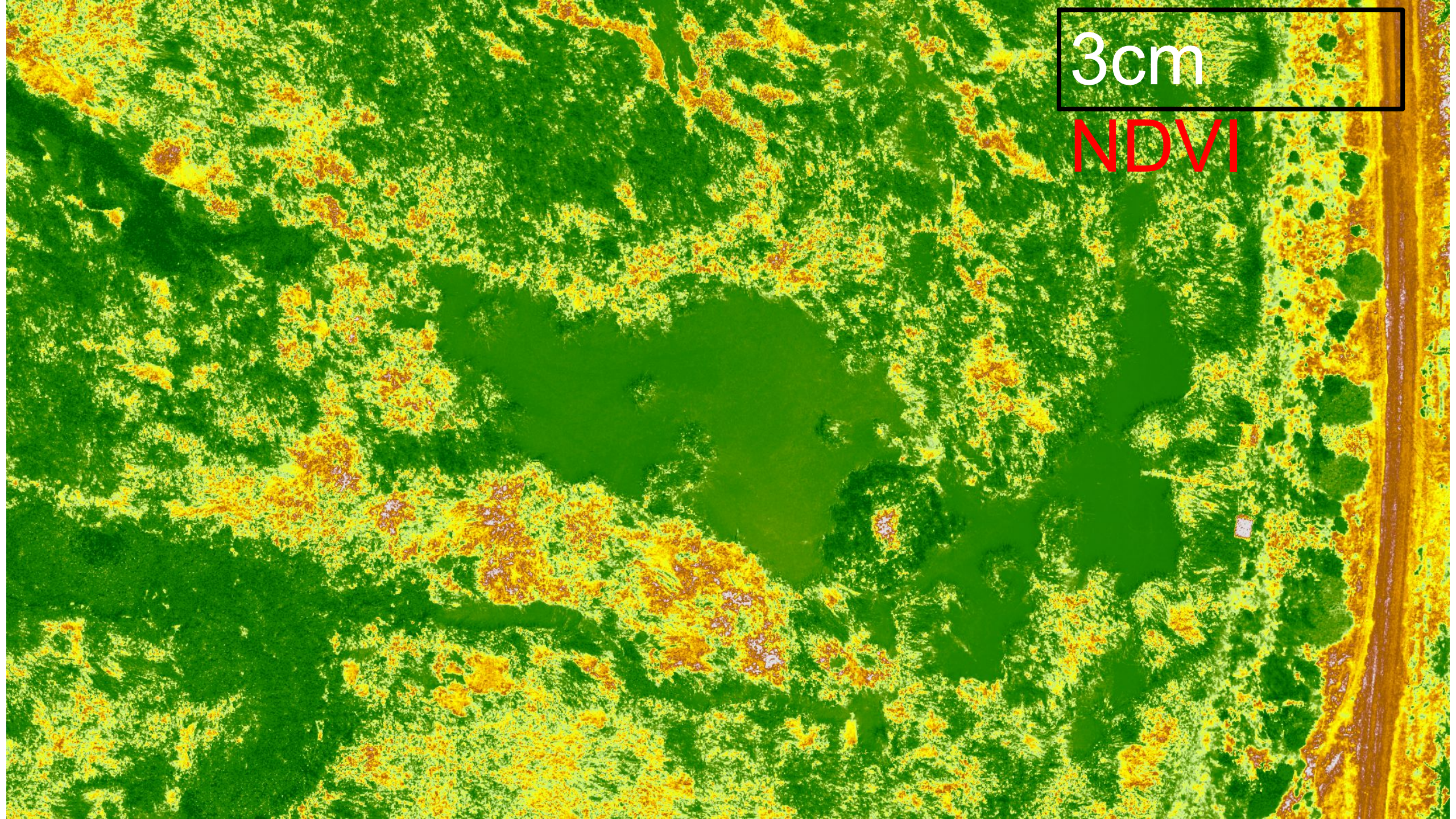




3cm

This is an aerial photograph of a wetland or marshy area. A large, irregularly shaped pond is the central feature, surrounded by dense, low-lying vegetation. The vegetation appears in various shades of green and brown, indicating different plant species or moisture levels. To the right of the pond, there is a small, dark, rectangular structure, possibly a building or a shed, and a small, white, rectangular structure, possibly a fence or a marker. The overall scene is a natural, undisturbed landscape.

