Estuarine environments often demonstrate variable S and carbonate system decoupling, with special attention previously given to pH and pCO2 disruptions from freshwater riverine, or hurricane/flooding, inputs. Estuarine mixing complicated in areas when the residence time is higher, like what may occur in TX estuaries. Estuaries are also home to a diverse range of species, with special import for bivalves and aquaculture industry, which relies on estuarine coasts to support its X$ annually. In other areas that are seeing declines in coastal pH due to increased CO2 absorbption elevating DIC (with no additional increase in TA), growers are co-growing bivavles with species that help to elevate pH by converting seawater CO2 into tissue mass that can be harvested as well (kelps/seaweed).

Carbonate system is important for oysters because they build calcium carbonate shell using calcite mineral forms, which is a more sensitive mineral to dissolution (lower omega saturation state). Oysters, like other bivalves, likely have multiple pathways to deliver carbon ions to the EPF. One such way is to use bicarbonate, a highly available source of carbonate if the oyster can remove the proton and pump it against its gradient. If the pH of the seawater is too low, the benefit of added HCO3- may be counteracted.

In areas like estuaries, the co-species may instead be seagrasses, like X. Although not harvested for consumption, seagrasses have a far greater purpose remaining in the estuary, as the species buries C deep in the sediments (a potential sources of blue carbon removal of CO2), elevates pH during photo periods to support higher growth, provides damped flow which may increased the deliver of suspended materials for food, algae that grows on the surface of the blade may support oyster when it dies?.

Studies have looked at the effects of low omega alone to oyster X and found X.

Studies have done X for high TA studies? (what do our TA/omega/pH patterns look like)

Many studies have not looked at the potential for elevated TA to raise growth rates in oysters living in areas where TA may become concentrated.

Salinity is important for oysters because they are osmoconformers (i.e. internal osmolality matches ambient conditions) and will first respond to low salinity conditions by sealing their mantle cavities from the external environment [56]. Prolonged valve closure is accompanied by metabolic depression and a switch to anaerobic metabolism [57]. However, this capacity is time limited by organismal tolerance of asphyxia and metabolic waste products [57]. Therefore, oysters are capable of tolerating short-term low salinity fluctuations but not prolonged low salinity extremes, such as the event recorded in March 2011.

What about oysters that are living in areas that receive seasonal pulses of low S from variable FW sources; what is the role of TA when coupled with S under moderate reductions

Studies have also looked at the effect of low salinity paired with low pH (through depleted TA) on X in oysters and found Sealing if extreme (not what we targeted) and Takes a lot of energy to conform to variable s env; here we aren’t targeting the extreme

studies that deplete S are automatically changing the carbonate system, and therefore, low S effects are often actually an interaction between low S and altered TA.

few have looked at the potential for freshwater to contribute a unique TA signature (Rain/lowTA/highTA), and therefore interact uniquely with lower salinity conditions.

Finally, lots of studies have looked at growth either in short term (cite) or after about a month (cite), a common duration to be inundated with FW conditions after a storm in many places where CV are found (cite).

However, few have looked to see whether the effects that we see on oyster growth are similar within the first few weeks of exposure, and later on after lag effects. We also look at gut wt and CI as a relative way to understand how oysters choose to allocate energy during exposure to low S and altered TA conditions by pairing with shell growth data. Combining shell growth and gut wt data allow us to look for differences in overall energy storage output as growth.

We solve this by doing the following:

* Looking at the effects of TA on net growth in CV
* Looking at the effects of just S on net growth in CV by maintaining TA near ambient conditions
* Looking at the effects of TA in low S conditions
* Looking at the effects of time on incremental growth in CV
* Looking at the effects of TA and S on Gut wt. and CI

treatments:

