Blue Crabs and Marine Bacteria – Future Habitat Quality Questions
The Blue Crab Forum™ Environment and Conservation #12 - June 2016
A Capstone Proposal for FFA – Non Experimental SAE

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{The views expressed here do not reflect the Citizens Advisory Committee nor Habitat Working Group of the EPA Long Island Sound Study. On February 16, 2016 I have asked resource management agencies to recognize Sapropel as a distinct habitat type. This is the viewpoint of Tim Visel}.

The Connecticut Career and Technical Education System issues Agriculture/Aquaculture Performance Standards and Competencies. These performance standards are from the 2015 edition issued from the Connecticut State Dept of Education Academic Office. The Environment and Conservation post #12 (The Blue Crab Forum™ the following standards are referenced.

AE #4 Conversion of ammonia to nitrite and nitrite to nitrate
AE #6 Identify environmental factors – temperature, salinity, ammonia, nitrate, nitrite, dissolved oxygen and pH.
AE #9 Define non infectious diseases, including those from environmental conditions.
NRE #4 Identify ecosystems structure in terms of food web, biodiversity and carrying capacity.
#9 Describe process of ecological habitat succession.
#14 Identify water quality indicators pH, temperature nitrates, nitrites ammonia, dissolved oxygen and turbidity.

Capstone Questions

1) Can any relationship be drawn from Vibrio bacteria populations to estuarine habitat quality for the Blue Crab during different climate periods.

2) In the strength of the Sulfur Cycle indicated by the absence of abundance of Vibrio bacteria – will Vibrio impact future shore waders/swimmers in high heat – high organic habitats.

3) Should in shore fisheries including the Blue Crab fishery be concerned about the rise of Vibrio Bacteria in warm organic deposits located in shallow water habitats.

Students interested in this as a Capstone Project please see Tim Visel in the Aquaculture Office.

Environment and Conservation – The Blue Crab Forum™ - Bacteria Nitrogen Series

I want to thank the Blue Crab Forum™ for allowing me to post in a new thread – Environment and Conservation and also Connecticut Fish Talk for reposting these reports. This is my twelfth report about bacteria and nitrogen cycles. Coastal habitats once praised for valuable habitat services are impacted by bacteria and at times become nature's killing fields, eliminating critical nursery and spawning grounds for many inshore fish and shellfish species. Coastal fishers often observe these events, mats of bottom bacteria, chocolate or purple waters, brown tides, blue crab jubilees or just fish kills. Beyond these public events bacteria and nitrogen change the habitat qualities that we recognize today as "good" onto something that is "bad" for inshore fish and shellfishing. Out of sight and rarely discussed, these conflicting bacteria strains have important implications for estuarine health and seafood production worldwide.

#12 Blue Crabs and Marine Bacteria June 2016

#11 Eelgrass, Blue Crabs, lobsters and Vibrio Bacteria - March 2016

#10 Oxygen and Sulfur Reducing Bacteria Questions – Dec 17th 2015

#9 Nitrogen and Eelgrass Habitat Questions 11/18/2015

#8 Natural Nitrogen Bacteria Filter Systems 10/20/2015

#7 Salt Marshes a Climate Bacterial Battlefield 9/10/2015

#6 Bacteria Disease and Warm Water Concerns 7/23/2015

#5 Nitrogen, Inshore Habitats and Climate Change 1/12/2015

#4 Black Mayonnaise Impacts to Blue Crabs and Oysters 1972 to Present 10/16/2014

#3 A Caution Regarding Black Mayonnaise Habitats 10/2/2014

#2 Black Mayonnaise, Leaves and Blue Crab Habitats 9/30/2014

#1 What About Sapropel and the Conowingo Dam? 9/29/14

Fishers should follow this bacterial conflict as more and more information comes in regarding habitat quality and important recreational fisheries such as striped bass, winter flounder and blue crabs or lobster habitats are subject to bacterial impacts. It is also important that shallow water fishers be aware that sulfur bacteria contain a series of antibiotic resistant strains first identified in "Contaminate Effects On Biota of the New York Bight" by Joel, O'Connor, NOAA (1976). Soft organics with bacteria do pose risks to fishers and bathers – coastal bacteria benthic monitoring programs are needed. – My View.

