Briefing on recent research with relevance to public trust priorities and groundwater for Keauhou, Kona

Leah Bremer, Henrietta Dulai, Veronica Gibson, Diamond Tachera

Commission on Water Resource Management

November 19, 2024

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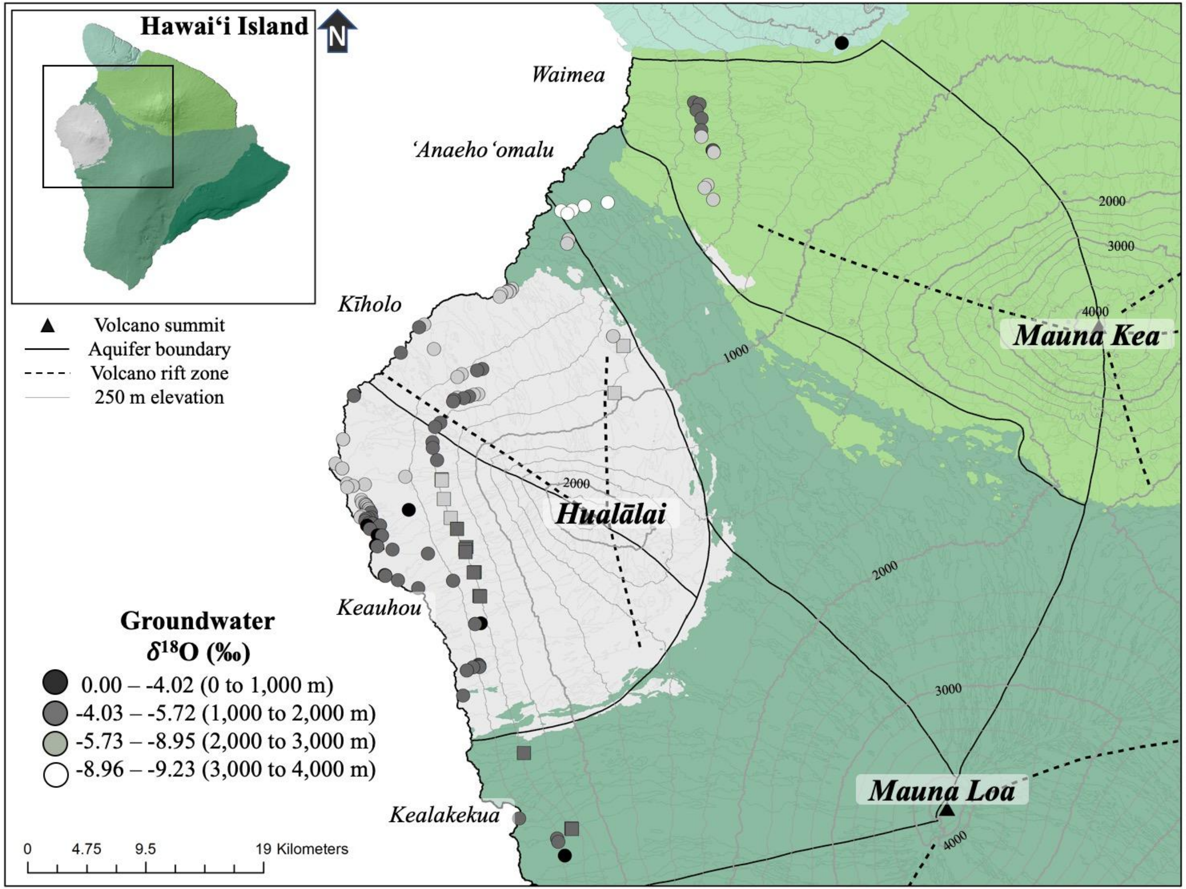
Presentation outline

- Groundwater and SGD connectivity in Kona (Henrietta Dulai and Diamond Tachera)
- Groundwater dependent ecosystems (Veronica Gibson)
- Linking climate, land and water management, and GDEs through land-sea modeling (Leah Bremer)

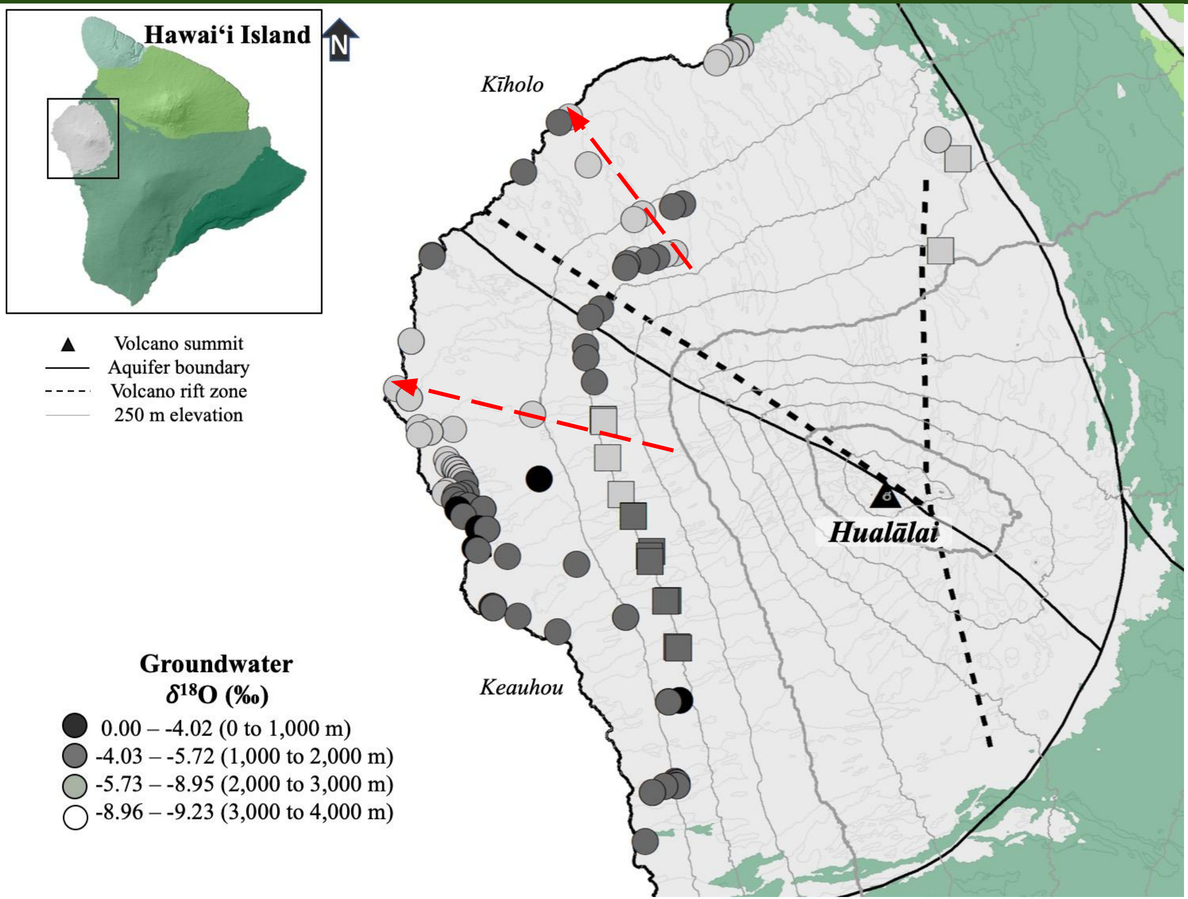

1. Groundwater and SGD connectivity in Kona

Inland and coastal groundwaters



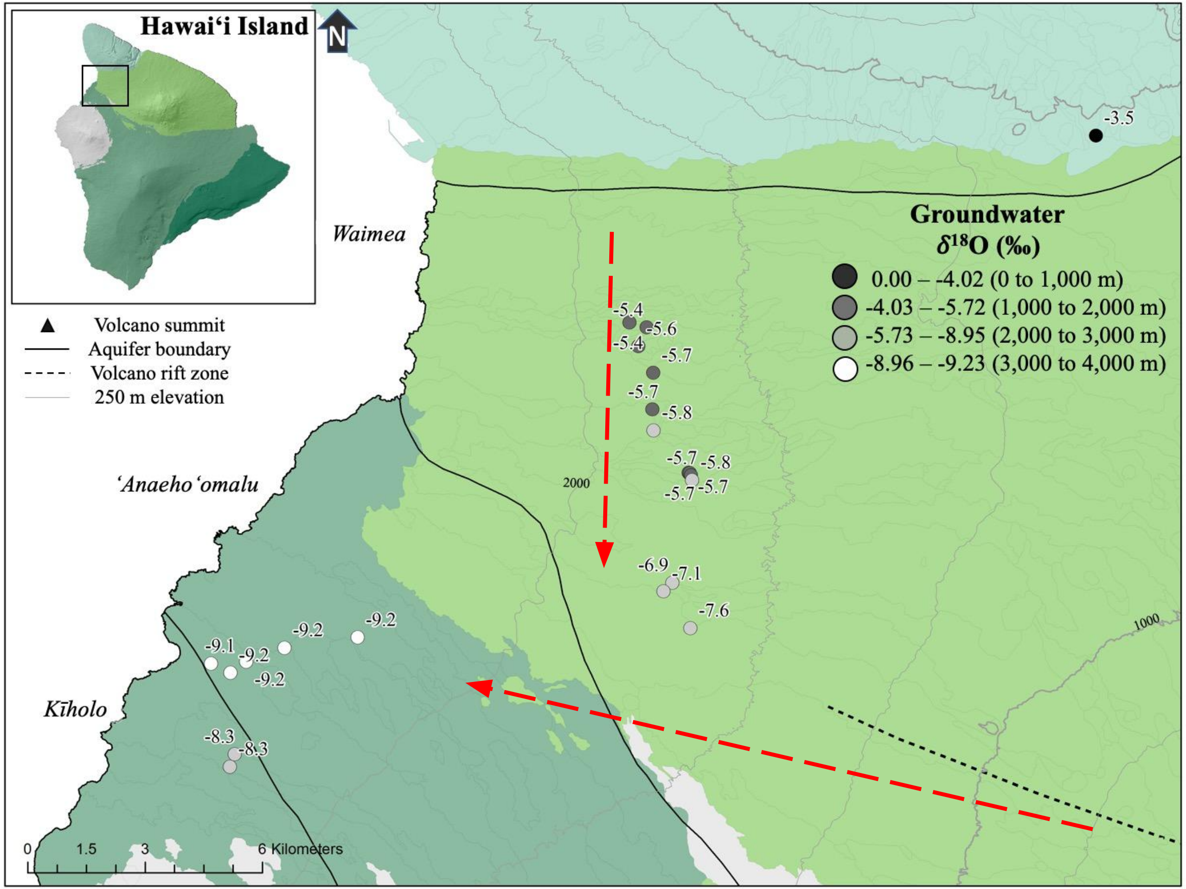
- Groundwater stable isotope data can be related to elevations of recharge
- Understanding source, flow, connectivity of waters
- Can see areas of potentially isolated flow vs. mixing