* Trends in mortality comparison to other studies

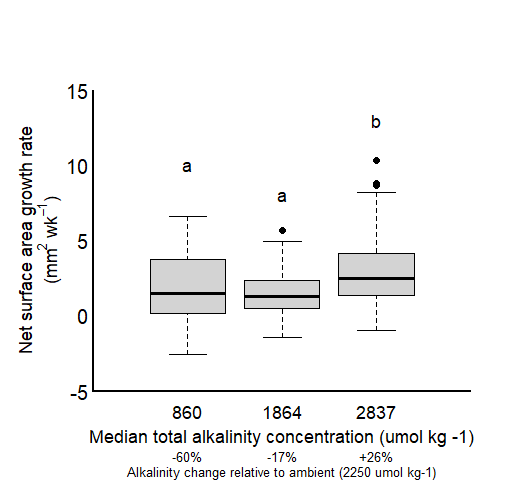
**Main Results:**

1. **Oysters have similar shell and tissue growth in varying TA conditions (S = 34) with ample food (compared to control oysters in flowing ambient seawater).**
2. **But comparatively, oysters had higher shell growth in low S conditions when TA was maintained near ambient.**
3. **When oysters were exposed to low S conditions, their shell growth was elevated in high TA relative to conditions prepared with DI.** Therefore, the simultaneous exposure to low TA from DI dilutions, may be adding a carbonate stress on top of osmotic consequences**.**
4. **Oyster growth declined following 2.5 weeks of initial exposure…**
5. **High TA benefits oyster SA growth rate following a few weeks of exposure to elevated conditions; no difference in net growth from just altered TA (with food)**

**Oysters experience variability in their environment due to fluctuations in the carbonate system. We have previously seen an increase in growth of Mussels when introduced to elevated elvels of TA over short term exposures, indicating that living near other species that elevate TA (seagrasses) may help elevate their growth, beyond through modifying the carbonate system taking up CO2. We are interested to apply this question to osyters, that live along gradients of TA with high salinity, like in TX. Here we ask whether the average shell growth rate of juvenile oysters differed when raised in low, ambient, or elevated TA conditions. We find that there is no significant difference. However, we do see that there is an overall decrease in the incremental growth (possibly due to latent effect of stress? Or from being bigger?), but that the higher alkalinity seemed to perform better than the other two, later one. This suggests that the elevated effect of TA may take effect only a few weeks after exposure. Given that we did not see an overall difference in the treatments, though, abrupt changes in TA (or something else unknown in the sw?) don’t seem to have an overall effect on growth rate, suggesting that even in depleted TA conditions (omega < 1) oysters that are fed are able to keep up shell building and gut tissue.**

**Q1: What is the effect of TA on oyster growth (solo stressor, ambient salinity)**

* **Shell growth rate: NO EFFECT**



**Ω**

* **A graph of a number of different sizes and colors

  Description automatically generated with medium confidenceIncremental difference in shell growth?** 
  + **Incremental growth was higher at the beginning of the treatment, possibly due to larger organisms have lower growth rates as they get bigger? Or maybe an unknown condition became stressful to all organisms, as all growth rates declined in the latter half, as well as the control oysters on the seawater flow through system at the laboratory.**

**Ω**

* + **In elevated alkalinity it seems like the incremental growth rate is a bit higher than the other two in the latter half, suggesting that this treatment allowed for elevated calcification later on…why is this?**

**Many studies that look at the effects of low S to oysters, dilute the seawater with distilled or deionized freshwater. This directly dilutes the alkalinity, which is visible in the seawater chemistry tables (cite). Alkalinity was not directly a focus for these authors. Our study was interested to see whether average net growth rate was high in low salinity, without TA change, than in ambient salinity. We were interested, because may studies peg rapid salinity change as a general problem without recognizing the notable, corresponding shift in the carbonate system. Which here, looks like actually shows improved shell building function over ambient salinity, and that the rapid drop is actually due to a rapid carbonate system change. This was the case, potentially due to the preference of oysters to be in lower salinity environments and so the decline inadvertently improved shell growth through upregulating of metabolism under stress or improved performance related to shell building that we did not measure. Regardless, this suggests that as long as oysters have maintained TA, like with other species that increase TA locally (seaweeds) and oysters may be able to use them as a chemical refuge, they can elevate net calcification (without lowering their tissue mass, CI is trending lower) during rainy/low S seasons.**

