

The role of crab burrows as preferential conduits for tidal water in low hydraulic conductivity mangrove peat in Everglades National Park, Florida, USA

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Introduction

Mangroves are adapted for harsh marine conditions by excluding salt from root water uptake. However, lower sediment salinity is less metabolically stressful to mangroves. Mangrove root peat in the southwestern coastal estuaries of Everglades National Park has a low hydraulic conductivity 0.23 m/d (Anderson, 2001). Burrowing crabs create preferential conduits by tunneling, allowing tidal flood water to flush out the upper 25 cm peat soil matrix, reducing porewater salinity near mangrove fine rootlets (figure 1).



Figure 1. “Engineers of the mangrove” Left: Mud crab (*Eurytemora*, sp.); Right: Fiddler crab (*Uca*, sp.). Photo credits: K. Balentine and T. Enright.

Susilo and Ridd (2005) reported crab holes can increase hydraulic conductivity (k) through mangrove peat by more than ten times. Crab burrows reduce diffusion distances within the soil and provide an efficient mechanism for removal of excess salt accumulated in the soil around mangrove roots due to exclusion (Stieglitz, 2000).

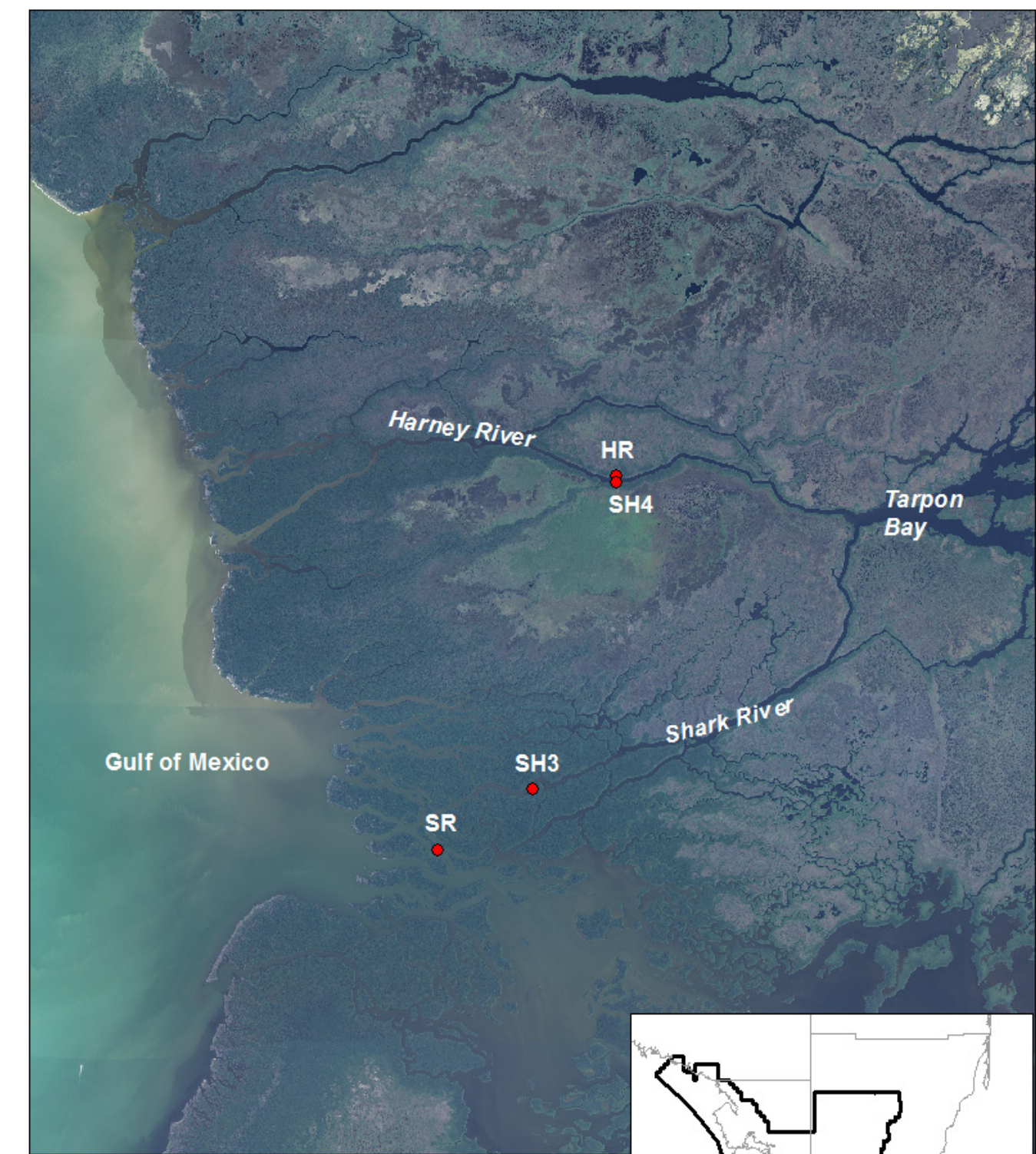


Figure 2. Two study sites: SH4-HR, a mid-reach estuary site on the Harney River and SH3-SR, a lower-reach estuary site on the Shark River.

In addition to sediment salt removal, tidal flushing increases soil aeration, reduces sulfides and ammonium, enhances the nitrogen cycling by bacteria and increases mangrove sapling productivity (Smith et al, 1991 and Vopel and Hancock, 2005).

Along the Shark-Harney estuary (figure 2) mean burrow density was 64.2 per m² (Whelan, 2005) and sampled burrow resin casts typically had three entrances (figures 3 and 4) with an estimated void space volume of 3 to 6 L/m² in the upper 25 cm of sediment (Balentine et al, 2007).