Inland and coastal groundwaters



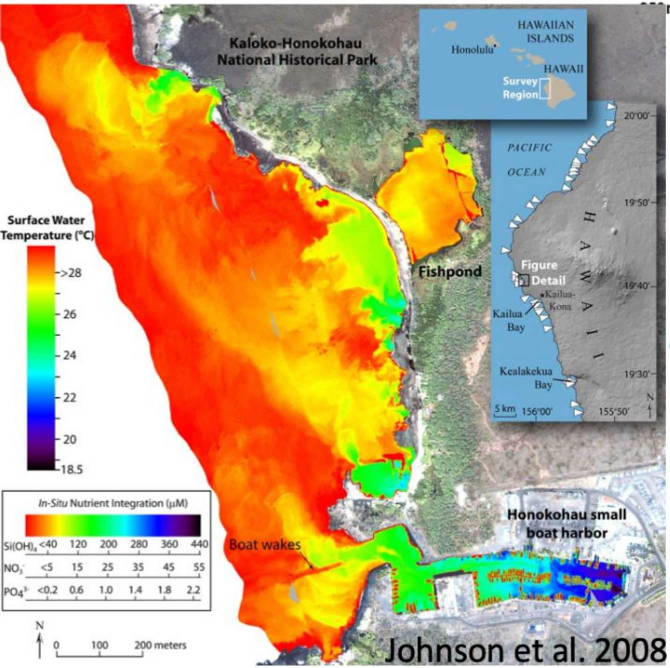
- Sharp transitions laterally indicate potentially isolated flows
- Mauka to makai flow

Inland and coastal groundwaters

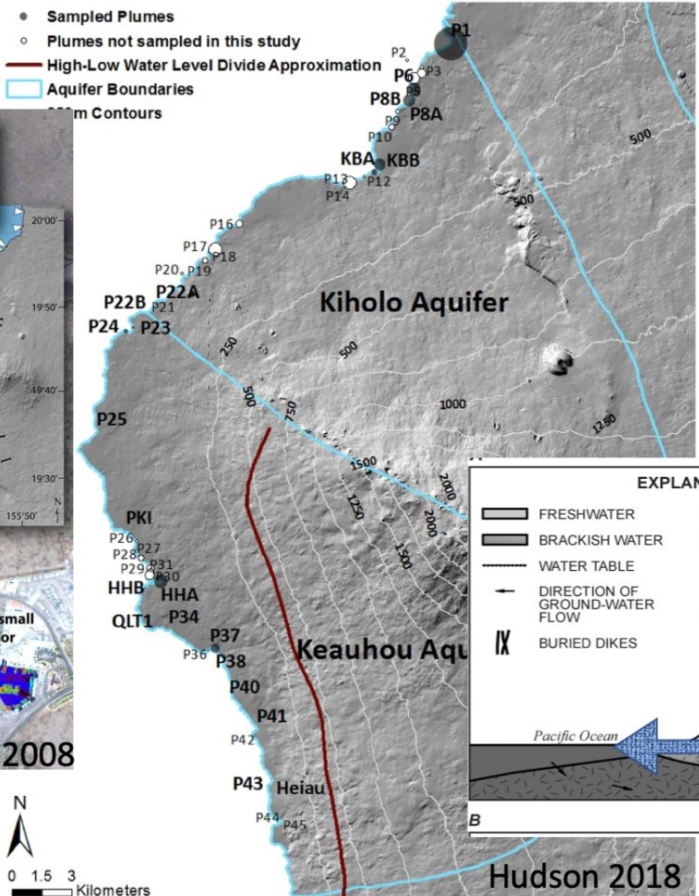


- Potentially mixing across aquifer "boundaries"

Submarine groundwater discharge $\delta^{18}O$ signatures

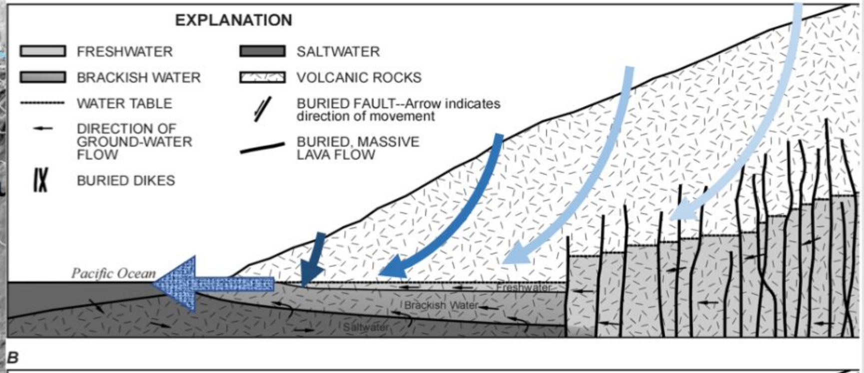


Johnson et al. 2008



Hudson 2018

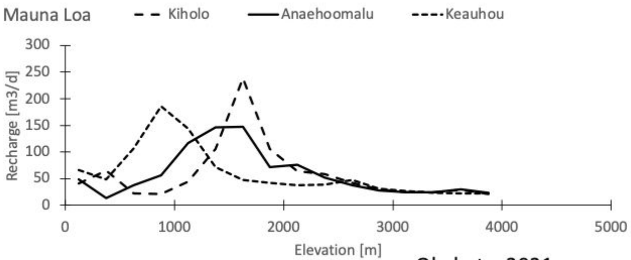
Groundwater oxygen and hydrogen isotope composition ($\delta^{18}O$ of H_2O) indicates elevation ~recharge origin



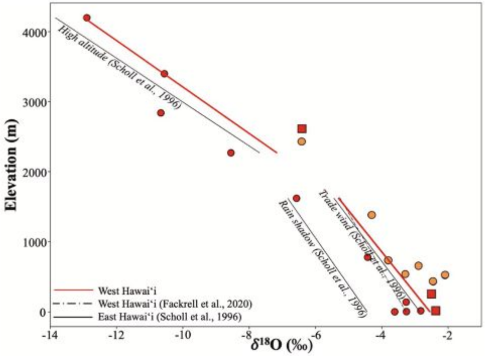
Oki et al 1999

METHODS

- Located and sampled coastal springs
- Salinity corrected $\delta^{18}O$ for mixing with ocean
- Identified theoretical groundwater flow path trajectories
- Quantified recharge along flow paths
- Assigned $\delta^{18}O$ to corresponding recharge elevations based on previously determined $\delta^{18}O$ lapse rate
- Integrated recharge until $\delta^{18}O$ of groundwater was matched