**Talk about variability; time is biggest effect (we need to address variability in time as an interaction)**

**Q2: What is the effect of S on oyster growth (solo stressor, near ambient TA)**

* **CI: trend but not significant**
  + **Trend is that lower S has a lower CI than ambient S**
  + **But it doesn’t appear that the oysters struggled to maintain tissue weight, as gut wt was the same across all oysters.**
  + **Therefore, food, with abrupt low S (like hurricanes or flash flooding) accompanied by a maintained TA may provide enough chemical refuge so that the organism does not close up and switch to anaerobic metabolism.**
  + **Both treatments had an omega value well > 1, indicating that lower growth rates did not stem largely from abiotic dissolution.**
  + **Instead, this means that oysters in lower salinity, but maintained TA increased their net growth rate of their shell. Low S/amb TA did not significantly influence gut weight, which lowered their CI relative to ambient S and ambient TA.**
  + **Oysters that are presented with low S stress may recover their ability to deposit shell material, and quickly, if accompanied by an increase in total alkalinity.**

**A graph of a diagram

Description automatically generated with medium confidence**

* **Shell growth rate:** 
  + **low S had higher net growth rate (per d) than ambient…TA differences (27S = 1929, 34S = 2219); Om differences (OmC was between 2.5 – 2.65; no strong tie there)**
  + **oysters prefer lower salinity as long as alkalinity is maintained. Meaning that oysters grown near areas that maintain alkalinity (potentially through the co-farming of seaweeds) may be able in elevate growth in low S seasons. Seasonal flood triggers a response to upregulate metabolism?**

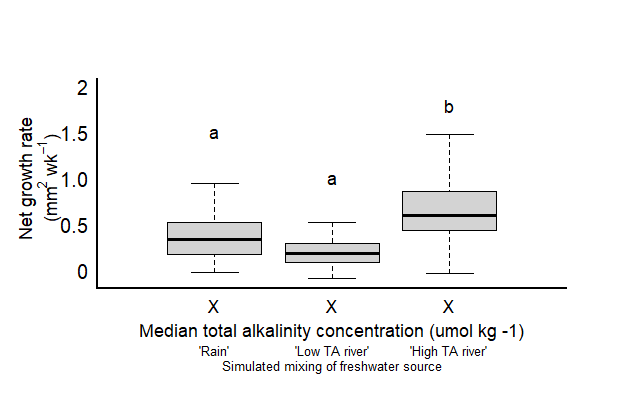
**Oysters also experience TA variability in their estuarine environment in the form of salinity reductions from freshwater inputs like precipitation flooding events (including hurricanes) or from rivers that receive rain farther up within their watersheds that is able to carry either a low Ta or high Ta signature with it. Here, we present an experiment that explores oyster surface area shell growth rates following exposure to these three scenarios. We track oyster growth in two time increments, the first 2.5 weeks and the latter 2.5 weeks, and compare how time intersects with our low S, TA treatments. Oysters that are presented with low S stress may recover their ability to deposit shell material, and quickly, if accompanied by an increase in total alkalinity. This suggests that rivers bringing in high TA are able to increase their calcification with the onset of low S.**

**incremental growth was highest in the beginning of the low S and high TA treatment. Because only one stressor was changing during this treatment (S was declining) it is not surprising that it does better than the other treatments. The next lowest were the lowest TA and then middle TA early on and high TA later. This suggests that the elevated TA treatment did not see as severe of a decline in the growth rate after the mid period, as the other two treatments did. Finally, the two lowest TA treatments did the worst at the end of the trial; not surprising because swapping over energy investments is hard work (and they maintained their gut mass) and doesn’t leave time for shell growth. This could also mean that rivers, although when bringing low TA do not stimulate calcification (shell growth), instead, they stimulate maintenance of the gut (as long as it is not accompanied by hypoxia). We did not observe oysters closing up, even though we used an instant shock approach. This is probably due to the decline in S being smaller than an extreme precipitation event. And so, the oysters were not in extreme pressure from the event, however, showed persistent declines in performance throughout the month. They were able to maintain shell growth (near or above zero) and gut weight event in the lowest alkalinity and salinity. However, the overall growth rate declined after a few weeks, potentially due to a latent effect of the pulse change to seawater conditions. Or maybe due to some seasonal trigger that comes after a shock of low S water?**