Study question

Can salinity flux be used to show if crab burrows facilitate preferential flow in low hydraulic conductivity mangrove peat?

Study location

Two Everglades mangrove estuary sites were selected based on long-term hydrologic data availability: Lower-reach site SH3 on the Shark River and mid-reach site SH4 on the Harney River (figure 2).

Methods

Two study methods were used to evaluate salinity change in Practical Salinity Units (PSU) from tidal flushing: 1). Comparing variability of mangrove surface water salinity with adjacent river salinity; 2). Construct artificial crab burrows to monitor salinity change over tidal cycles.



Figure 3. Crab burrows in mangrove peat at site SH3. Photo credits: G. Anderson.

Mangrove-river salinity comparison

High frequency (15 min. interval) mangrove water level and salinity data from USGS long term hydrology gages (SH3, SH4) and adjacent NPS river gages Shark River (SR) and Harney River (HR) from water-years 2009 - 2011 were used for this comparison (Water year = Oct. thru Sep.).

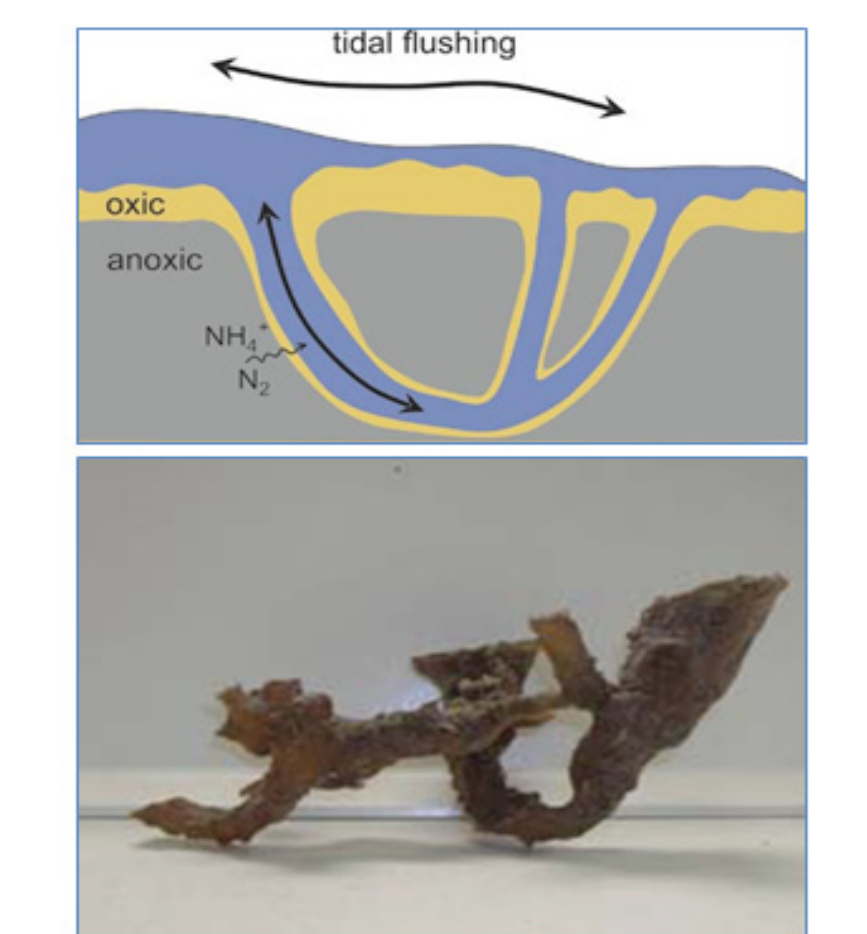


Figure 4. Top: Burrow tidal flushing pattern (Vopel and Hancock, 2005). Bottom: Resin burrow cast from Shark River. Photo credit: K. Balentine.

Salinity values were segregated by mangrove surface water levels. When water levels were below local ground surface elevation (GSE), corresponding mangrove surface water salinity were grouped as “Below GSE”; and when surface water levels were between GSE and 0.1 ft. above local GSE, salinity was grouped as “0.1 ft. above”. Salinity values “0.1 ft. above” represented the transitional surface flooding period when crab burrows were actively flushed.

Artificial Crab Burrows

As a pilot study in March 2012, we constructed three replicate PVC artificial crab burrow (ACB) array near SH3. Each ACB was constructed to simulate an actual burrow (figures 3, 4, 8 and 10). A salinity sensor set in each ACB recorded values at 15 min. intervals.

Results

Mangrove-river salinity

Mid-reach estuary site SH4 “below GSE” and “0.1 ft. above” averaged monthly salinity showed no statistically significant differences with HR salinity (figure 6).

SR salinity did show statistically significant differences with mid-reach estuary site SH4 “below GSE” ($z=2.65$, $p<0.01$) and “0.1 ft. above” ($z=2.73$, $p<0.01$). The difference between SR salinity and SH3 salinity may be an artifact of higher seasonally averaged monthly salinity at SR (23 PSU) than observed at SH3 in the “0.1 ft. above” data (19.6 PSU).