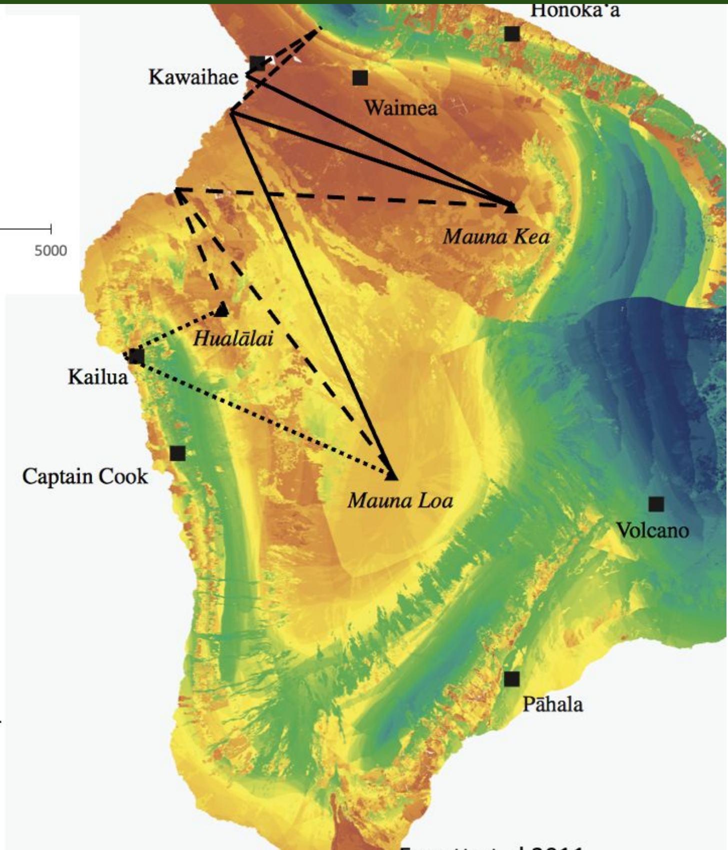
Okuhata, 2021



Tachera, 2021

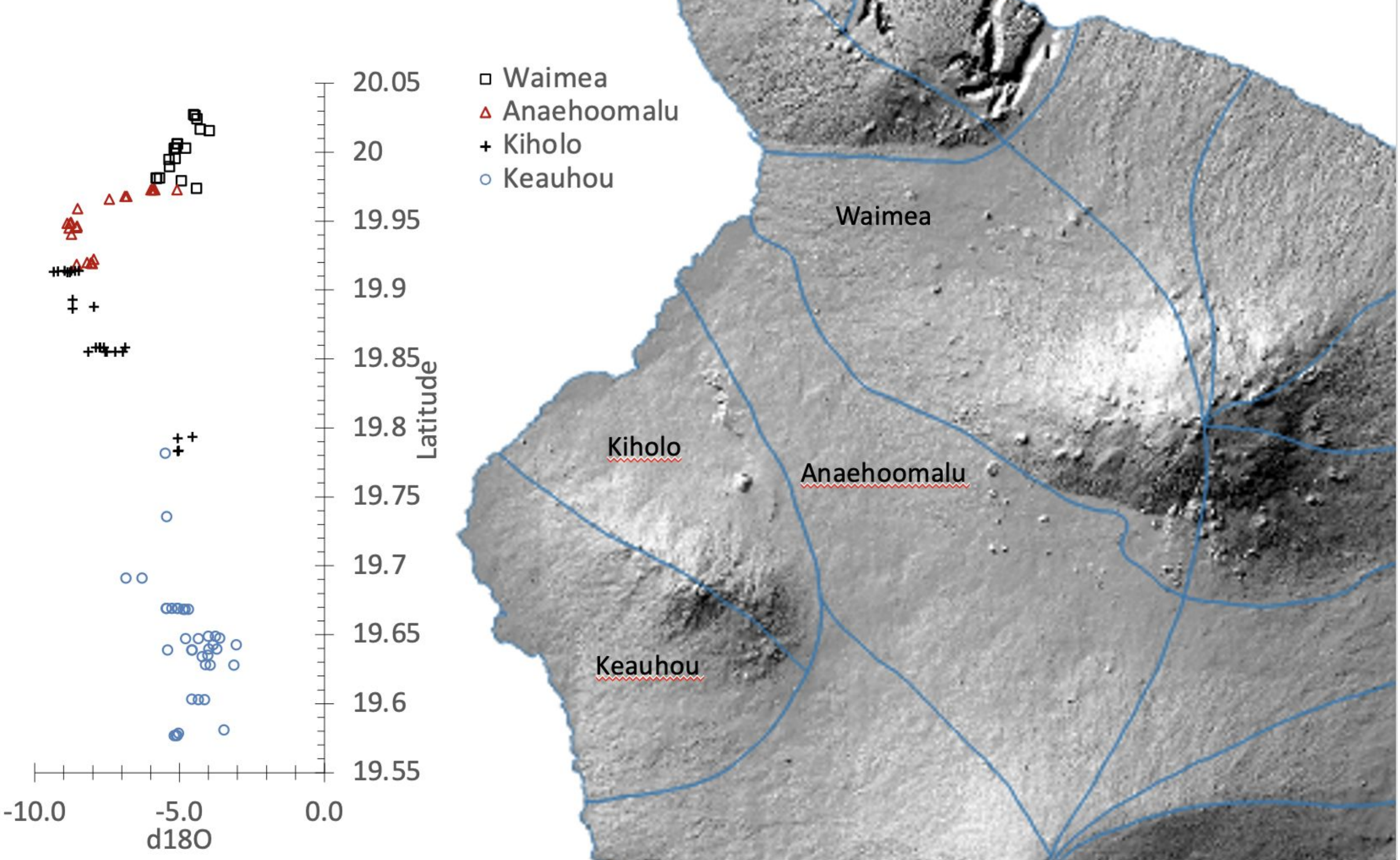
$$\delta^{18}O_{sample} = \frac{\sum_{int=1}^{n}(\delta^{18}O)n(R)n}{\sum_{int=1}^{n}(R)n}$$