**Therefore, food, with abrupt low S (like moderate flash flooding) accompanied by a maintained TA may stimulate chemical refuge so that the organism does not close up and switch to anaerobic metabolism. Both treatments had an omega value well > 1, indicating that lower growth rates did not stem largely from abiotic dissolution. Instead, this means that oysters in lower salinity, but maintained TA increased their net growth rate of their shell. Low S/amb TA did not significantly influence gut weight, which lowered their CI relative to ambient S and ambient TA. Oysters that are presented with low S stress may recover their ability to deposit shell material, and quickly, if accompanied by an increase in total alkalinity.**

**Q3: What is the effect of TA at low S on oyster growth (‘stressors’ together)**

* **Shell growth rate: highest shell growth in low S and High TA treatment**

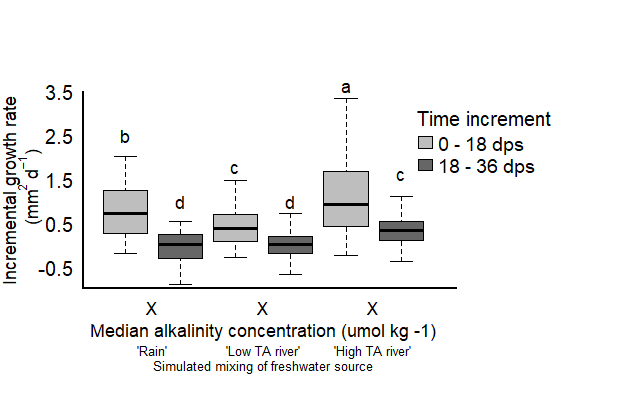


**Ω**

**This suggests that rivers bringing in high TA are able to increase their calcification with the onset of low S.**

**Incremental difference in growth?**

* + **incremental growth was highest in the beginning of the low S and high TA treatment. Because only one stressor was changing during this treatment (S was declining) it is not surprising that it does better than the other treatments. The next lowest were the lowest TA and then middle TA early on and high TA later. This suggests that the elevated TA treatment did not see as severe of a decline in the growth rate after the mid period, as the other two treatments did. Finally, the two lowest TA treatments did the worst at the end of the trial; not surprising because swapping over energy investments is hard work (and they maintained their gut mass) and doesn’t leave time for shell growth. This could also mean that rivers, although when bringing low TA do not stimulate calcification (shell growth), instead, they stimulate maintenance of the gut (as long as it is not accompanied by hypoxia). We did not observe oysters closing up, even though we used an instant shock approach. This is probably due to the decline in S being smaller than an extreme precipitation event. And so, the oysters were not in extreme pressure from the event, however, showed persistent declines in performance throughout the month. They were able to maintain shell growth (near or above zero) and gut weight event in the lowest alkalinity and salinity. However, the overall growth rate declined after a few weeks, potentially due to a latent effect of the pulse change to seawater conditions. Or maybe due to some seasonal trigger that comes after a shock of low S water?**



**Ω**

**Q\*: Also, TA/S exhibited no influence on:**

* **Relationship between shell area and shell mass, unlike others have seen where oysters change their shell growing behavior (thicker vs. wider)**
* **Incremental growth rate: need to address**

A graph of a number of dots

Description automatically generated with medium confidence**Q4: Gut wt, CI, inc growth per SA, mortality/survival**

* **Gut wt was elevated relative to controls (ie sufficient feeding to increase gut mass), but did not differ between TA or S treatments**
* **When we compared size dependent growth rate across the initial SA of the time period we see the following pattern…**
* **A graph of a number of bars

  Description automatically generated with medium confidenceThere was a different relationship between ‘initial’ size (of the time increment) and the subsequent incremental growth rate. Specifically, within the first 2.5 weeks, we see a positive relationship between starting SA and growth rate indicating that larger individuals had higher incremental growth. When we compare the average growth per area between the two dates, we see that earlier on, individuals grew more per unit shell than after 2.5 weeks.**
* **survival, although trending lower in the low S and low TA treatment, did not differ from 90% (assumed value from X paper), suggesting that none of the treatments should be considered with special lethality.**