Introduction

John "Clint" Hammond told me if I wanted to learn about habitats I would first need to understand climates, and to fully investigate that I should "follow the fish." The past fisheries could tell us much about climate change – the biological responses to habitat stability or quality. Fish swim and some of the first New England Halibut trips to the Davis Straits in the 1890s shows the ability of fishing fleets to follow them. In early 1884 Danish fishing vessels had found that the halibut had moved far north to the coast of Greenland. The first US Gloucester Halibut vessels arrived shortly after that. (US Fish Commission Report – pg 94 (see Case History for CT Halibut Fleet 1848 – 1881 IMEP #51 Blue Crab Forum™ fishing/eeling, oystering thread). This is the first mention of the fishery in the Davis Straight on the western side of Greenland and a notation about our climate,

> " The depth of water on the banks is from 15 to 90 fathoms and air and water temperatures cold – surface sea temperatures between 38 and 43 degrees (f) the temperature was thus favorable for work, through perhaps a little chilling in foggy weather (air temp ranged from 36º F to 52º F). But nevertheless much better than the sweltering heat of summer in our own latitude."

It was getting hotter (sweltering) and the 1890s saw increasing heat waves in the east. By 1898 the lobsters started to die off as Tarpon were caught in Narragansett Bay. The warmer waters brought the end of the Narragansett deep water scallop beds but also facilitated the rise of oysters – with increasing sets.

At times cycles of surprising abundance of seafood are often followed by dramatic declines with a climate connection. In the analytical aspect of fisheries sciences data has often replaced observation, chemical analysis for our impacts (pollution) and perhaps in the process giving nature a "free ticket" for climate change. One of those free tickets could be Vibrio bacteria. A century ago our first Aquaculture Experiment Station at the University of Rhode Island Dr. Field indicated his research interest, the smallest life forms which be called lowly forms which according to Dr. Field "lie close to the basis of life." The study of these small life forms may give us the best indicator for climate change and the quality of habitats impacted by it – the bacteria. This same bacteria decay in oxygen on the bottom was the scourge of wooden ships and fishing vessel owners, for all time. Growing up my uncle Edward Visel who owned a 1963, 32-foot Pacemaker named the "Blue Chip" gave me a lecture about bacteria eating wood (his vessel) every fall. After haul out and flushing the bilge and scrubbing with detergent the bilge clean he would have me sprinkle rock salt in the entire bilge, the salt he would say would "pickle the wood" preventing rot. He would reminded me of this bacterial war against his vessel – each spring as for years we would vacuum any remaining rock salt out before launching. What killed wood boats was the fresh water bacteria exposed to air, he would say. Years later George McNeil would also mention this salt aspect, oyster boats lasted a long time because of the salt water on their decks from oystering, he also was more concerned about the bacteria above the water line than below. It was Frank Dolan of Guilford however who told me that these wooden oyster boats were held together with black locust iron wood tree nails (trunnels) and sinking them was not looked upon as being that "bad" (before all the modern electronics no doubt)) and on occasions even welcomed, as it gave wood a chance to be "salted." I had seen this salting in grade school as well, frequent trips to see the Charles W. Morgan in Mystic then I was intrigued by the roped off in the bow below decks as it was packed in salt. Only later when I read the US Fish Commission reports that salt was used in the fish pen areas to reduce bacterial rot, from ice and fish slime and the 'Grand Bankers," the dry salted Halibut vessels lasted much longer than freshwater "wet" ice vessels that followed was linked to bacteria. The switch from trunnels to iron fasteners most likely allowed "ice" vessels to last longer I doubt that all the salt was good for them, but the practice of placing rock salt between fish pens lasted another 50 years.

Many older boat building books may mention this salt "pickeling" process. What was known is that bacteria in the presence of oxygen and water was a constant threat to the wood – the cellulose or sugars that were a part of glucose metabolism by bacteria, that strived to turn wood into compost. The same process that in time create Sapropel only a much larger process on bay bottoms with different types of bacteria.