Scholl, 2002

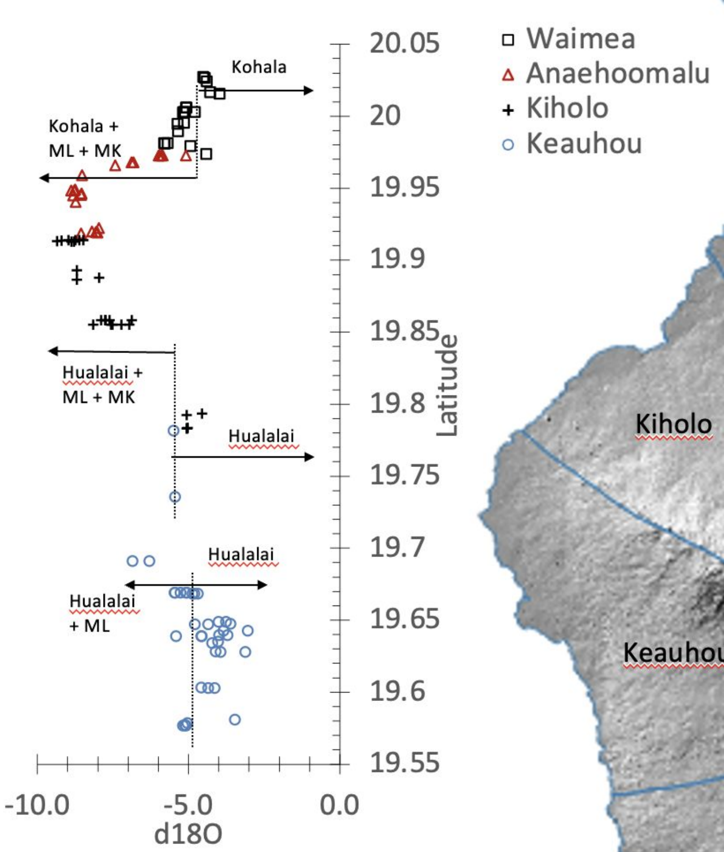


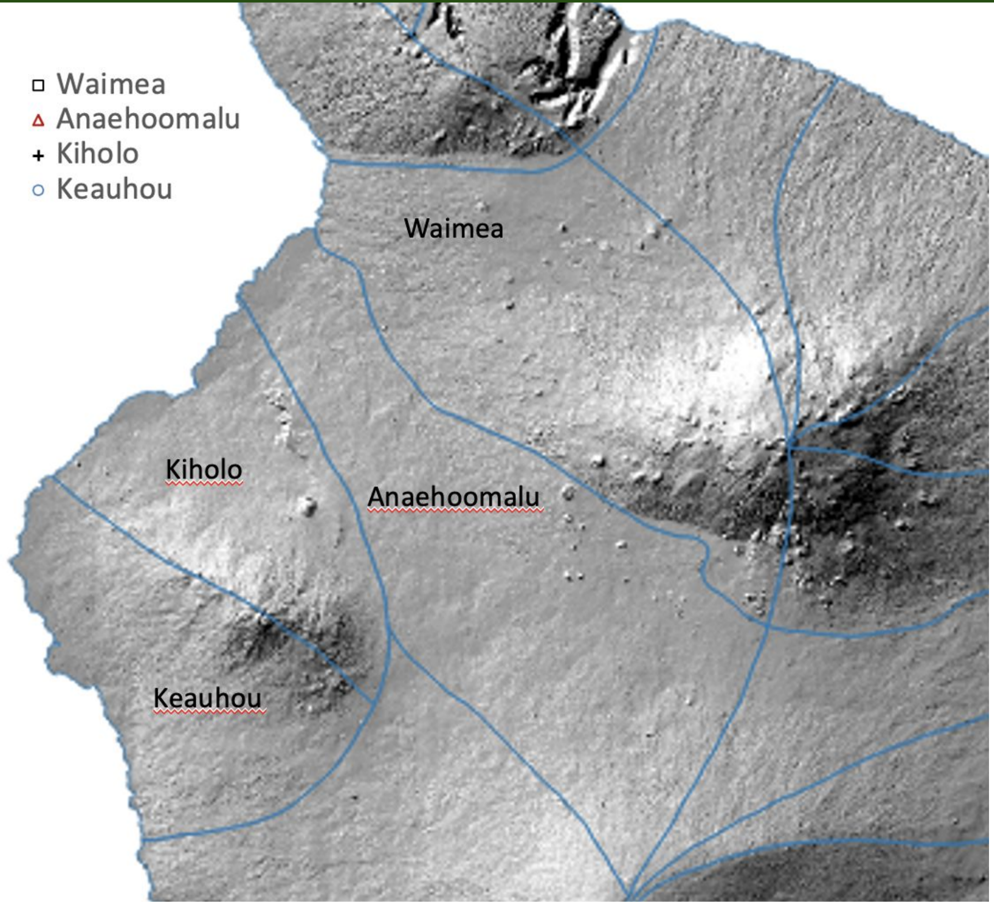
Engott et al 2011

Spatial pattern of $\delta^{18}O$ in coastal springs

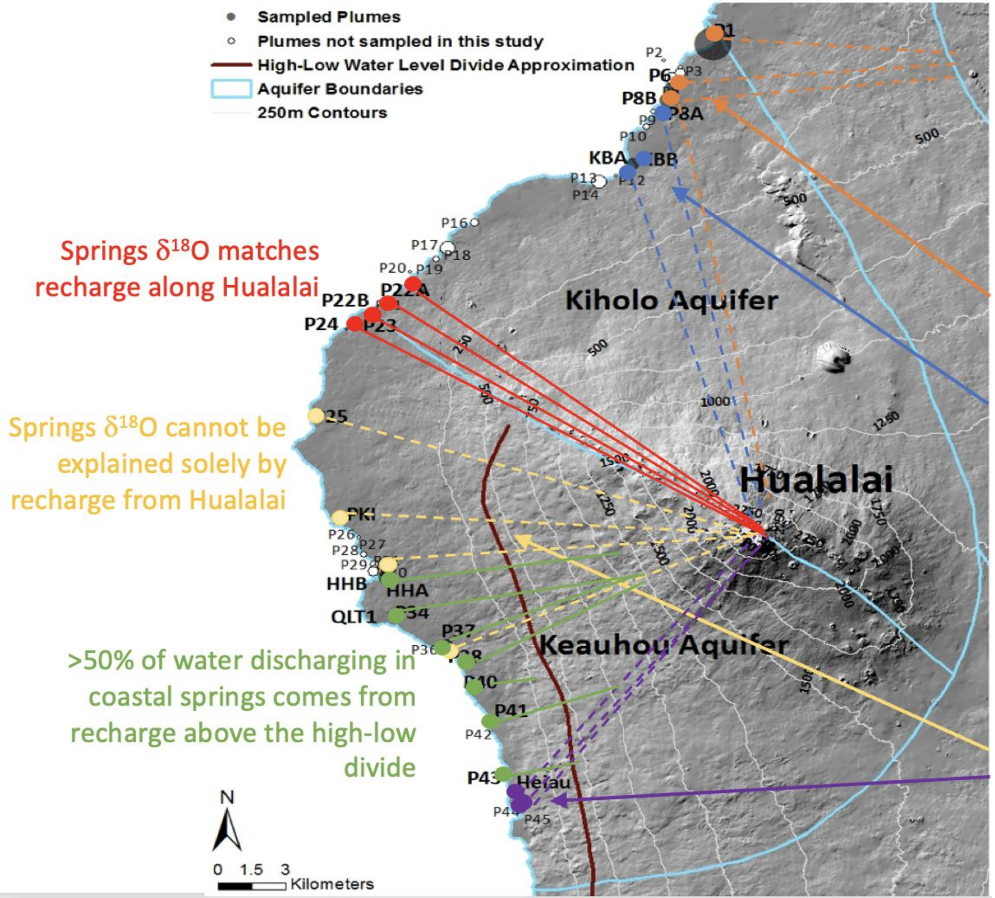


Spring flow is a mixture of recharge from different sources





CONCLUSIONS

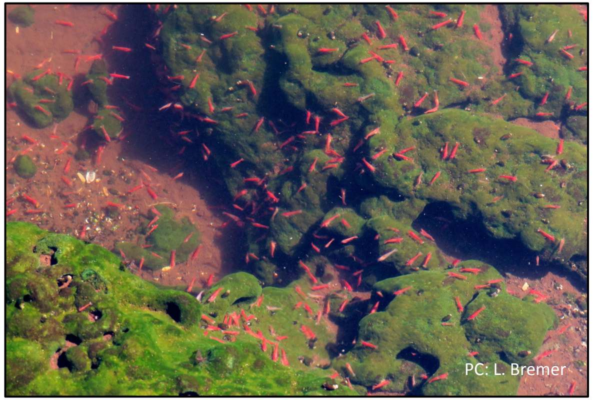


- Inter-aquifer flow is found across all studied aquifers
- Isotope signature transitions not always at aquifer boundaries
- Most springs in S Keauhou recharge from Hualalai; still >50% of spring water is from above the high-low divide

2. Groundwater Dependent Ecosystems

Groundwater dependent ecosystems (GDEs)

Anchialine pools



Loko iʻa

Estuarine nearshore ecosystems

*Gibson et al. (2022) Ecology and Society

GDEs are valued biocultural systems

"If you have anchialine pools in your ahupuaʻa, especially in a place like North Kona, Kekaha Wai ʻOle, you're considered very wealthy, because you have access to water, you have access to a refrigerator, and you have the source for your ʻōpelu fishing. ʻŌpelu, the source for the people in this region."

~*Kanaka ʻŌiwi resource manager*

Fig. 4. ʻŌ*pae ʻula* (*Halocaridina rubra*), the anchialine pool shrimp, and associated values that span all four social-ecological service categories.

Biocultural values of groundwater dependent ecosystems in Kona, Hawaiʻi

Veronica L. Gibson[1,2], Leah L. Bremer[2,3], Kimberly M. Burnett[2], Nicole Keaka Lui[4,5,6,7] and Celia M. Smith[1]

E&S

Ecology and Society 2022

Limu as a nearshore GDE-dependent species

- Food, ceremony, medicine
  - "It was a rare Hawaiian household that did not have some kind of limu at all times."
    - ~ *Dr. Isabella Aiona Abbott, La'au Hawai'i: Traditional Hawaiian Uses of Plants*