RGB

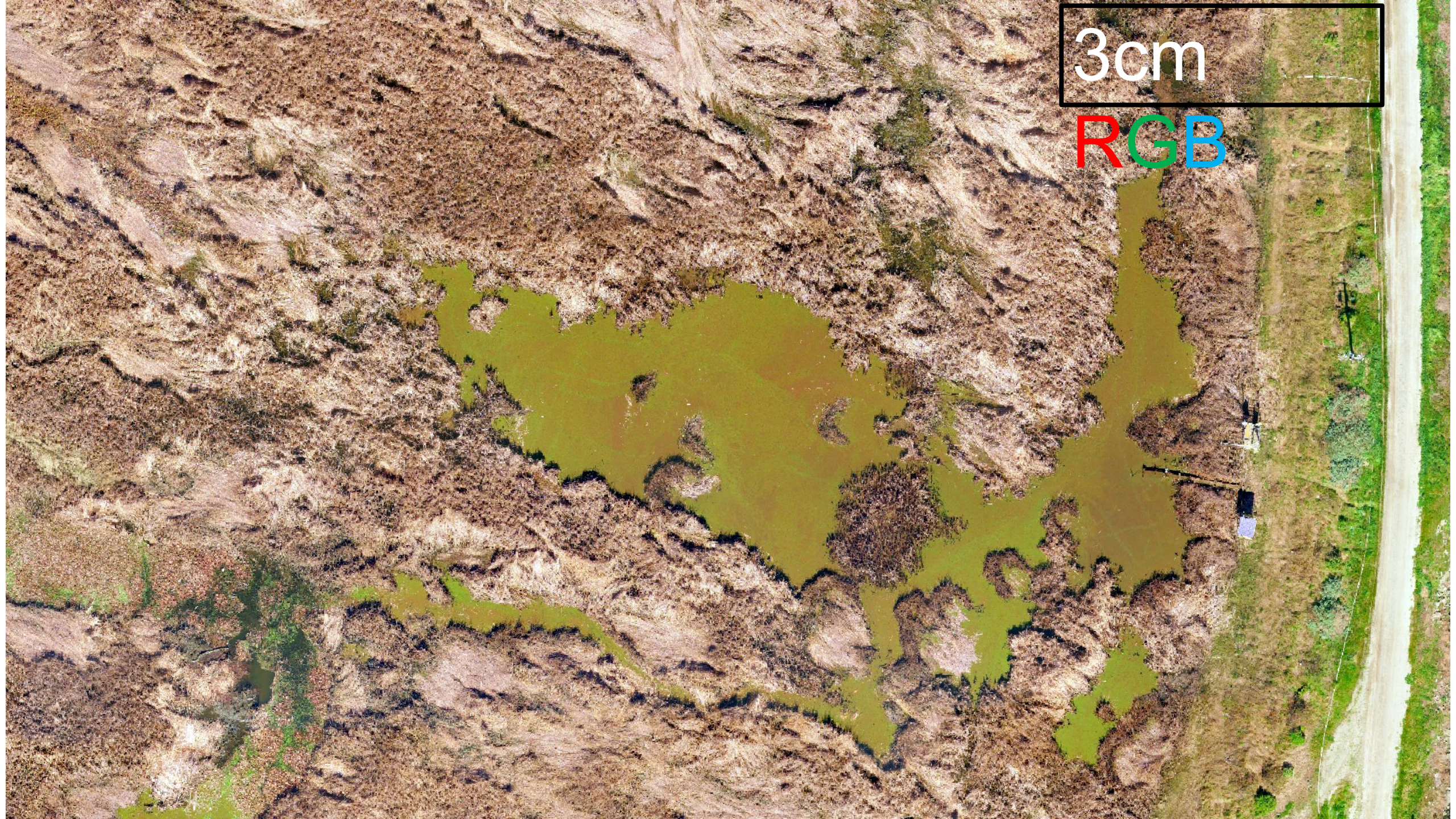
An aerial photograph overlaid with a Normalized Difference Vegetation Index (NDVI) map. The NDVI is represented by a color scale where dark green indicates high vegetation density and yellow/orange indicates lower density or bare ground. A large, irregularly shaped dark green area is visible in the center-left. The surrounding areas are a mix of green and yellow. A scale bar in the top right corner indicates a length of 3cm. The text '3cm' is in white, and 'NDVI' is in red.