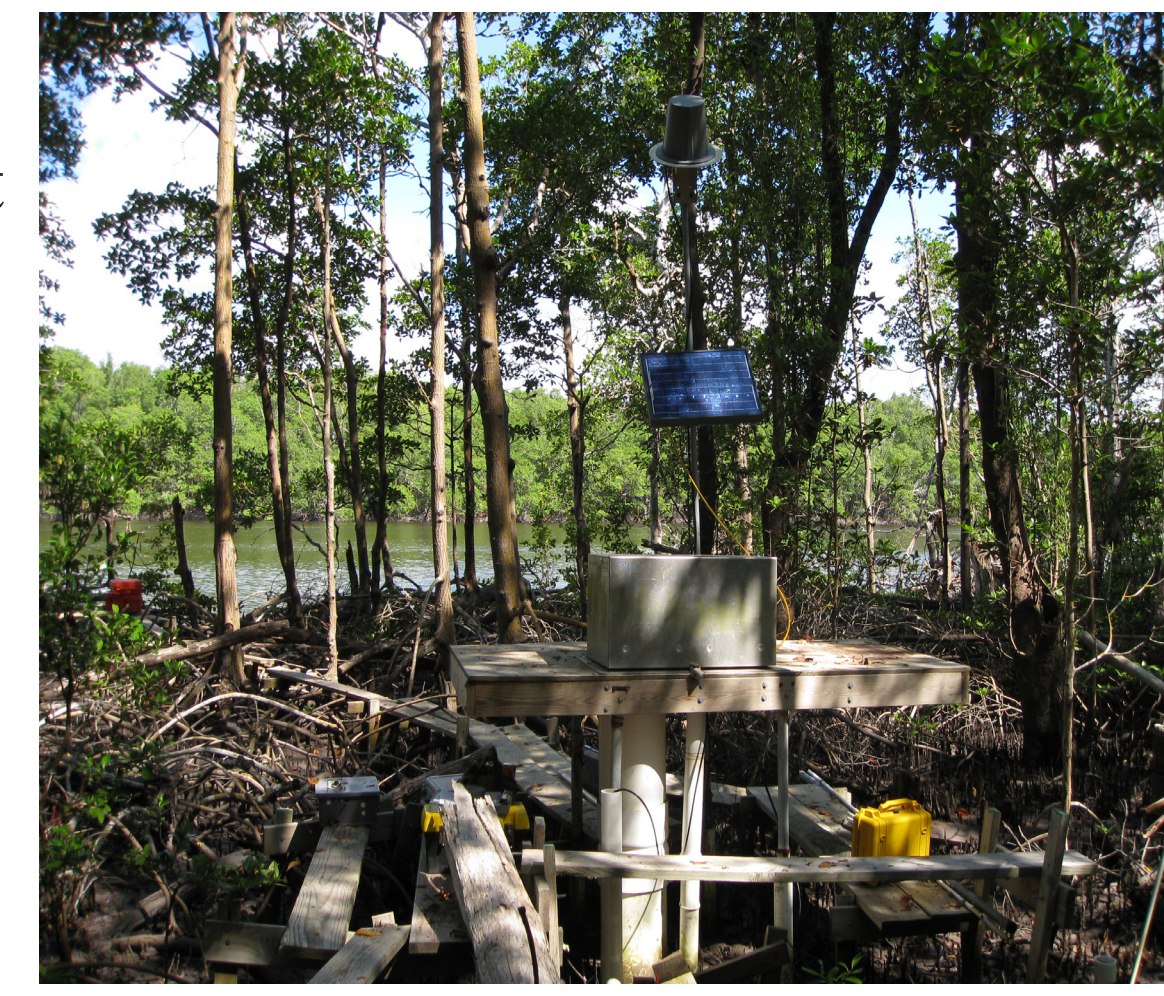
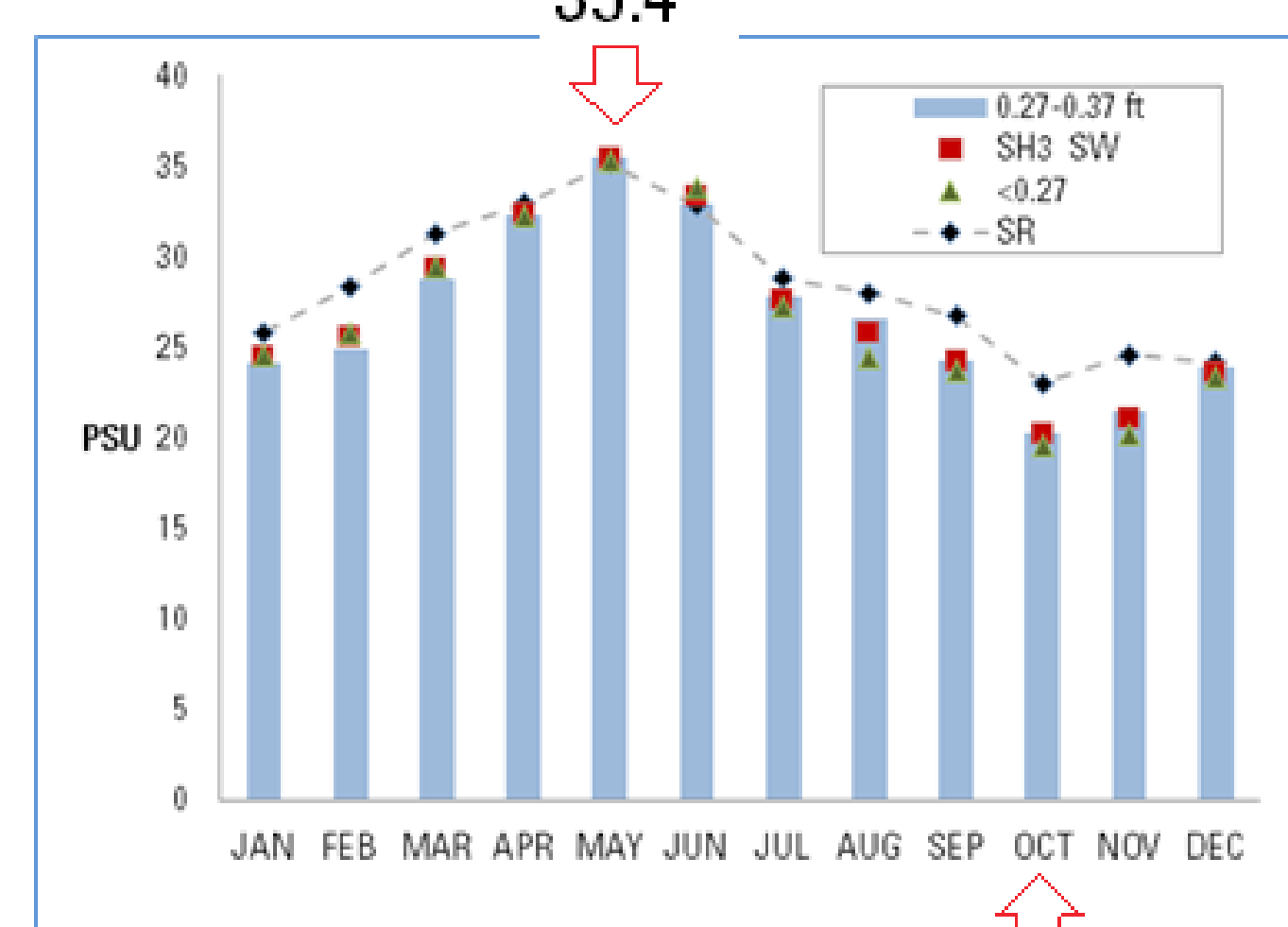