**USE FOR STORY LINE (BELOW) EITHER IN INTRO OR DISCUSSION?**

**How is this similar/different to other studies?**

* *(Stevens and Gobler): low pH lowered the growth rate alone and took away the negative effects of low DO when coupled. Low do coupled with warmer temps (31 vs 24C) was the only treatment to significantly impact survival. Tissue wt declined in higher temp and even more so when low pH, low DO and high temp were coupled.*
* *(Parter 2017 DOI10.1016/j.marpolbul.2017.06.052): Oysters (****Saccostrea glomerata)*** *acclimated to elevated CO2 showed a significant metabolic depression and extracellular acidosis with acute exposure to elevated temperature and reduced salinity, especially at the highest CO2 of 1500 mu atm*
* *A graph of different types of dry mass

  Description automatically generated with medium confidence(Dickinson 2012): Exposure of the juvenile oysters (11 weeks) to elevated P-CO2 and/or low salinity led to a significant increase in mortality, reduction of tissue energy stores (glycogen and lipid) and negative soft tissue growth, indicating energy deficiency. juvenile oysters maintain their cellular energy status at the expense of lipid and glycogen stores. combined effects of elevated P-CO2 and fluctuating salinity may jeopardize the survival of eastern oysters because of weakening of their shells and increased energy consumption. Under the conditions of our experiment, low salinity is a greater single stressor than high PCO2, whereas the combination of these two factors produces greater changes in the physiology and shell properties of these mollusks than each of the factors alone (Table 3). This result may be explained by the exacerbation of seawater acidification and other changes in seawater chemistry by low salinity, such that both stressors synergistically affect similar mechanisms. SW DILUTED ALSO HAD LOWER TA. NO TREATMENT OF LOW S WITHOUT LOWERING TA. NEED TO LOOK AT THEIR salinity data through the context of salinity and alkalinity and pH? We saw similar trends to those in the table that say low S and normocapnia…btu w low TA: high mortality, low body mass, low CA activity (shell growth)*
* *(*[*https://www.webofscience.com/wos/woscc/full-record/WOS:000341229300019*](https://www.webofscience.com/wos/woscc/full-record/WOS:000341229300019)*): we need to consider OA effects on oysters in combination with warming and reduced salinity. Here, the interactive effects of these three climate-related stressors on the larval growth of the Pacific oyster,* ***Crassostrea gigas****. TA diluted in the low S treatment. Control was same as low S (which was really, low S and low TA); low pH was high and same as low pH with low S. increased T was lower than C and S. TSP > T > C, S, TS > TP > P, SP*
* *(Waldbusser 2011 10.1007/s12237-010-9307-0): a) at low pH but low TA (low S) we see similar high growth to high pH, high TA, amb S. they see a stronger inlfuence of low S and low TA than high S and high TA on the effect of decreasing pH. (the slope of the low S low TA curve is steeper from high pH to low pH). The effect of pH at high S is minimal. The effect of low pH on low TA and low S is higher than low pH on high S and high TA.*
* ***(****10.1242/jeb.082909 Dickinson 2013):* ***juvenile hard-shell clams****. Low salinity (and low TA) had profound effects on survival, energy metabolism and biomineralization of hard-shell clams and modulated their responses to elevated P-CO2. Negative effects of low salinity (and low TA) in juvenile clams were mostly due to the strongly elevated basal energy demand, indicating energy deficiency, that led to reduced growth, elevated mortality and impaired shell maintenance (evidenced by the extensive damage to the periostracum). Moderate hypercapnia (similar to 800 mu atm P-CO2) increased shell and tissue growth and reduced mortality of juvenile clams in high salinity exposures; however, these effects were abolished under the low salinity (and low TA) conditions or at high P-CO2 (similar to 1500 mu atm). TA WAS DILUTED IN HALF IN THE LOW S TREATMENTS, REGARDLESS OF PH.*
* *(GAzeau 2013): Interestingly, in the study of Beniash et al. (2010), in contrast to shell mass, the average shell area was not affected by hypercapnic conditions, suggesting that juvenile oysters were depositing thinner shells. This further indicates that shell length or area might not be sufficiently accurate as indicators of the effects of ocean acidification on shelled molluscs as the organisms are potentially able to maintain a normal linear shell growth under low pH conditions. Shell dissolution might outcompete carbonate deposition consistently, resulting in thinner and lighter shells with maintained surface area. We did not see a thinning of the shells to low pH conditions. Across omega thresholds.*