3cm

NDVI

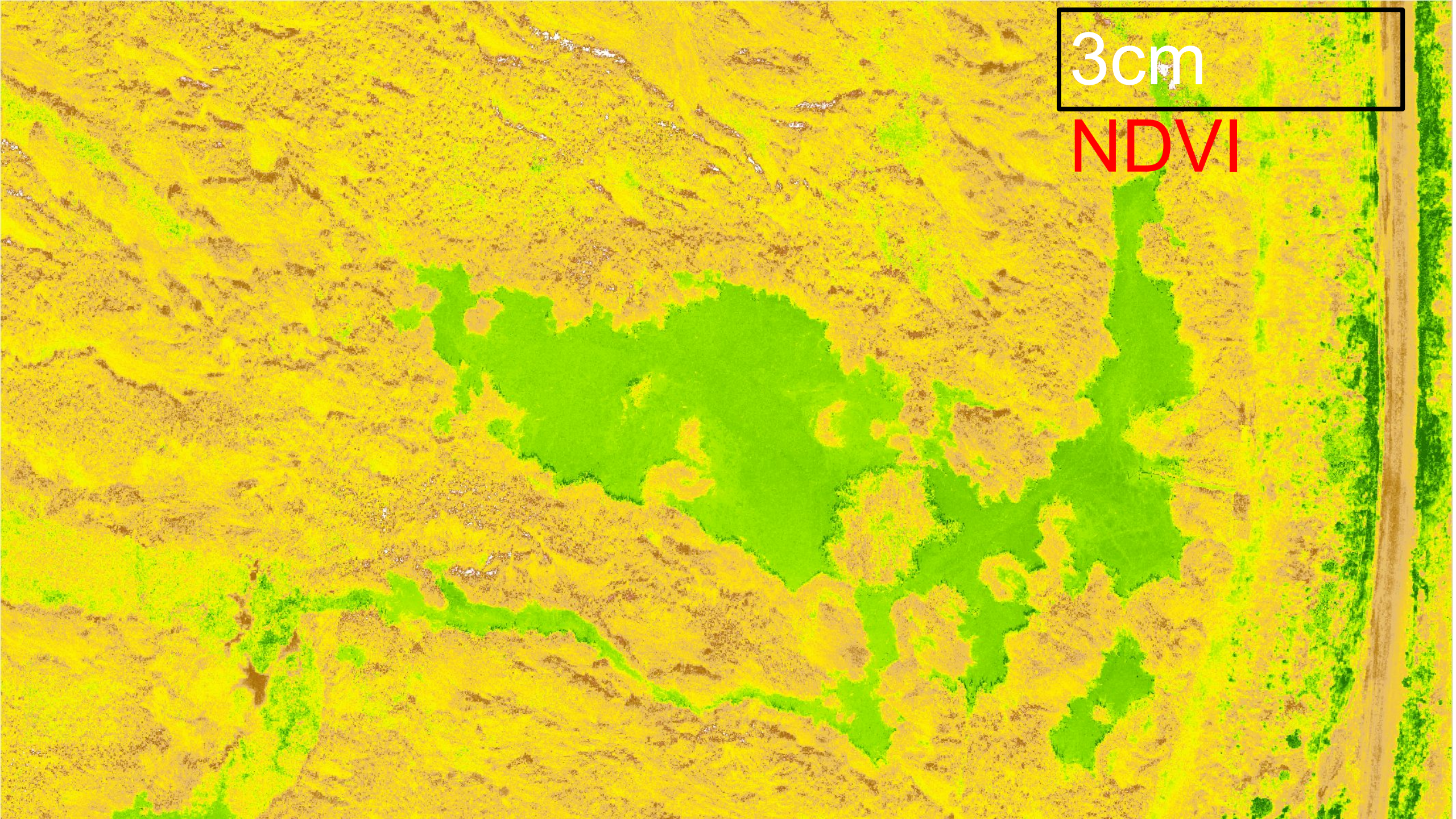
3cm

RGB

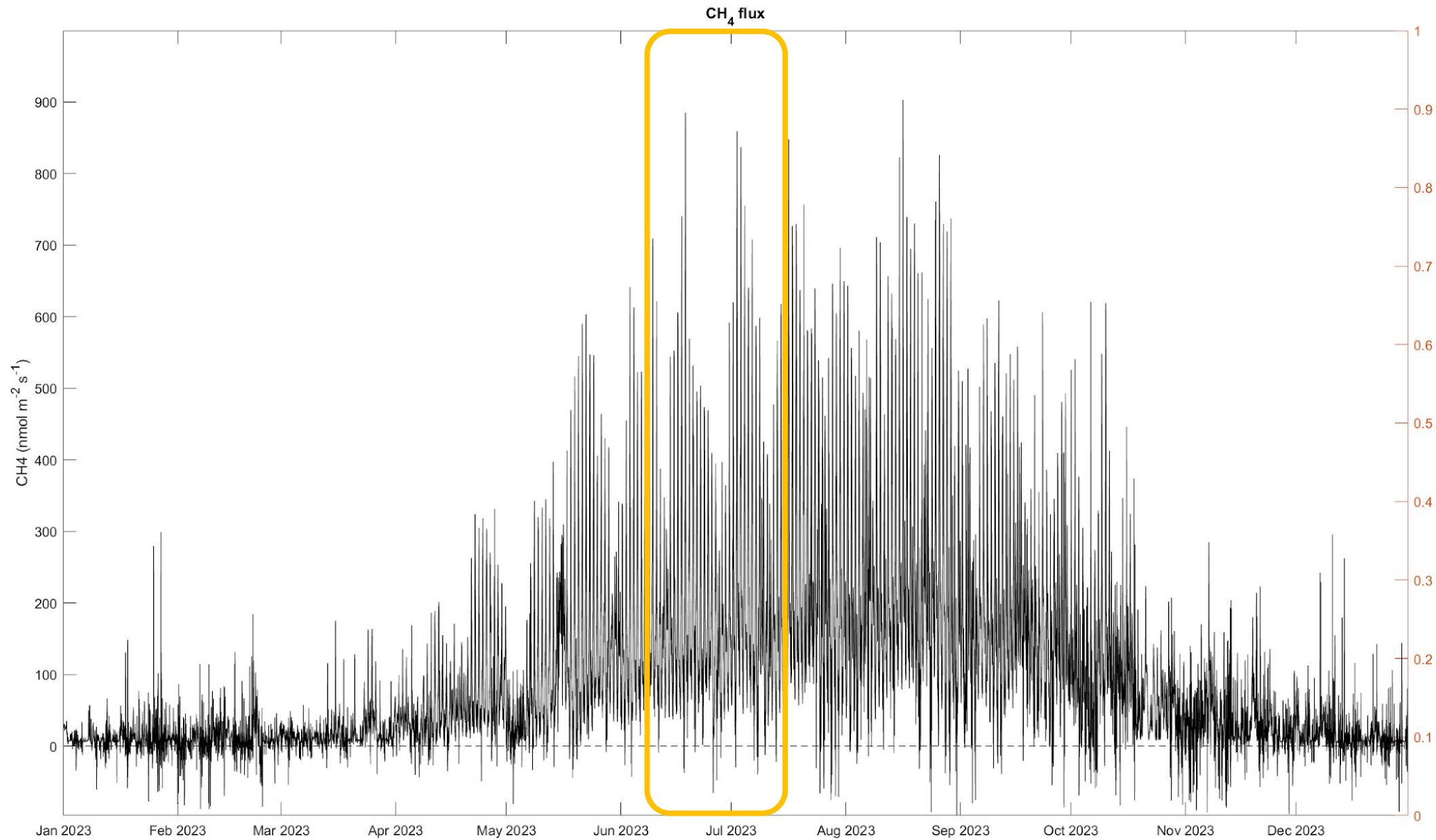


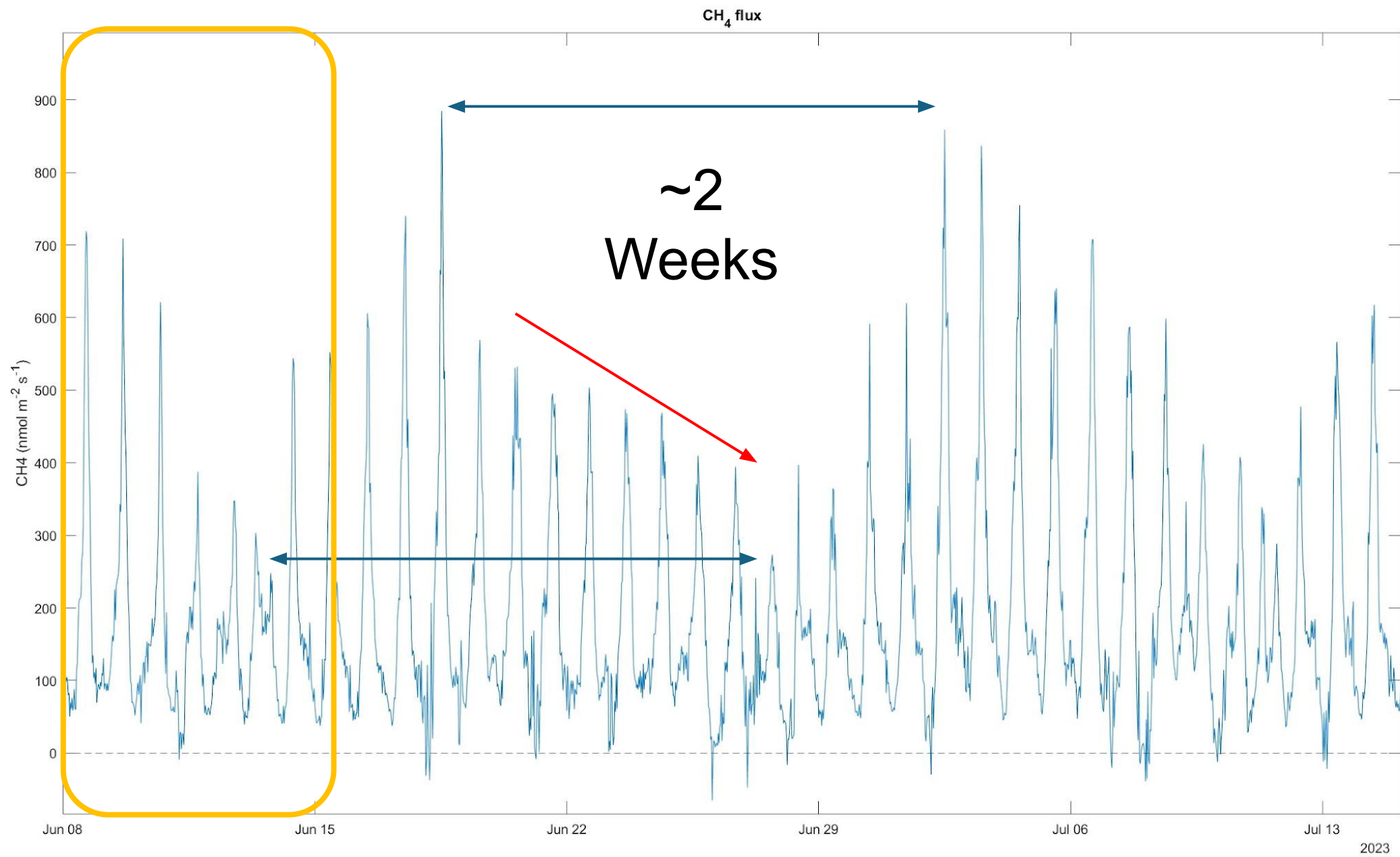