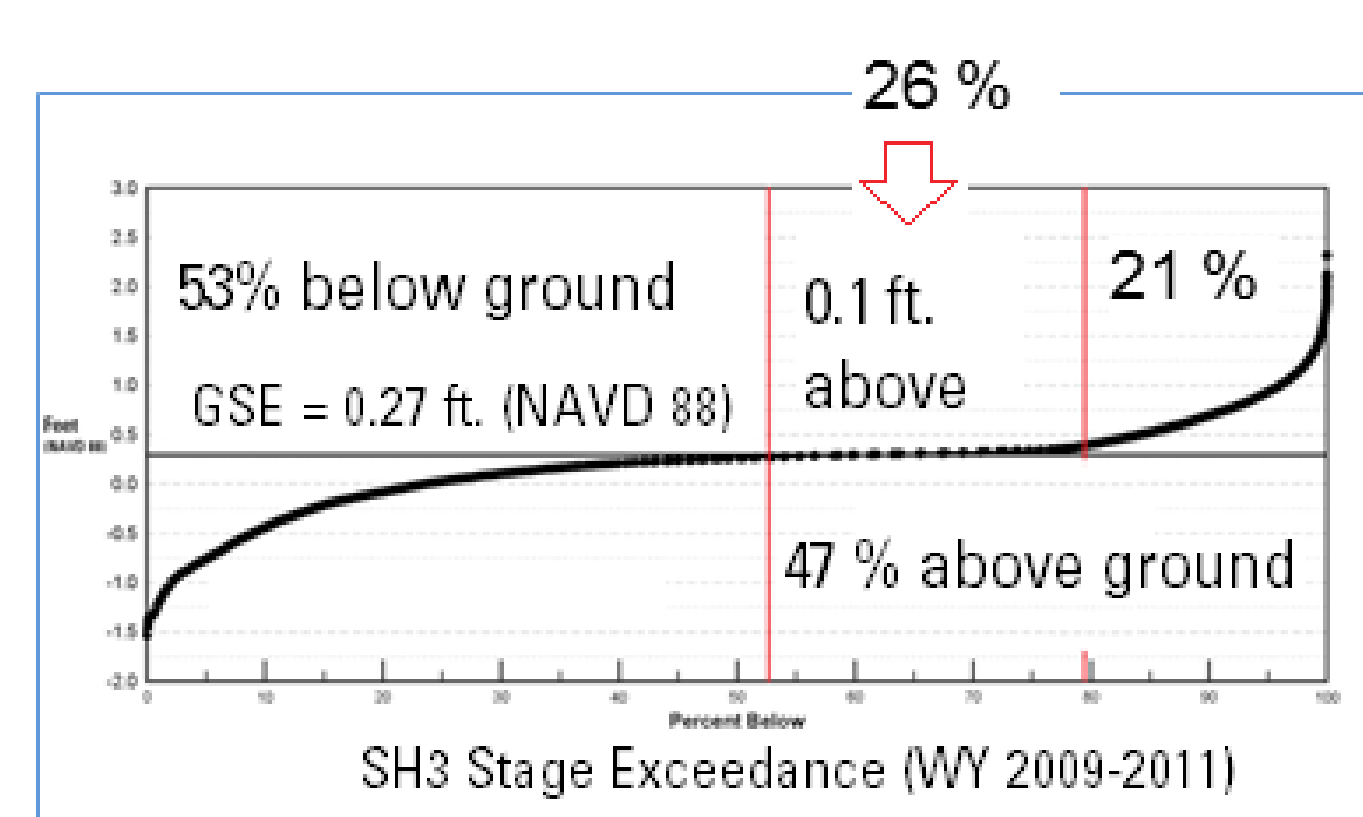