3. Linking climate, land and water management, and GDEs through land-sea modeling

Land-sea modeling research team



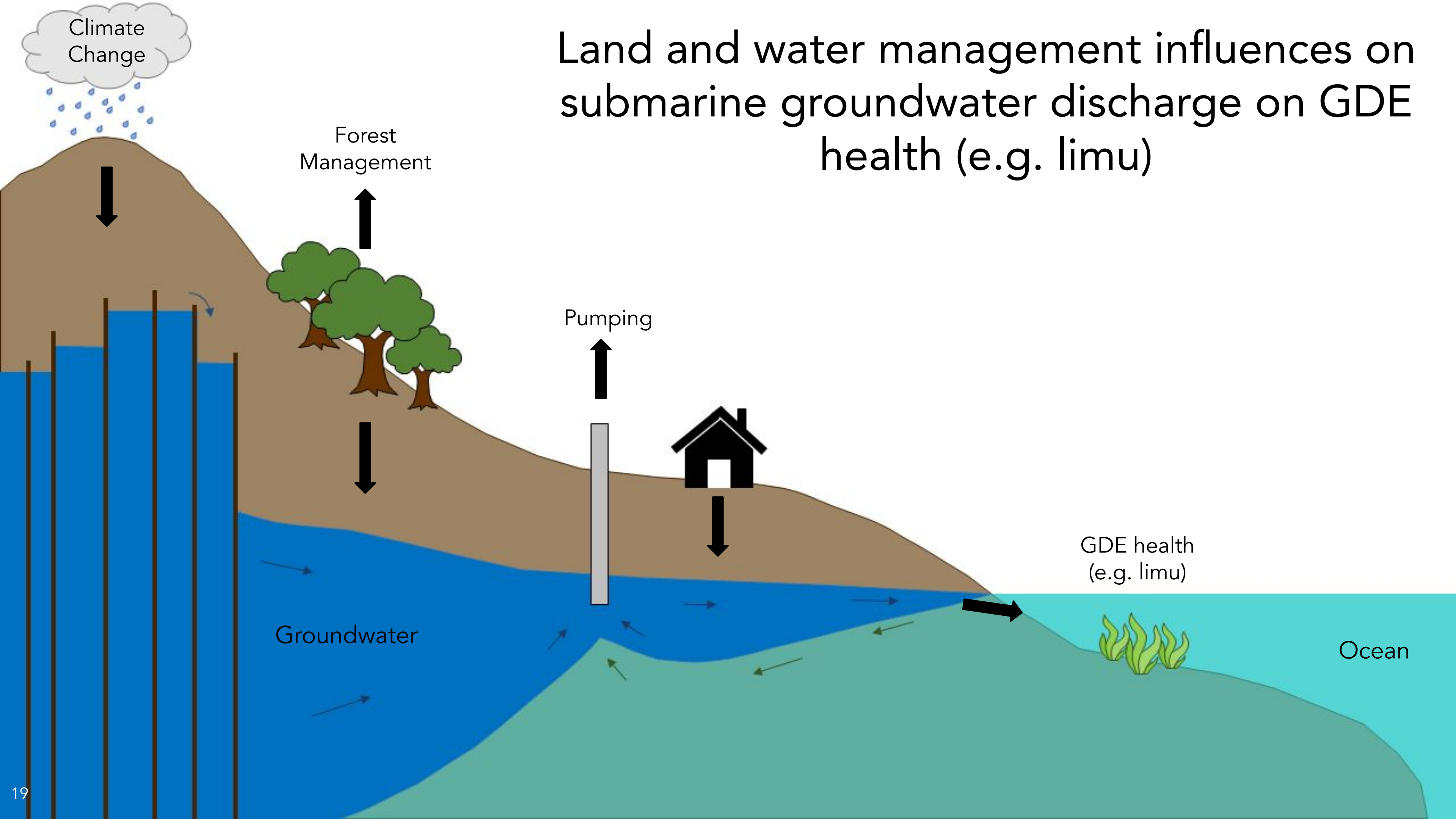




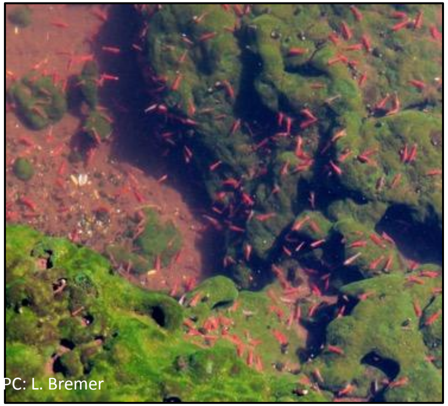


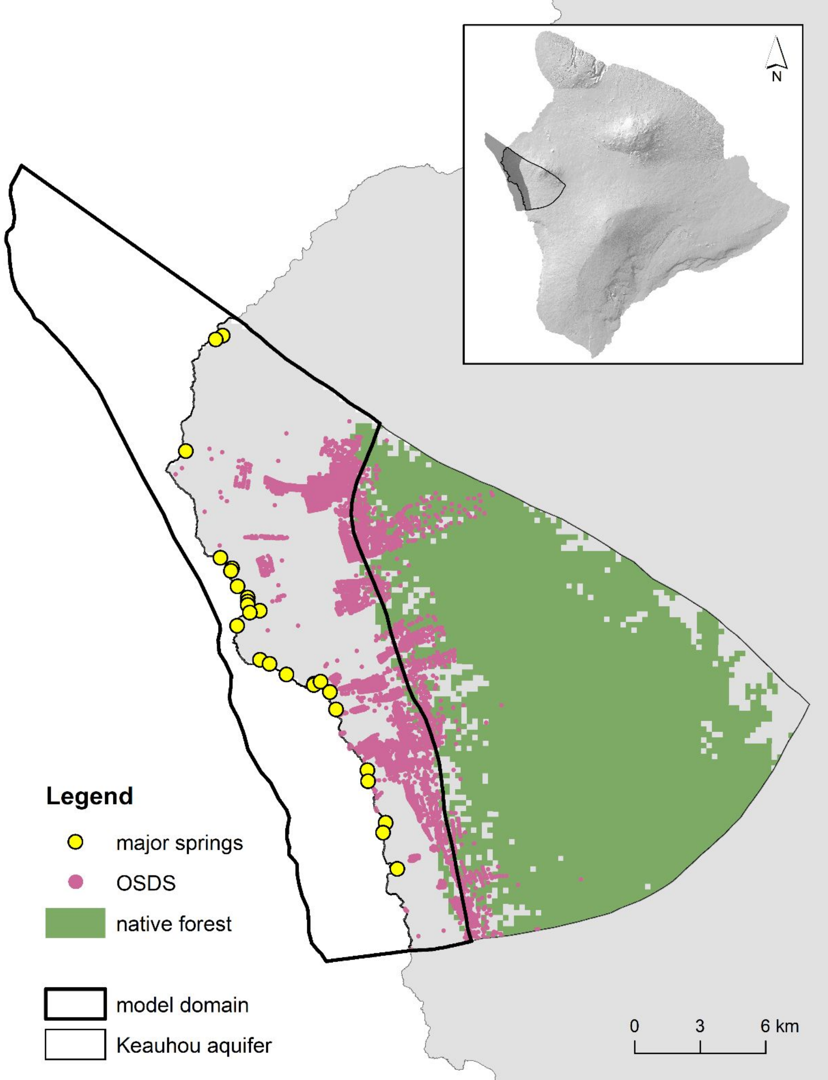


Land and water management influences on submarine groundwater discharge on GDE health (e.g. limu)



Study Area:
Keauhou Basal Aquifer





Research Objectives

1. Understand the relative influence of a dry future climate (RCP 8.5 mid-century), groundwater pumping, and native forest protection on nearshore water quality.

2. Assess how changes in nearshore water quality could impact the distribution and abundance of limu pālahalaha (*Ulva lactuca*), and an invasive seaweed (*Hypnea musciformis*).

SPACE SCIENCES

Water Resources Research

RESEARCH ARTICLE

10.1029/2023WR034593

Key Points:

- Lab and field data were combined with land-sea modeling to assess growth of a native and an invasive macroalgae under environmental change

Effects of Multiple Drivers of Environmental Change on Native and Invasive Macroalgae in Nearshore Groundwater Dependent Ecosystems

B. K. Okuhata[1,2], J. M. S. Delevaux[3,4,5], A. Richards Donà[1,6], C. M. Smith[6], V. L. Gibson[1,6], H. Dulai[1,2], A. I. El-Kadi[1,2], K. Stamoulis[5], K. M. Burnett[4], C. A. Wada[4], and L. L. Bremer[1,4]

scientific reports

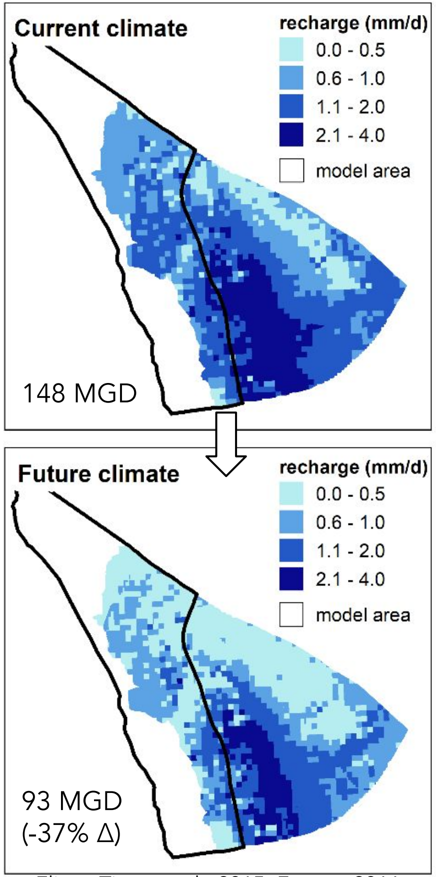
Check for updates

OPEN

Divergent responses of native and invasive macroalgae to submarine groundwater discharge

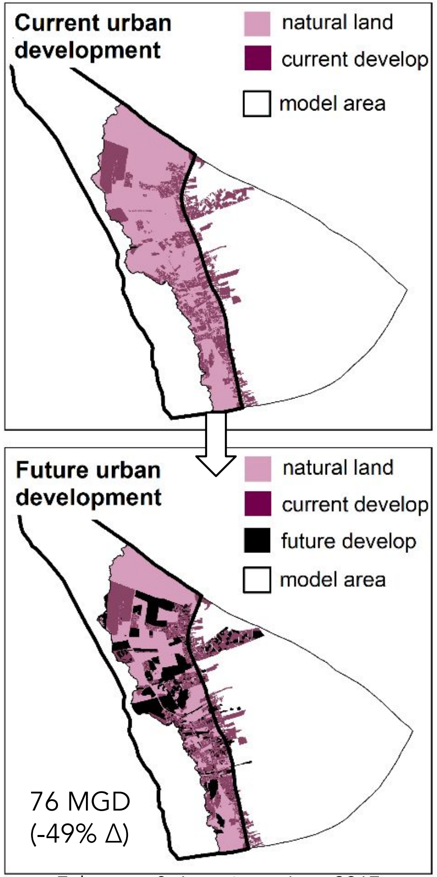
Angela Richards Donà[1✉], Celia M. Smith[1] & Leah L. Bremer[2,3]

Climate Change (RCP 8.5)