* *(10.3354/meps13826 Ashey 2021): salinity of distal environmental history primarily influenced* ***CV*** *physiological condition: but tempt, pH did not show up as an oyster stressor.*
* *(*[*https://www.webofscience.com/wos/woscc/full-record/WOS:000734889400004*](https://www.webofscience.com/wos/woscc/full-record/WOS:000734889400004)*): where oysters exposed to salinity increase showed less resilience than those to decrease after 48 h (****C cortensis?****)*
* *(10.1002/lno.11293 Hollarsmith, JA 2019): Our results reveal that seasonal inputs of upwelled or riverine water create important and predictable gradients of carbonate system parameters, temperature, salinity, dissolved oxygen (DO), and other variables that influence oyster performance, and that the influence of these gradients is contingent upon the location in the estuary as well as seasonal timing. During upwelling events (dry season), temperature, carbonate chemistry, and DO had the greatest impact on oyster performance. During runoff events (wet season), gradients in salinity, nutrient concentrations, and total alkalinity driven by river discharge were comparatively more important. These results suggest that the spatial importance of carbonate chemistry and temperature are seasonally variable and are two of several other factors that determine oyster performance.* ***Ostrea lurida and Crassostrea gigas.***
* (Effects of flood-associated stressors on growth and survival of early life stage oysters (**Crassostrea virginica**) Pruett 2021 10.1016/j.jembe.2021.151615 AND <https://www.webofscience.com/wos/woscc/full-record/WOS:000905367500001>: In the laboratory, we examined the interactive effects of acidification, hypoxia, and low salinity on larval and juvenile life stages of the eastern oyster (Crassostrea virginica) to better understand the impact of flooding events on oyster development and survival. Salinity stress in isolation reduced larval growth and settlement, and decreased survival and growth at the juvenile stage. Hypoxia was more stressful to oyster larvae than to juveniles, whereas low pH had negative effects on juvenile growth. In 24 day espoure; Low DO, pH, and salinity *(and low TA)* treatments reduced juvenile change in wet weight and shell growth rates, but had no effects on survival. Were then transplanted out… juvenile oysters were able to compensate for reduced growth during the lab exposure, even though survival was reduced for juveniles previously exposed to low pH during the first two weeks in the field.
* (Cheng 10.1111/gcb.12895): We test the interactive effects of diel-cycling hypoxia with both warming and decreased salinities *(and low TA)* using ecologically realistic exposures. Surprisingly, we found no evidence of negative synergistic effects on **Olympia oyster** growth; rather, we found only additive and opposing effects of hypoxia (detrimental) and warming (beneficial) WITH LOW S *(and low TA)*. We suspect that diel-cycling provided a temporal refuge that allowed physiological compensation. We also tested for latent effects of warming and hypoxia to low-salinity *(and low TA)* tolerance using a seasonal delay between stressor events. However, we did not find a latent effect, rather a threshold survival response to low salinity *(and low TA)* that was independent of early life-history exposure to warming or hypoxia. The absence of synergism is likely the result of stressor treatments that mirror the natural timing of environmental stressors.
* (10.2983/035.042.0103 Manuel 2023): One experiment **used wild oyster** spat collected from three distinct Delaware Bay salinity zones that were then transplanted into various salinity conditions in the laboratory, where growth was monitored. Transplanting into low salinity led to decreased growth compared with transplanting to higher salinity, and growth of oyster spat was overall highest for spat from the lowest salinity source. Therefore, in addition to the effects of acute salinity changes on growth, early postsettlement hyposalinity stress can generate compensatory juvenile oyster growth. DOES NOT SAY SO WE CAN ASSUME THEY DID NOT ALTER CHEM. DID NOT HAVE A TABLE FOR SW CONDITIONS FROM EXP.