Figure 5. Shark 3 (SH3) ~ 30 m from river. Gage records surface water levels and salinity. Parsed salinity values were used from slightly above GSE (0.1 ft.) as a proxy for tidal burrow flushing. Photo credit: G. Anderson.

Regardless of the analysis limitations, there were a few important observations:

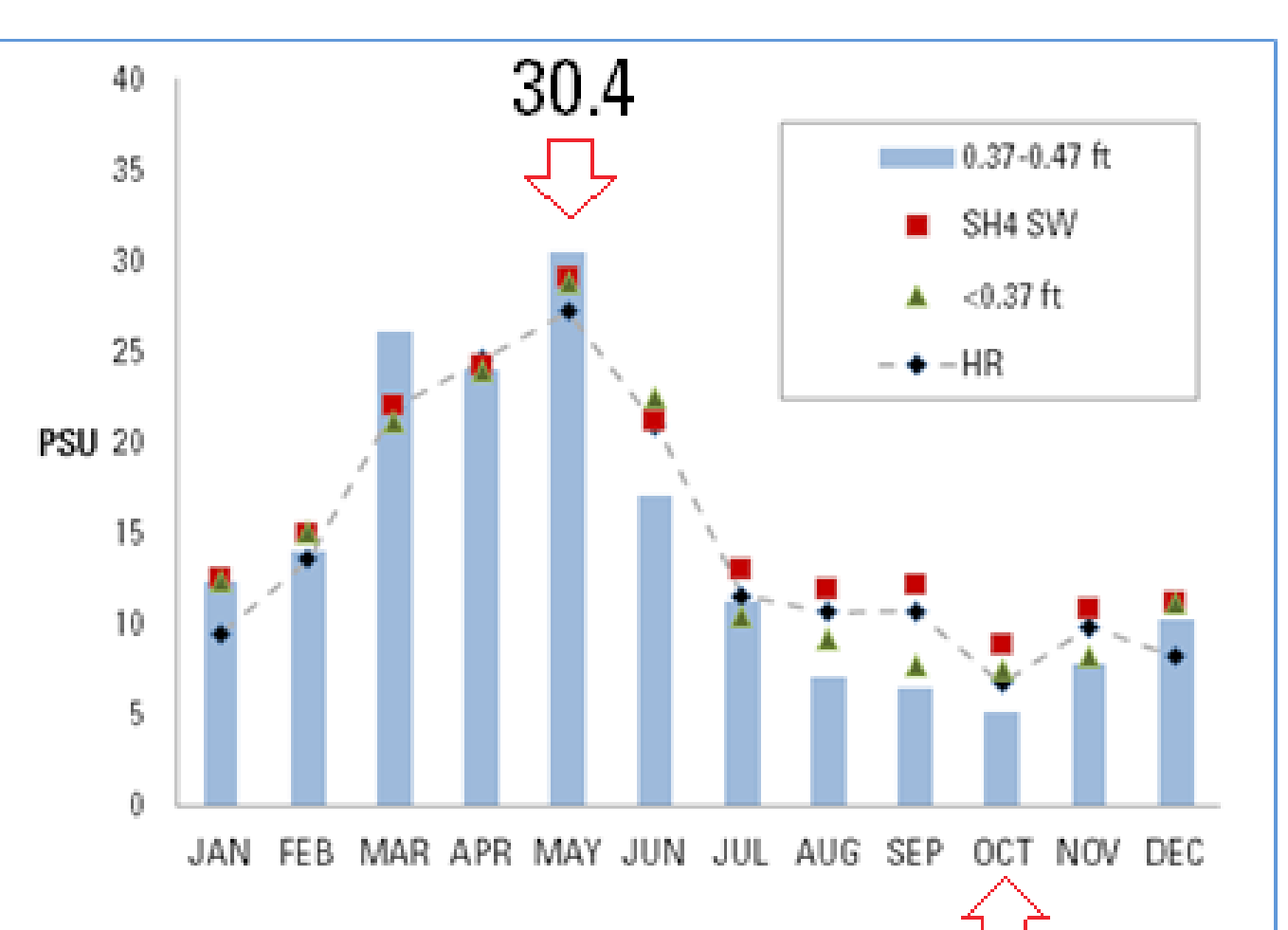
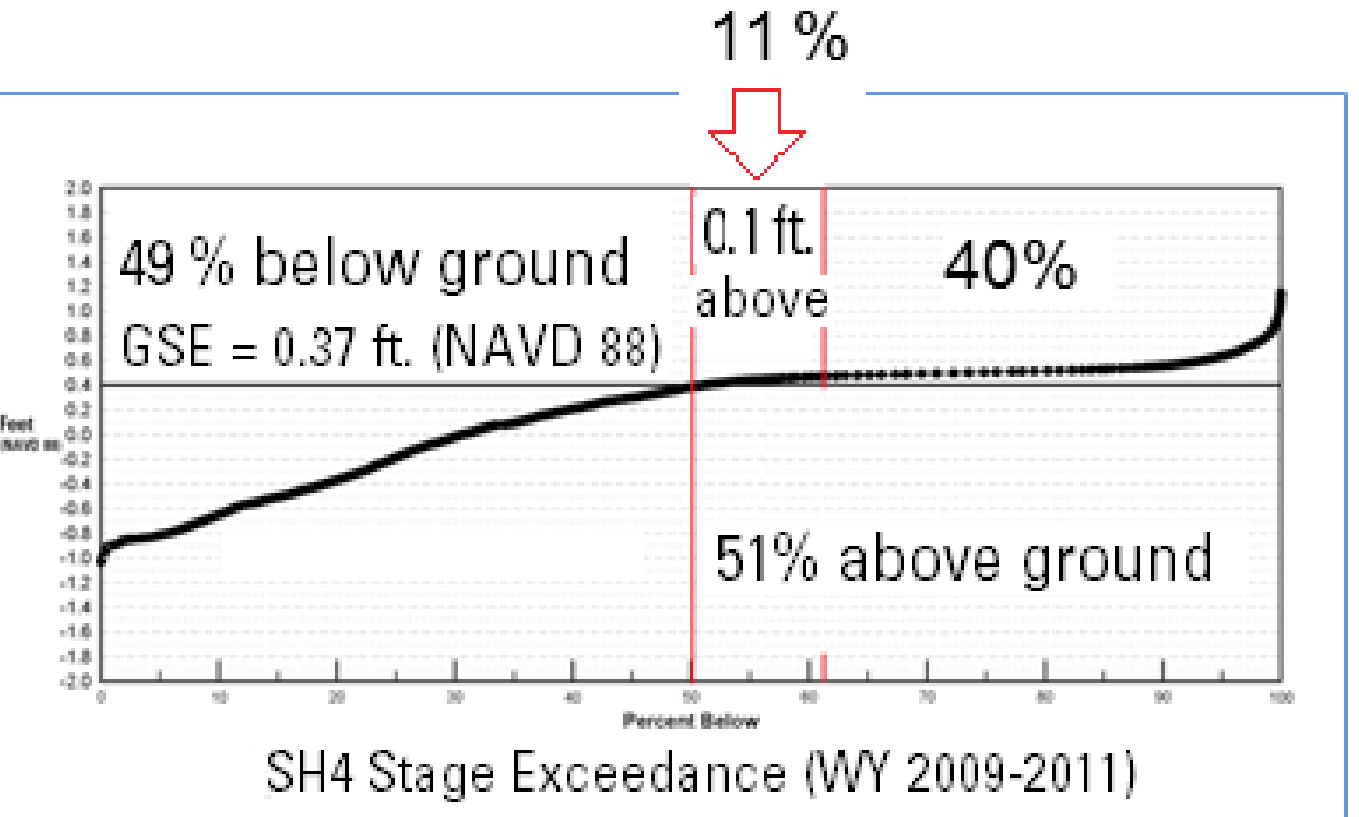
- During the burrow flushing transition period, “0.1 ft. above” averaged monthly salinities at SH3 and SH4 both showed higher salinities during the dry season (May) and lower salinities in the wet season (October) than “below GSE” or river salinities (figure 6).
- SH3 showed twice the transitional (0.1 ft. above) surface water exceedance duration than SH4 (26% to 11%) allowing for more diurnal burrow flushing, yet SH3 had less overall surface water exceedance duration (47% to 51%) than SH4 (figure 6).
- SH3 with a diurnal tidal flooding pattern had less burrow (proxy) seasonal salinity variability from daily salinity mixing of river water.
- SH4 with a spring tide flooding pattern (biweekly) had less burrow tidal flooding, but more burrow water dilution and more wet season salinity variability from rain and overland flow.