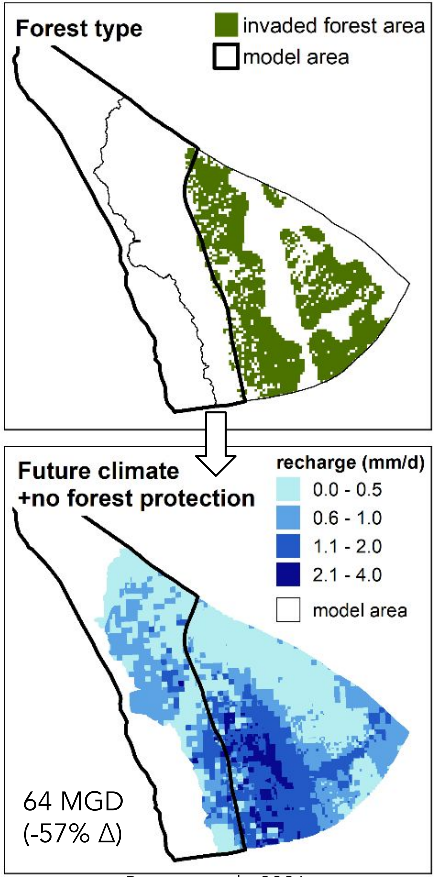
Elison-Timm et al., 2015; Engott, 2011

Urban Development



Fukunaga & Associates, Inc., 2017

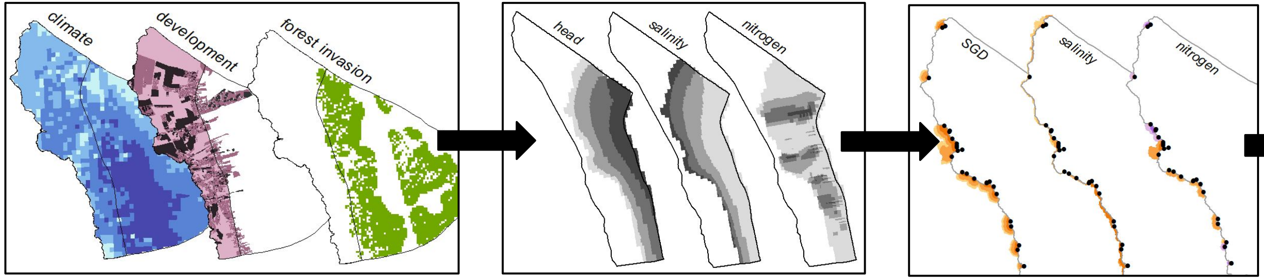
Native Forest Management

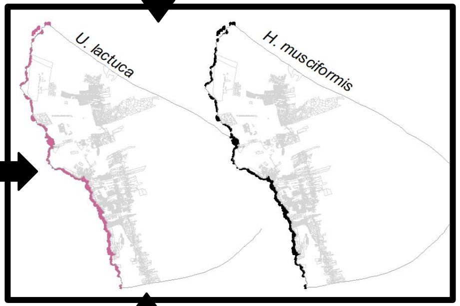


Bremer et al., 2021

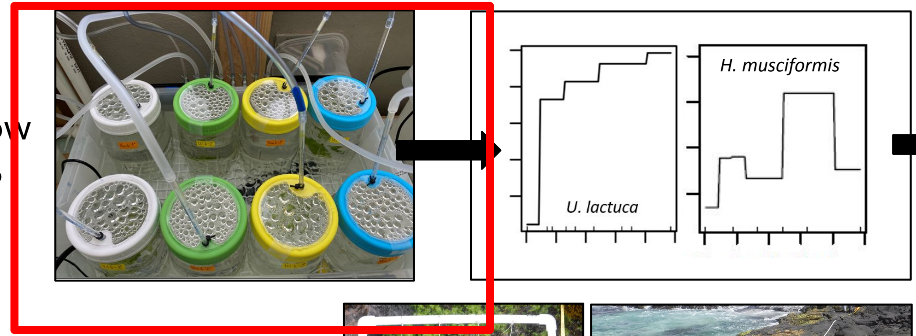
Land-sea modeling framework: Parallel workflows

Flow A





Flow B



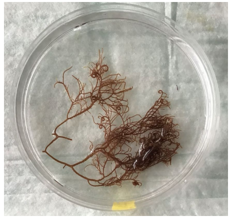
Built on previous modeling:

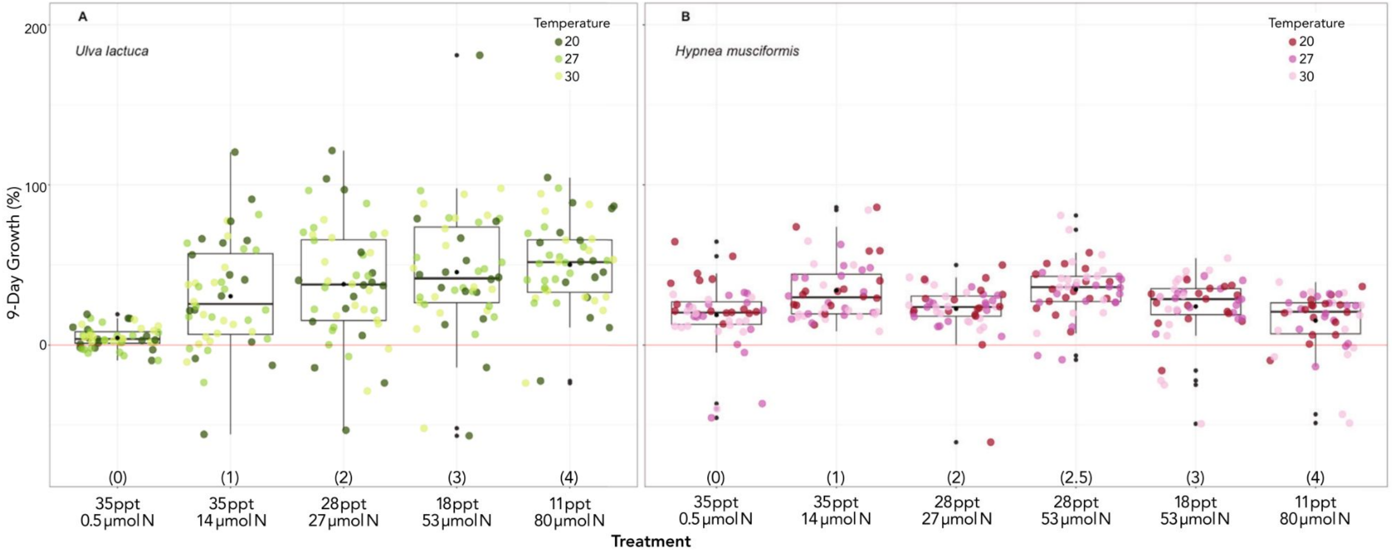
- *Okuhata et al. 2021*
- *Delevaux et al. 2018a,b*
- *Bremer et al. 2021*

Field Validation

Okuhata et al. (2023)

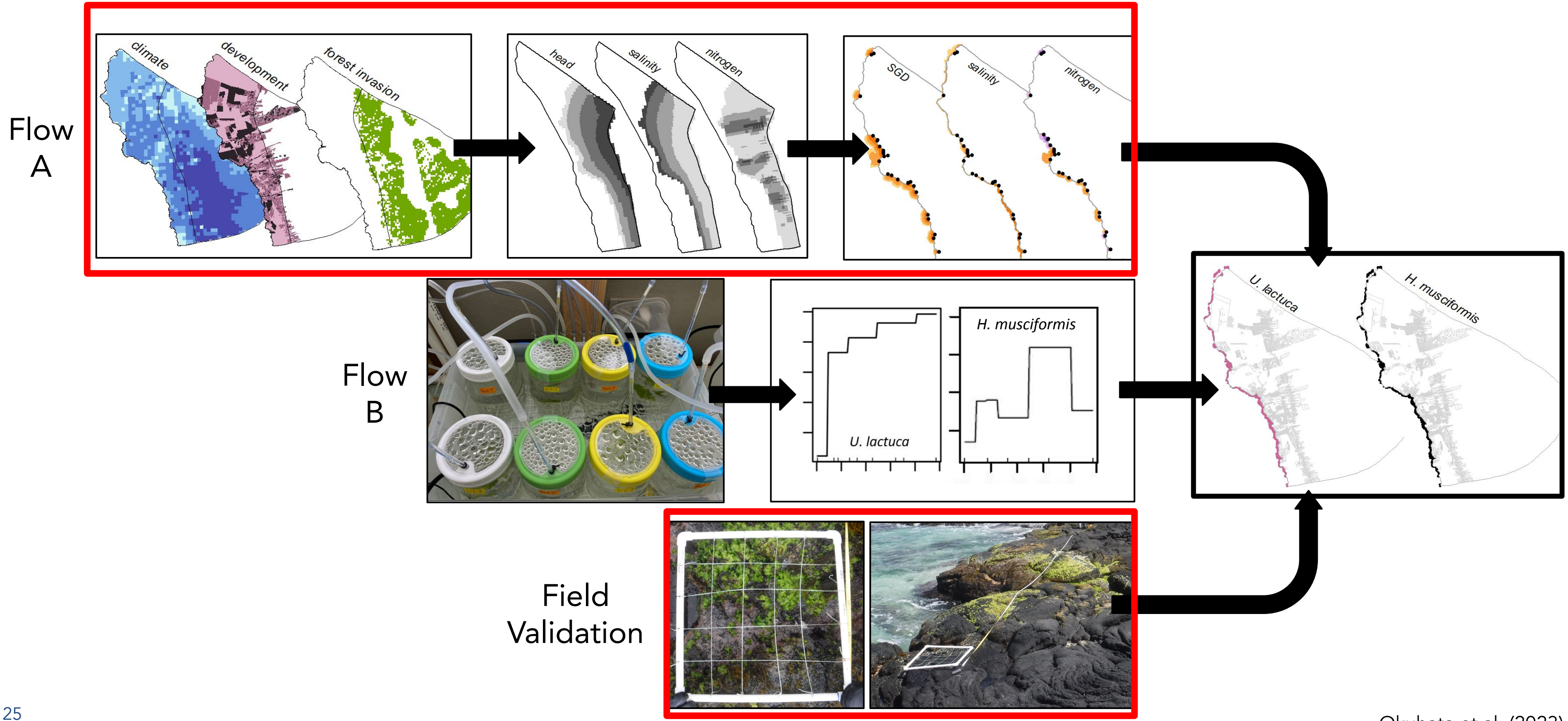
Ulva thrives in SGD conditions, *Hypnea* does not