3cm

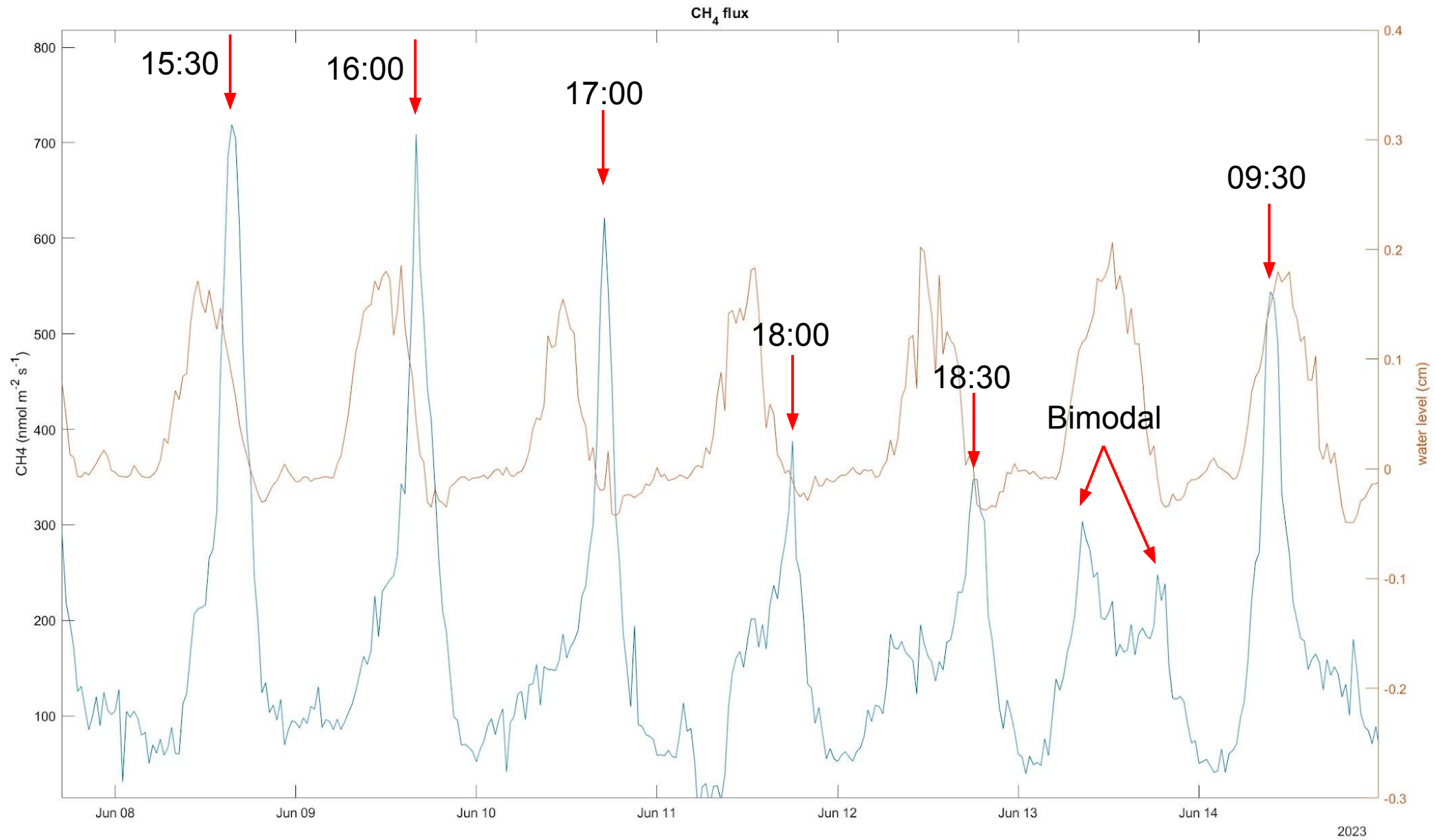
NDVI

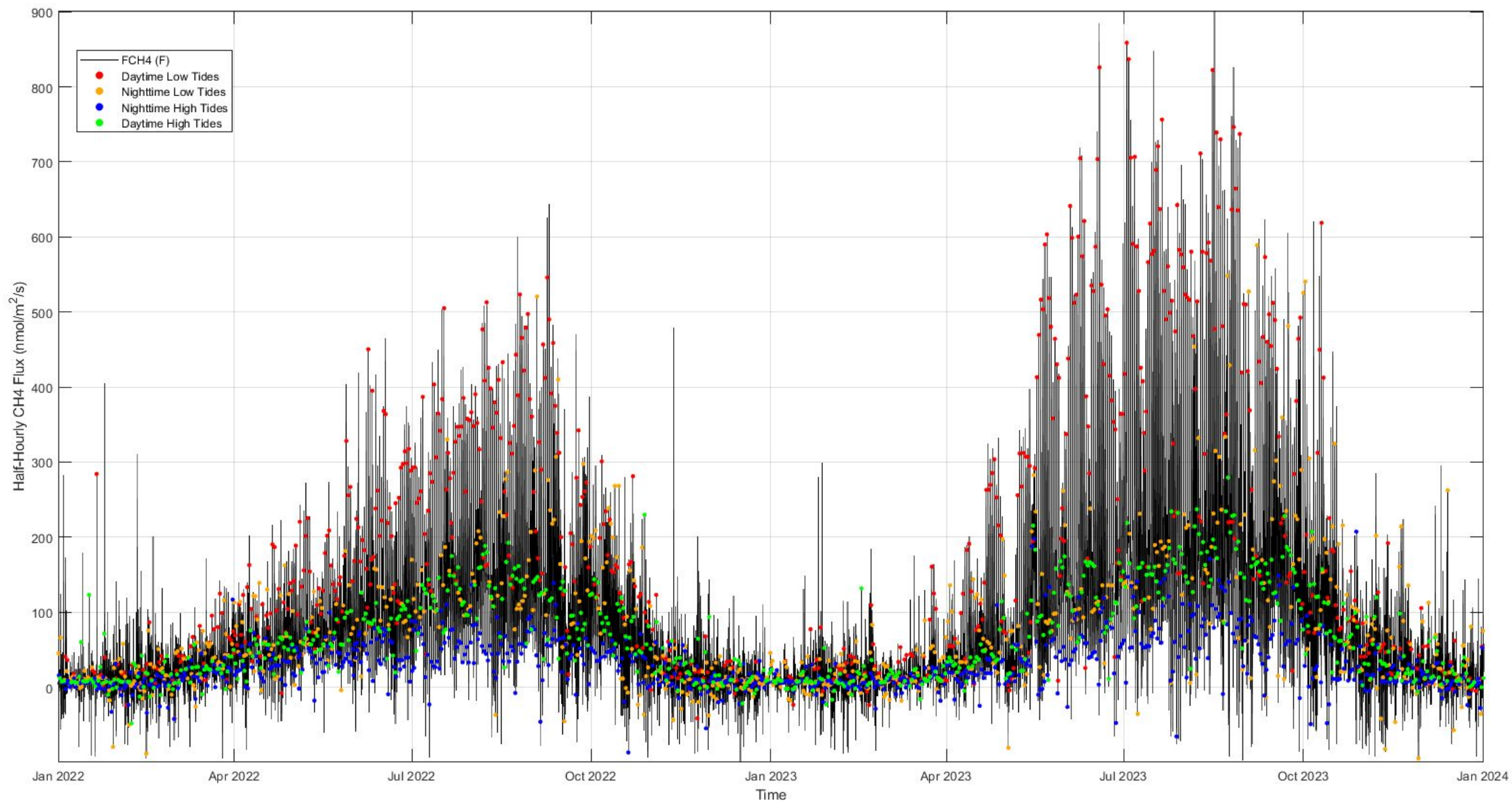




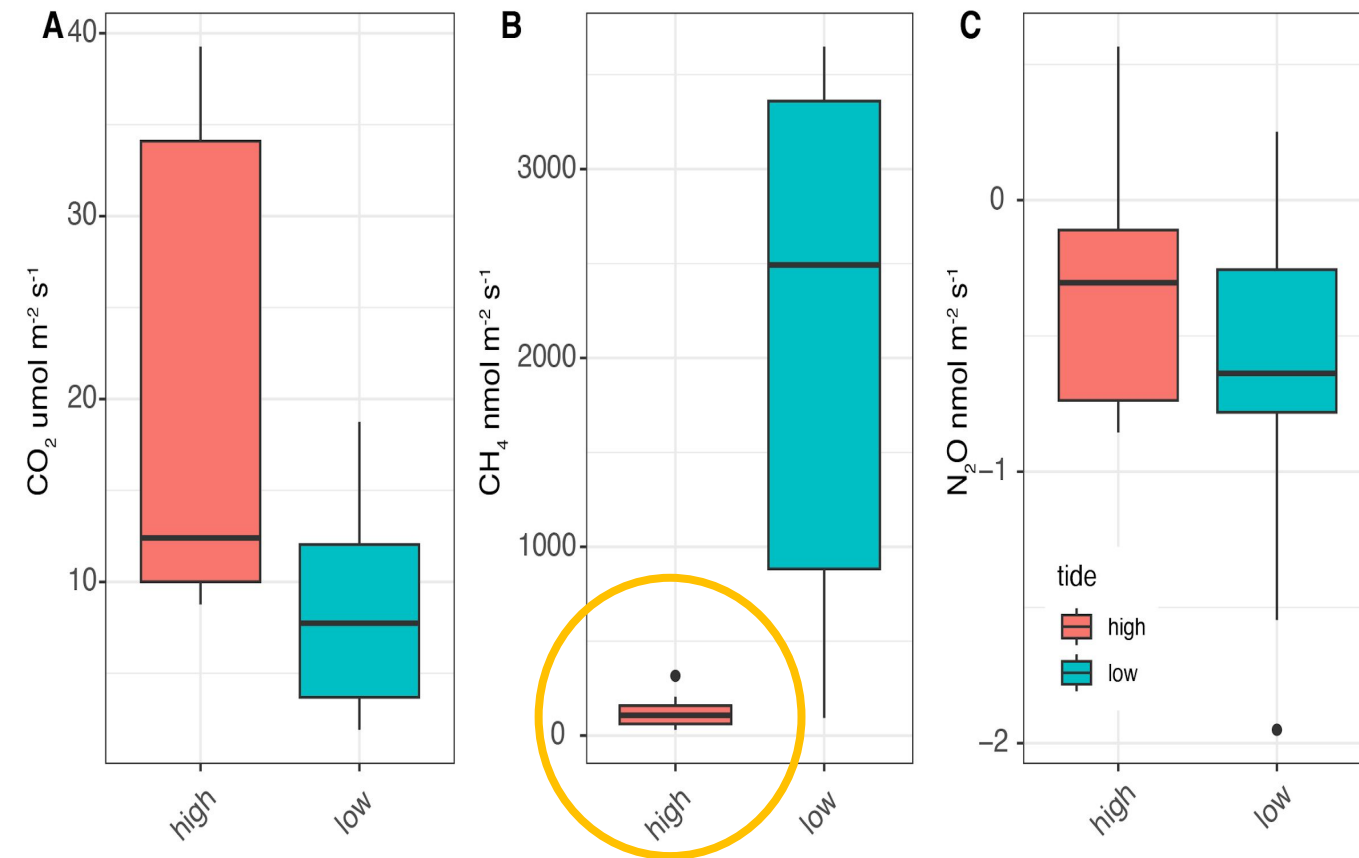








Further Field Work - Chamber



Takeaways

2) Intentional Restoration Pays Dividends

- Pre-planting, while expensive, can secure GHG benefits
- Perennial vegetation such as Azolla may be a powerful tool for GHG mitigation in the Delta

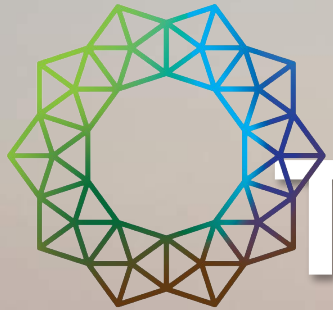
3) Keep Soil Submerged

- Mindful water management is essential to protect peat, and may be able to reduce methane as well

1) Disturbance Can be Beneficial for Fluxes

- Pests removed litter and may have improved subsequent GHG outcomes





AMERIFLUX

Thanks for Your Attention