Lower-reach estuary site (SH3)



Site SH3	SH3 Gage		Below GSE		GSE=0.1 ft.		Shark River	
	Month	PSU	Month	PSU	Month	PSU	Month	PSU
Avg high month	May	35.35	May	35.22	May	35.48	May	35.09
Avg low month	Oct	20.12	Oct	20.23	Oct	19.62	Oct	23.03
Avg (2009-2011)		26.69		26.68		26.62		26.47

Mid-reach estuary site (SH4)



Site SH4	SH4 Gage		Below GSE		GSE=0.1 ft.		Harney River	
	Month	PSU	Month	PSU	Month	PSU	Month	PSU
Avg high month	May	29.8	May	28.76	May	30.45	May	27.18
Avg low month	Oct	8.86	Oct	7.75	Oct	5.17	Oct	6.76
Avg (2009-2011)		15.98		14.34		14.69		14.62

Figure 6. (Top charts) Burrow flushing period (WY2009-2011) at lower-reach estuary SH3 represented 26% of the 47% of overbank surface water exceedance, whereas, mid-reach estuary represented only 11% of the 51% of overbank surface water exceedance at site SH4. (Middle charts) Both SH3 and SH4 averaged monthly salinities had a right-skewed distribution pattern with highest salinities in May and lowest in October. (Bottom table): SH3 and SH4 averaged monthly salinity seasonal as well as maximum and minimum values.