* (10.2983/035.035.0112 Rybovich 2016): Regardless of size class, **oysters** at the **lowest salinity site( no TA recorded)** (annualmean = 4.8) experienced significantly highermortality and lower growth than oysters located in higher salinity sites (annual means = 11.1 and 13.0, respectively); These studies demonstrate that high water temperatures (>30 degrees C) and low salinities *(and low TA)* (< 5) negatively impact oyster growth and survival differentially and that high temperatures alone may negatively impact market-sized oysters DILUTED W DI IN THE lab but IN THE FIELD THE GRADIENT WAS ALONG MI RIVER INFLOW…WHICH ELEVATES TA RELATIVE TO SW.
* (10.2983/035.036.0205 Southworth M 2017): A critical salinity-temperature combination of less than two at greater than 28 degrees C for more than 1 wk exposure for oyster mortality is suggested. Mortality of two size classes (<35 and >35 mm) of eastern oysters **Crassostrea virginica** when exposed to combinations of low salinity (1, 2, 3, and 4) for extended periods (up to 30 days) at summer water temperatures typical of the Virginia Chesapeake Bay subestuaries was examined. No info about their carbonate system param or seawater param table
* (10.1016/j.scitotenv.2021.145132 Du 2021): Oyster measurements at 130 sites in Galveston Bay show that the mean **oyster** mortality drastically increased from 11% before Harvey to 48% after Harvey. Post-Harvey oyster mortality exhibited large spatial variability and was up to 100% at some major reef complexes. For all the oyster sampling sites, brown shells were dominant, while black shells indicating mud burial were rare. Considering the little impact from sediment deposit, we hypothesized the low-salinity exposure as the main cause for the massive oyster kill. Oyster mortality was found to be significantly and positively correlated with the bottom low-salinity exposure time (duration of bottom salinity continuously less than 5 PSU), while there was no significant relationship with the thickness of storm-induced sediment deposit.
* (La Peyre 2013 10.1016/j.ecss.2013.10.001): LOW S WAS DURING FLOODING EVENTS IN RESPONSE TO OIL SPILL AND ALSO A BIG NATURAL FLOOD SO LOW TA ASSUMED. Extended low salinity (<5) during hot summer months (>25 degrees C) significantly and negatively impacted oyster recruitment, survival and growth in 2010, while low salinity (<5) for a shorter period that did not extend into July (<25 degrees C) in 2011 had minimal impacts on **oyster growth** and mortality. In both 2010 and 2011, Perkinsus marinus infection prevalence remained low throughout the year at all sites and almost all infection intensities were light. Oyster plasma osmolality failed to match surrounding low salinity waters in 2010, while oysters appeared to osmoconform throughout 2011 indicating that the high mortality in 2010 may be due to extended valve closing and resulting starvation or asphyxiation in response to the combination of low salinity during high temperatures (>25 degrees C).
* (Petes 2012 10.1002/ece3.291): investigate the effects of reduced freshwater input on **Apalachicola oysters**. Oysters suffered significant disease-related mortality under high-salinity, drought conditions, particularly during the warm summer months. Mortality was size-specific, with large oysters of commercially harvestable size being more susceptible than small oysters
* (Marshall 2021 10.1093/conphys/coab065): Wild **oysters** were collected from four estuarine sites from Texas [Packery Channel (PC): 35.5, annual mean salinity, Aransas Bay (AB): 23.0] and Louisiana [Calcasieu Lake (CL): 16.2, Vermilion Bay (VB): 7.4] and spawned. The progeny were compared in field and laboratory studies under different salinity regimes. For the field study, F1 oysters were deployed at low (6.4) and intermediate (16.5) salinity sites in Alabama. The results of the field study and laboratory study with acclimation indicated that PC oysters are adapted to high-salinity conditions and do not tolerate very low salinities. The AB stock had the highest plasticity as it performed as well as the PC stock at high salinities and as well as Louisiana stocks at the lowest salinity. Results from the laboratory studies without salinity acclimation showed that all F1 stocks experiencing rapid mortality at low salinities when 3-month oysters collected at a salinity of 24 were used and at both low and high salinities when 7-month oysters collected at a salinity of 14.5 were used.