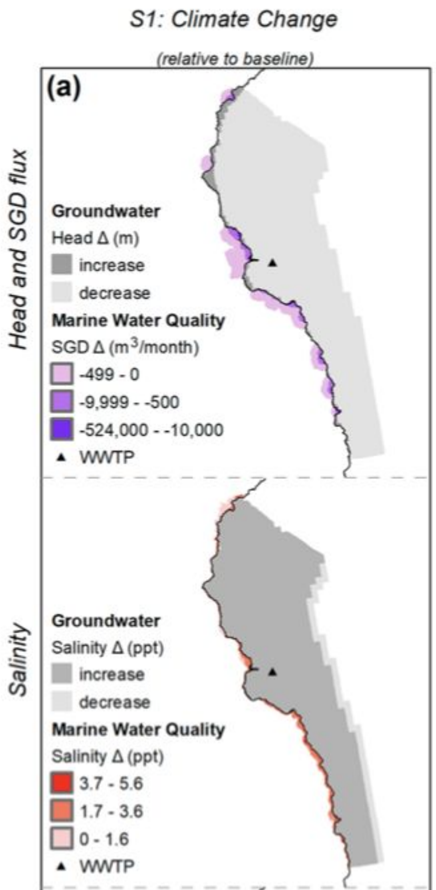
Richards Donà et al. 2023

Land-sea modeling framework: Parallel workflows

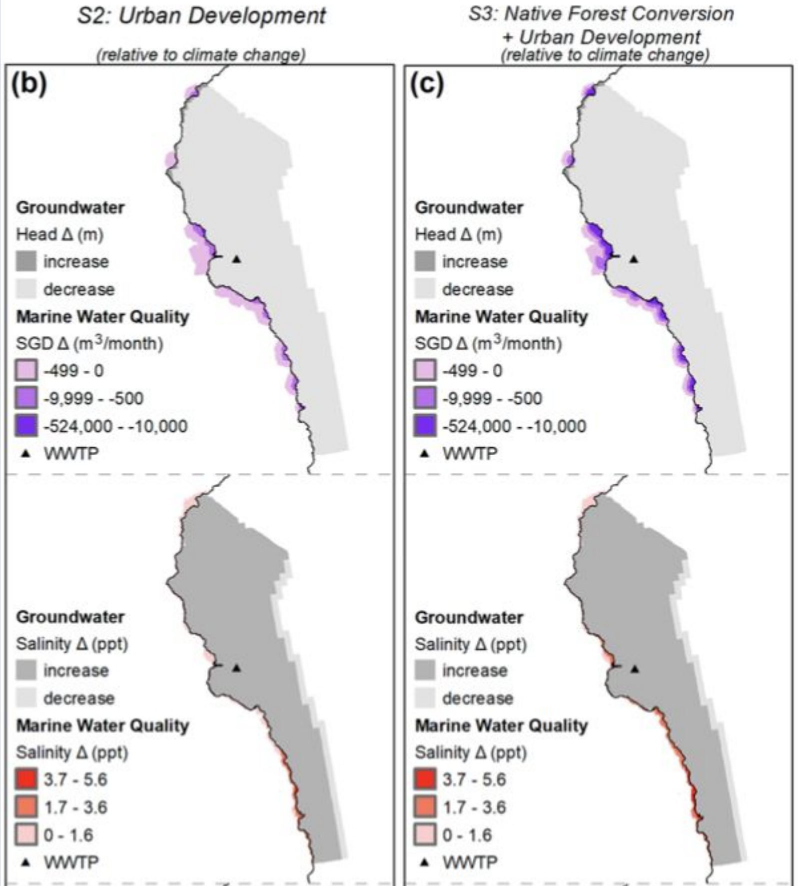


Okuhata et al. (2023)

Climate change, groundwater pumping, and conversion of native forest all reduce SGD and increase salinity



Climate change, groundwater pumping, and conversion of native forest all reduce SGD and increase salinity



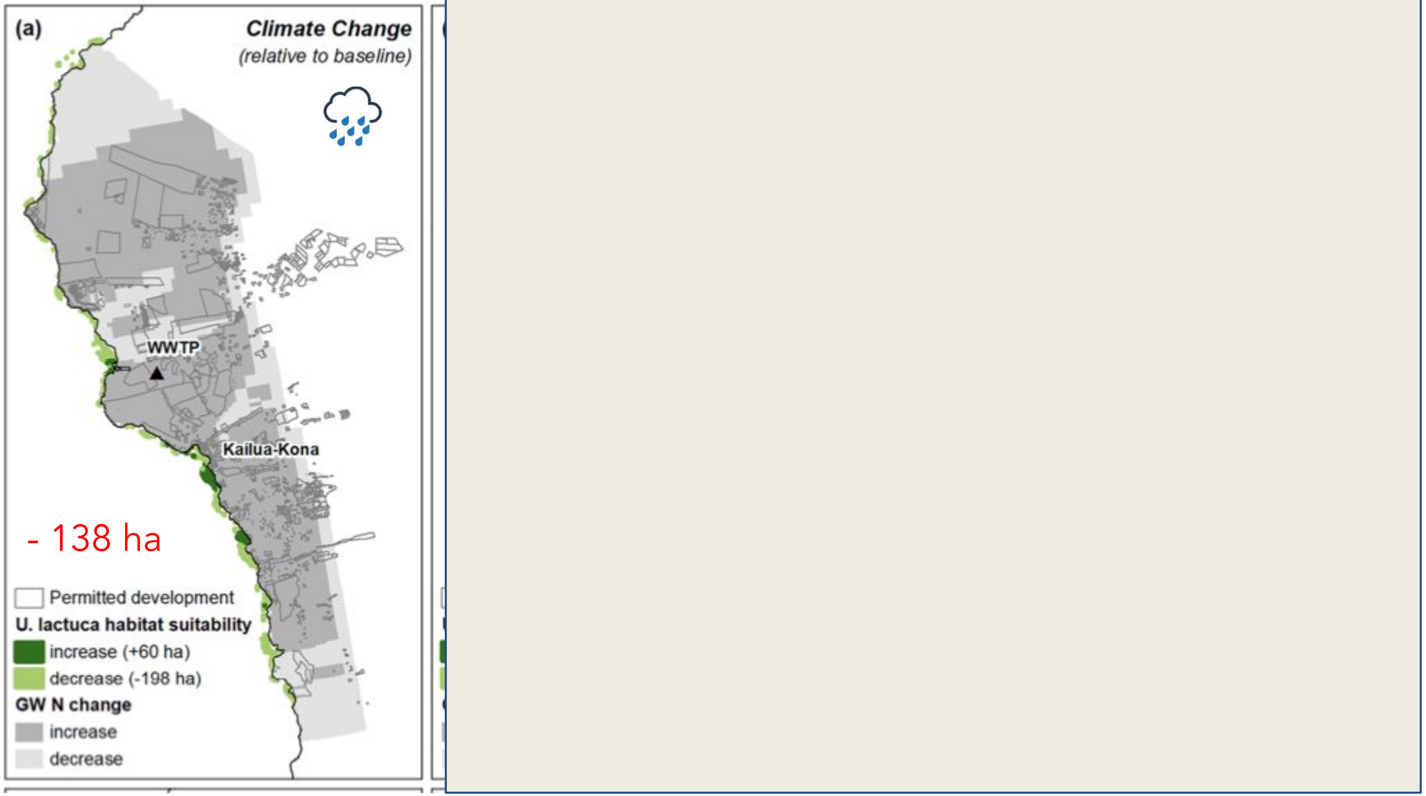
Scenario Comparisons:
Decrease SGD - Increase salinity - Increase nitrogen

Scenario	Change in groundwater parameter		
	SGD quantity (m^3/mo)	Average salinity (ppt)	Nitrogen (kg/mo)
Climate change (relative to baseline)	-255,000 (-7%Δ)	+2.5 (+15%Δ)	+120 (+3%Δ)

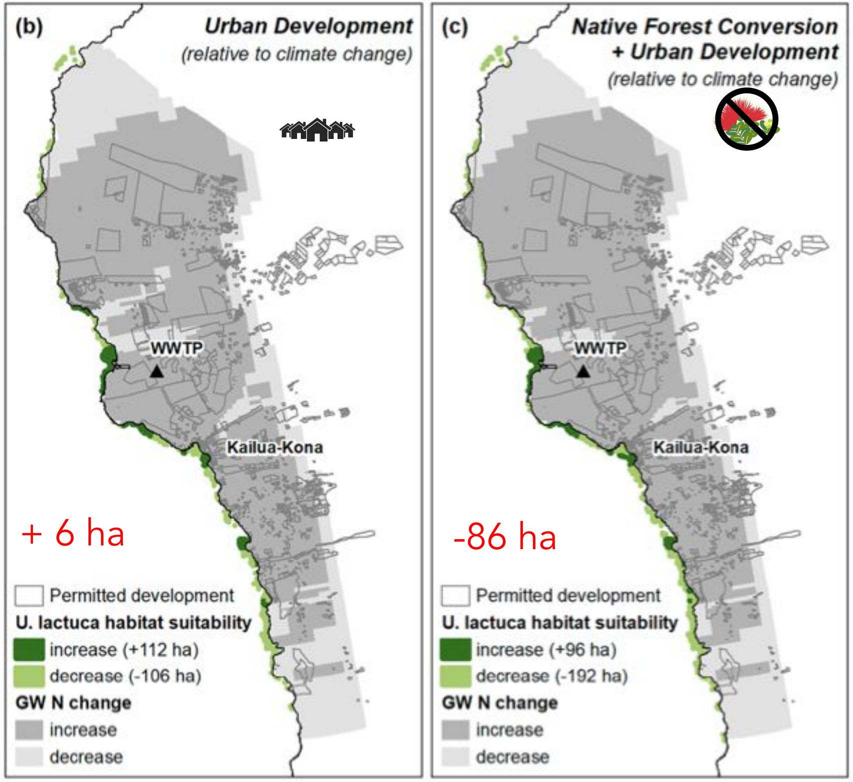
Scenario Comparisons:
Decrease SGD - Increase salinity - Increase nitrogen