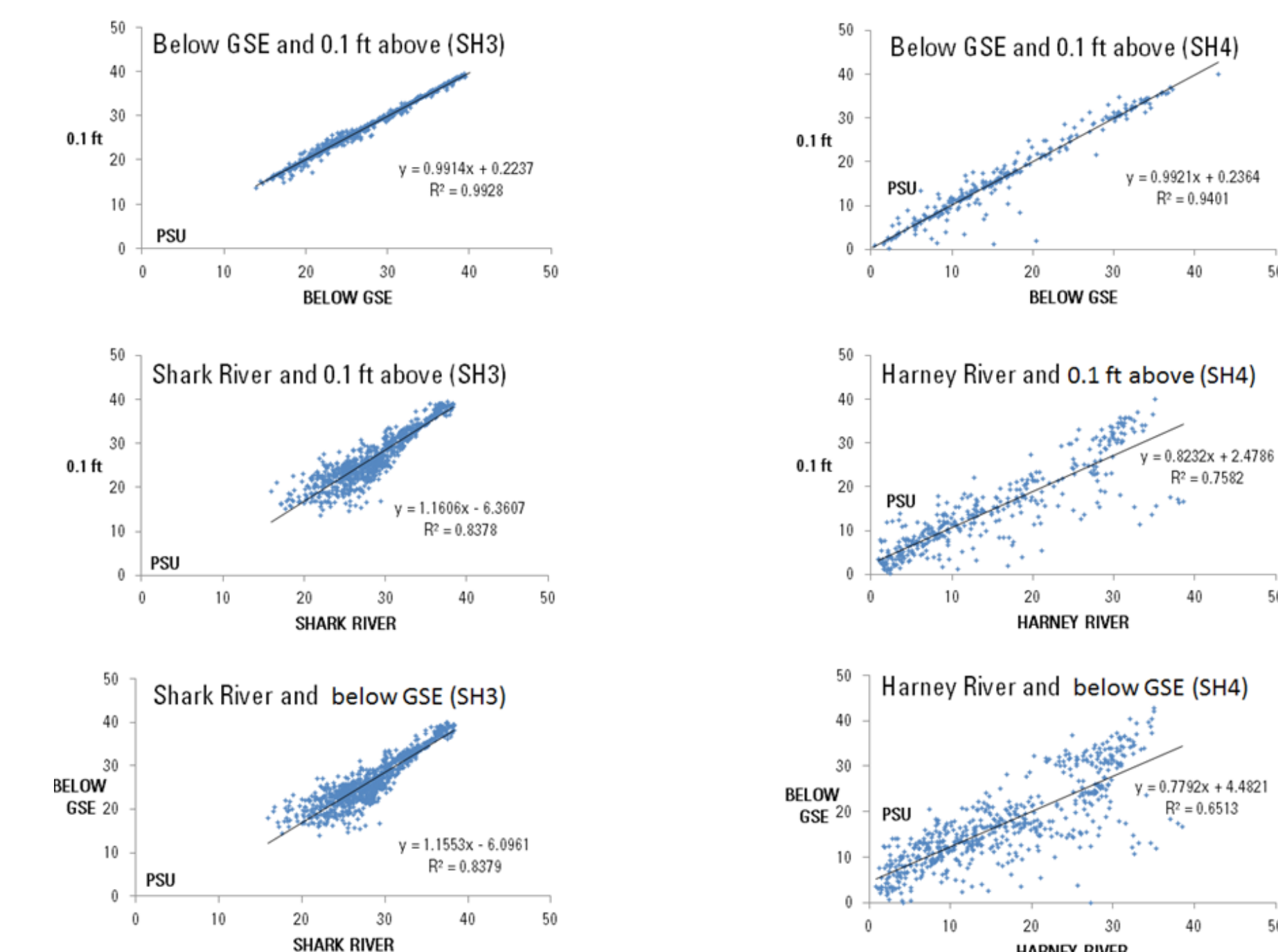


Figure 7. Left, SH3 (Top) Strong relationship suggests well-mixed from tidal flooding. (Middle and Bottom) Mean salinities are significantly different with river. Right, SH4: (Top) Strong correlation suggests site salinity well-mixed. (Middle and Bottom) Mean below GSE and 0.1 ft salinity high variably with no significant difference with river.

Artificial Crab Burrows



Figure 8. Artificial Crab burrow (ACB) pilot study: (left to right): PVC pipe ACB prototype, small pipe acts as a burrow with an inter-connected larger pipe where salinity sensor is placed; Field installation of ACB into the mangrove peat; Functional ACB with water (arrow shows burrow) in artificial burrow. Photo credits: G. Anderson.

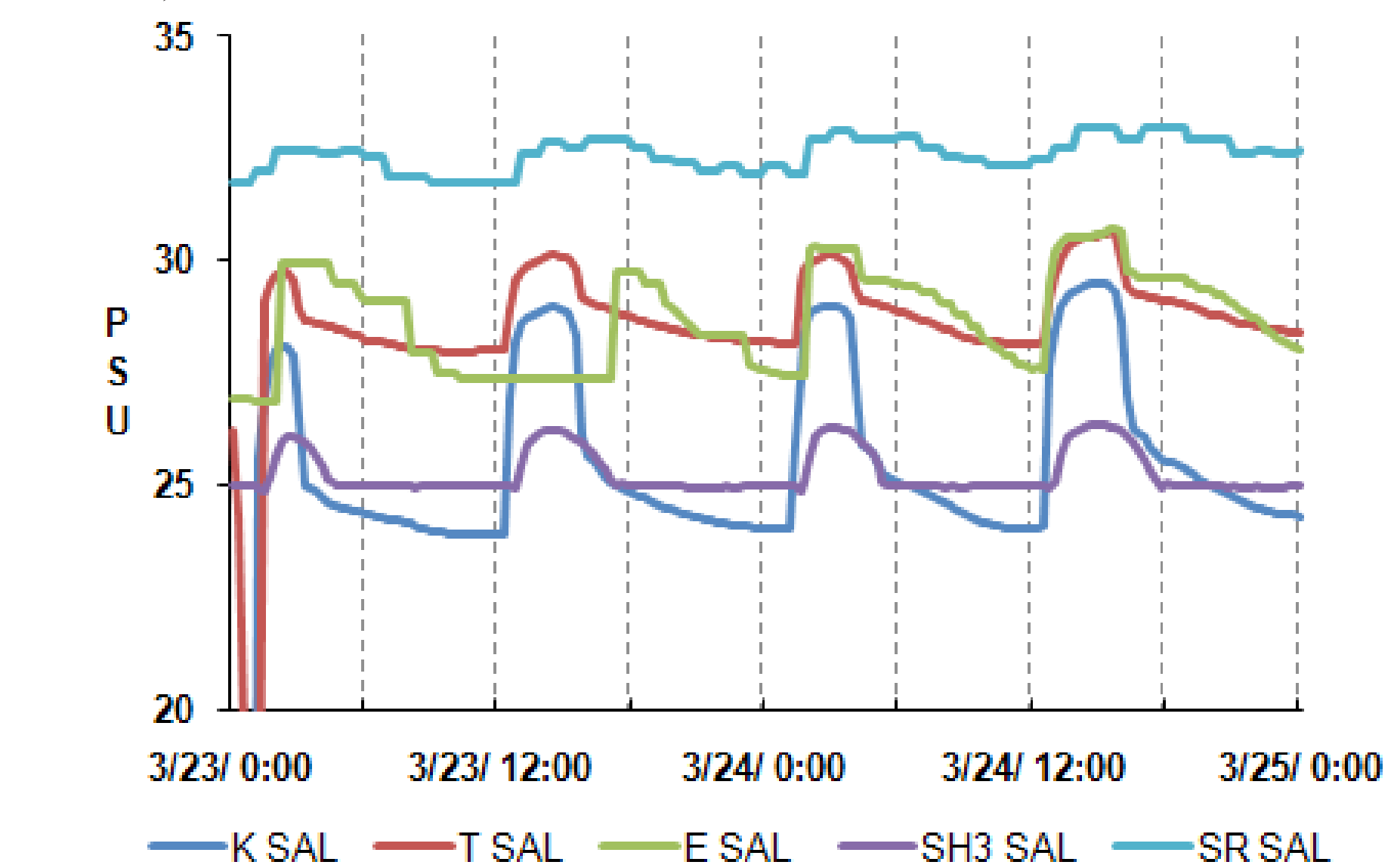


Figure 9. Comparison of ACB and Shark River salinities during four tidal cycles (March 23-25, 2012). Note: SH3 surface water salinity ~30 m from river bank does not capture (flat line during low tide) the full extent of the salinity variability of the three replicates only 3 m from bank. River salinity higher values are primarily an artifact that SR is 3 km closer to the Gulf of Mexico than SH3 site.