* (10.1098/rspb.2016.1462 Cheng 2016): **Ostrea lurida** Here, we use biological data coupled with remotely sensed and in situ environmental data to describe the role of ARs in the near 100% mass mortality of wild oysters in northern San Francisco Bay (8 days of low S). This discharge caused sustained low salinities (less than 6.3) that almost perfectly matched the known oyster critical salinity tolerance and was coincident with a mass mortality of one of the most abundant populations throughout this species' range. These high salinity regimes may have resulted in little selection for prolonged low salinity tolerance, when compared with oysters within the genus Crassostrea. San Francisco Bay may be the exception for Olympia oysters, largely because of the vast watershed that the estuary drains. In response, oysters from northern San Francisco Bay appear to be locally adapted to modest exposures of low salinity [54], but relatively intolerant of prolonged and extreme low salinity as seen here.
* Oyster mortality from large-scale physical features (e.g. tropical cyclones) has been documented for wild eastern oysters (**C. virginica**), a species that appears to have greater tolerance to low salinity than Olympia oysters ( (doi:10.1016/j.ecss.2013.10.011) Livingston RJ, Howell RL, Niu XF, Lewis FG, Woodsum GC. 1999
* (10.1016/j.jembe.2018.06.001 Casas 2018): direct comparison of two eastern oyster (**Crassostrea virginica**) populations that occupy contrasting temperature and salinity habitats, New Brunswick, Canada (47 degrees N - Gulf of St. Lawrence) and Louisiana, USA (29 degrees N - Gulf of Mexico). Specifically, clearance rate, valve opening, and oxygen consumption rate were measured in oysters of both populations following a full factorial design with three temperatures (10, 20, 30 degrees C) and two salinities (15, 25). In low S (15 vs 25) and lower Ts (10 and 20) but not high (30) temp show that the low TA (I am assuming as bc new brunswick) site has lower clearance rate/oxygen consumption than those in the higher TA area. The highest rates were in the higher temperatures (strongest effect). Within temps, there was a decline overall in rates with salinity, in both locations (with high TA (Louisiana MI river) and low TA).
* (10.1111/gcb.16571 Donelan 2023): We explored within-generation carryover effects of two coastal climate change stressors-hypoxia and warming-on oyster (**Crassostrea virginica**) growth and nitrogen bioassimilation, an important ecosystem service. Oysters were exposed to a factorial combination of two temperature and two diel-cycling dissolved oxygen treatments at 3-months-old and again 1 year later. Hence, even brief exposure to climate change stressors early in life may have persistent effects on an nitrogen bioassimilation, 1 year later. Our results show for the first time that within-generation carryover effects on individual phenotypes can impact processes at the ecosystem scale and may therefore be an overlooked factor determining ecosystem service delivery in response to anthropogenic change.

***Introduction—***

Influence of TA as a predictor of shell growth mechanistically

Separate influence of osmotic stress under maintained salinity conditions

Why this matters? Estuarine influence by freshwater is dynamic

Rain events causing mass die offs

Oyster performance elevated in estuaries, however, at risk to climate change shifts in precip regimes, nutrient loading (hypox), disease, etc

Focus not only on shell growth and aesthetics, but also on gut tissue

Focus on juveniles, more sensitive than adults and may be a bottleneck to extreme freshwater conditions

Food availability not limiting\* may or may not occur simultaneously with changing seawater conditions

***Methods—***

Experimental overview:

Species: Natural History

Chemical manipulation of seawater

Organismal performance quantification:

Shell growth

Net growth

Incremental growth

Energetic allocation

Condition index

% Organic carbon in shells

***Results—***

Seawater conditions

***Discussion—***

Aslgnsdf

In effect, the shell represents cumulative growth, being the secretory product of the animal’s metabolism, whereas the amount of body tissue may vary greatly depending on the current sexual and metabolic activity of the organism. It is thus possible to evaluate the extent of current metabolic or reproductive activity by comparing the amount of tissue to the amount of shell.