Scenario	Change in groundwater parameter		
	SGD quantity (m^3/mo)	Average salinity (ppt)	Nitrogen (kg/mo)
Urban development (relative to climate change)	-162,000 (-5%Δ)	+1.6 (+8%Δ)	+5,000 (+107%Δ)
No forest protection + urban development (relative to climate change)	-255,000 (-8%Δ)	+2.6 (+13%Δ)	+5,700 (+122 %Δ)

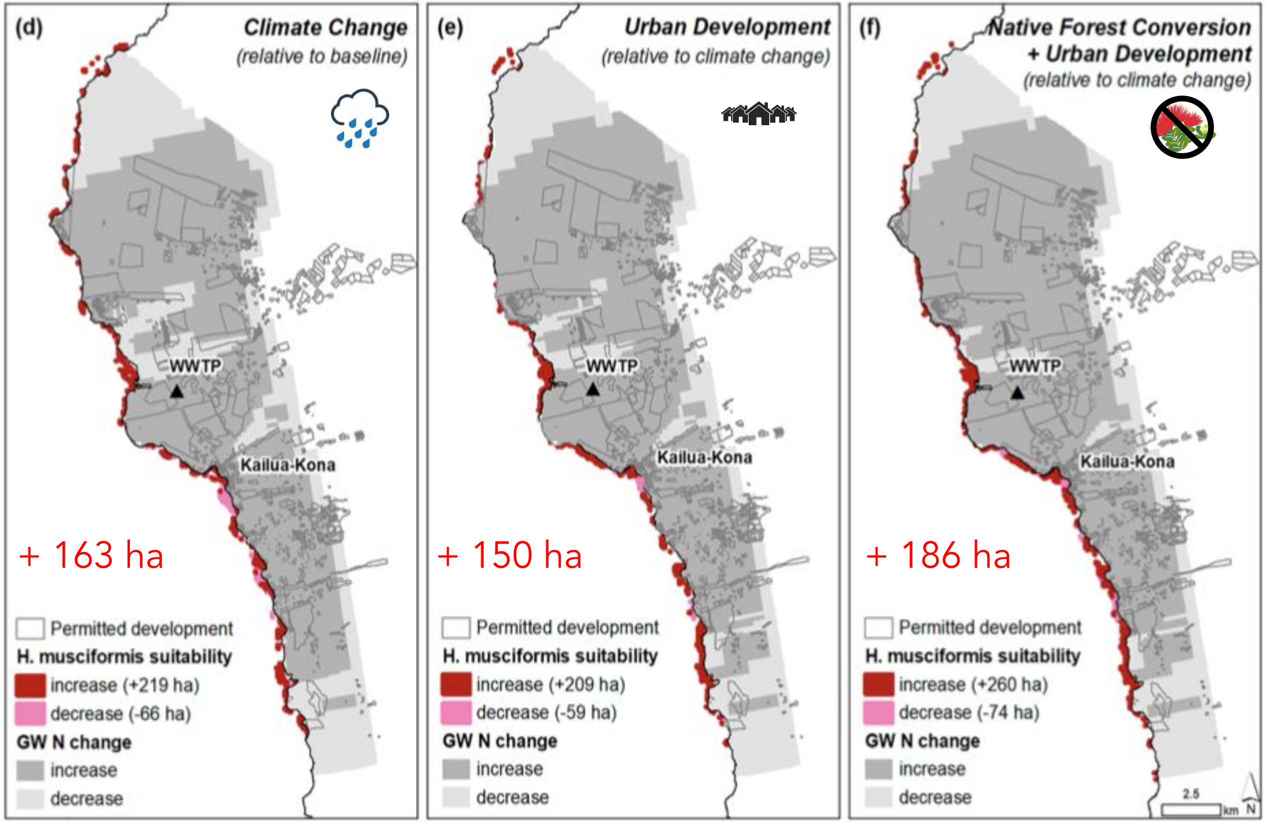
Increased salinity reduces habitat suitability for Ulva



Increased salinity reduces habitat suitability for Ulva



Increased salinity increases habitat suitability for Hypnea



Summary land-sea modeling

- Climate change, pumping and invasion of native forest all reduce SGD quantity and increase salinity. This decreases habitat for *Ulva* and increases it for *Hypnea*
- Implementation of sustainable groundwater management and forest protection are likely to be effective ways to maintain low SGD salinity that favors *Ulva* and probably other native coastal species.

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Conclusions

- Isotope ($\delta^{18}O$) results suggest inter-aquifer groundwater flow, isolated mauka to makai flows, and variation of water sources within aquifers
- Isotope results suggest strong connection between basal and high-level aquifers, and even with groundwater outside of the Keauhou aquifer
- Groundwater dependent ecosystems are critical public trust resources with high biocultural value that are influenced by changing SGD flows.
- A native limu species (limu pālahalaha) shows reduction in habitat with less SGD, whereas an invasive macroalgae (*Hypnea musciformis*) thrives in low SGD conditions.
- GDE health can be measured, monitored, and modeled and can support adaptive management

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Publications

- Watson, S. J., Arisdakessian, C., Petelo, M., Keliipuleole, K., Tachera, D. K., Okuhata, B. K., & Frank, K. L. (2024) Groundwater microbial communities reflect geothermal activity on volcanic island. Geobiology 22(2). https://doi.org/10.1111/gbi.12591
- Richards Donà, A., Smith, C. M., & **Bremer, L. L.** (2023). Divergent responses of native and invasive macroalgae to submarine groundwater discharge. *Scientific Reports*, *13*(1), 13984. https://doi.org/10.1038/s41598-023-40854-7
- Okuhata, B.K., Delevaux, J.M.S., Richards Donà, A., Smith, C.M., Gibson, V.L., Dulai, H., El-Kadi, A.I., Stamoulis, K., Burnett, K.M., Wada, C.A. and **Bremer, L.L.**, (2023). Effects of multiple drivers of environmental change on native and invasive macroalgae in nearshore groundwater dependent ecosystems. *Water Resources Research*, *59*(7), p.e2023WR034593. https://doi.org/10.1029/2023WR034593
- Dulai, H., Smith, C. M., Amato, D. W., Gibson, V., & Bremer, L. L. (2023). Risk to native marine macroalgae from land-use and climate change-related modifications to groundwater discharge in Hawaiʻi. *Limnology and Oceanography Letters*, *8*(1), 141-153. https://doi.org/10.1002/lol2.10232
- Watson, S. J., Arisdakessian, C., Petelo, M., Keliipuleole, K., Tachera, D. K., Okuhata, B. K., Dulai, H., & Frank, K. L. (2023) Geology and land use shape nitrogen and sulfur cycling groundwater microbial communities in Pacific Island aquifers. ISME Communications 3(1): 58. https://doi.org/10.1038/s43705-023-00261-5
- Gibson, V., **Bremer, L.L**, Burnett, K., Lui, N., & Smith, C. (2022). Biocultural values of groundwater dependent ecosystems in Kona, Hawaiʻi. *Ecology and Society*, *27*(3). https://doi.org/10.5751/ES-13432-270318
- Tachera, D. K. (2022) A Hydrogeochemical Examination of West Hawaiʻi's Water Cycle. Dissertation.
- Okuhata, B.K., A.I. El-Kadi, H. Dulai, J. Lee, C.A. Wada, **L.L. Bremer**, K.M. Burnett, J.M.S. Delevaux, C.K. Shuler (2022). A density-dependent multi-species model to assess groundwater flow and nutrient transport in the coastal Keauhou aquifer, Hawaiʻi, USA. Hydrogeology Journal, 30 (1), 231-250. https://doi.org/10.1007/s10040-021-02407-y.
- **Bremer, L.L.**, DeMaagd, N., Wada, C. A., & Burnett, K. M. (2021). Priority watershed management areas for groundwater recharge and drinking water protection: A case study from Hawai ʻi Island. *Journal of Environmental Management*, *286*, 111622.
- Wada, C. A., Burnett, K. M., Okuhata, B. K., Delevaux, J. M., Dulai, H., El-Kadi, A. I., Gibson, V., Smith, C., & **Bremer, L. L.** (2021). Identifying wastewater management tradeoffs: Costs, nearshore water quality, and implications for marine coastal ecosystems in Kona, Hawaiʻi. *Plos One*, *16*(9), e0257125. https://doi.org/10.1371/journal.pone.0257125
- Tachera, D. K., Lautze, N. C., Torri, G., & Thomas, D. M. (2021) Characterization of the isotopic composition and bulk ion deposition of precipitation from Central to West Hawaiʻi Island between 2017 and 2019. Journal of Hydrology: Regional Studies 34.

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