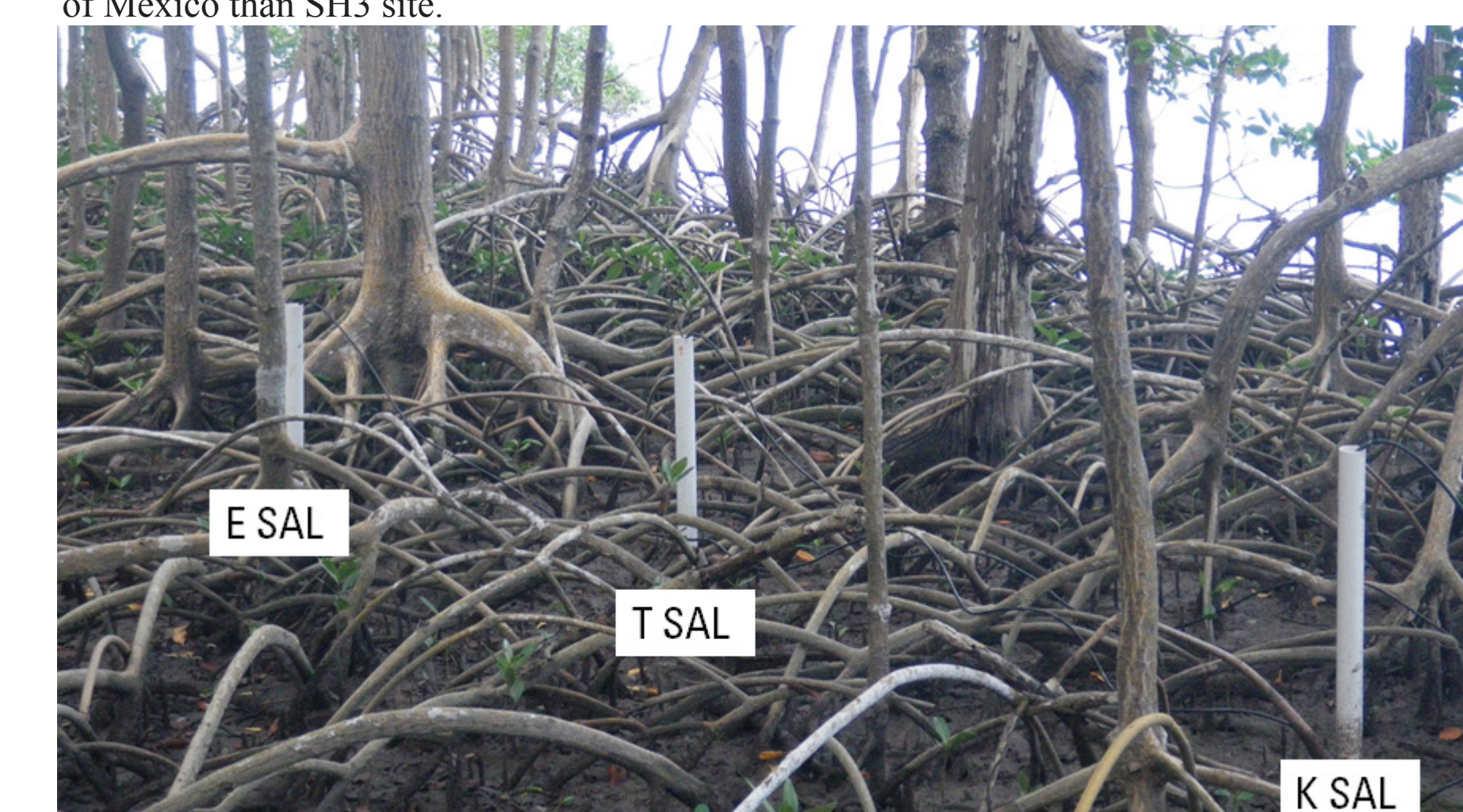


Figure 10. Three Artificial Crab Burrows (ACB) laid out 3 m apart and parallel the Shark river bank by 3 m. Site is typically tidal inundated twice daily. Photo credits: G. Anderson.

Discussion

The sustainability of Everglades mangroves in rising sea levels is an important ecological concern. The role of crab burrows as a mechanism to regulate sediment salinity and nutrient exchange, enhancing mangrove productivity, could be a useful indicator for evaluating the ecological health of the coastal Everglades.

The usefulness of surface water salinity as a proxy for burrow flushing exchange during overbank transitional tidal flooding is promising, especially if incorporated with other investigative methods, such as tracer dyes, time-lapse photography, dissolved oxygen measurements, burrow flushing model simulation and over bank current velocities (Hollins et al, 2009; Ridd et al, 2001; Stieglitz et al, 2000 and Xin et al, 2009).

In mangrove forests, an effective alternative to traditional long term salinity monitoring is the installation of instrumented ACB arrays. These systems offer salinity data that is readily interpretable with respect to tidal flushing and root zone salinity, providing data on coastal ecosystem health in times of sea level rise and climate change.

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