Our Blue Crab populations in Long Island Sound currently is in decline – I have found little evidence of a widespread successful Megalops recruitment in both 2014 or 2015 (The Search for Megalops Crab reports, Northeast Crabbing Resources, The Blue Crab Forum™). Gone are the days of blue crab waves or ocean schools of crabs mentioned in the historical literature. The Connecticut River Blue Crab fishery "failed" last summer. At catches increased in the 2000s (Megalops Reports 5, Sept 17, 2015 Blue Crab Questions Northeast Crabbing Resources) to some very high catches rates, they collapsed in 2015. A popular blue crabbing dock in Essex, Connecticut – one that I mention many times in The Search for Megalops series – only 3 crabs were reported to be caught the entire season. In September a small increase in crab catches were reported as crabs moved to the Sound in search of more saline habitats but dredged areas or rivers which act as salt ponds now hold the last habitat refuges. As they represent crabs hatched 4 to 5 years ago they should be quite large.

Because blue crabs have short life cycles (similar to bay scallops) they quickly reflect changes in habitat quality, especially out of its "normal" range. We may be seeing a large change in species – increasing lobsters (eastern CT) or return of bay scallops and a good quahog set. Cooler winters and more intense storms have historically been poor for striped bass, oysters and blue crabs in Long Island Sound. A return to cooler temperatures and a marked increase in storm intensity blue crabs may now indicate a much larger species shift. Some of the cooler water crabs namely Jonah crabs have experienced a dramatic rise in abundance. Jonah Crab catches in New England have recently soared.

The recent warming in Long Island Sound 1972-2012 had tautog decline while the reproductive capacity of black sea bass surged to very high levels. In the 1950s and 1960s tautog was a dominant species in Long Island Sound – this was during a cooler negative NAO weather pattern. When populations change habitat conditions change we may find evidence of past habitat reversals from those who lived along the coast far before this time. Last year researchers Smithsonian Environmental Research Center reported on some blue crab research involving dozens of Native American shell middens that indicated blue crabs once grew to much larger sizes – Journal of Archaeological Science March 2015 Vol 55, pages 42-54. Other shell middens suggest better habitat/climate conditions for larger oysters as well. Some of the best shell middens descriptions I have found came from 1950s historian, Harold Castner who wrote about the shell middents in coastal Maine – an except from his account is found in appendix EC #11, Environment and Conservation, The Blue Crab Forum™ posted April 28, 2016). At the turn of the century Mr. Castner described very large oysters from the Damariscotta River exposed during a dredge project. To grow this large oysters required a long term stable but warm habitat conditions.

The Blue Crab may be an important indicator species and over time will assist in defining both past and future habitat conditions. Eelgrass, blue crabs and oysters to appear to share similar cycles of historic abundance and how that happens may in fact be answered by bacteria, we should take a closer look at that - my view.

Tim Visel – The Sound School

Vibrio and Sapropel

Many Blue Crabbers might be interested in some of the recent overseas research into Vibrio (sulfate and sulfur reducing) bacteria and eelgrass meadows. Recent research indicates eelgrass forms "Vibrio pools" in the organic matter deposits under it. That is not surprising as these bacteria consume the glucose locked up in organic matter created by plants both marine and terrestrial. In high heat and low oxygen Vibrio thrive, they need the heat to vanquish the oxygen requiring bacteria – the "fast" organic matter decomposers. What sulfur reducing bacteria lack in speed they compensate for habitat impacts – all negative. They need heat and the absence of oxygen to survive – perfect conditions under dense eelgrass meadows. The return of the Sulfur Cycle in shallow habitat has far reaching deadly consequences for both seafood consumers and inshore fisheries.

Sulfate reducing bacteria slowly consume organic matter, fixing carbon but as they do releasing ammonia, sulfides, and complexing heavy metals-even mercury. They also make it possible for acidic conditions when they occur to release once "bound" toxic aluminum. The sulfur reducing bacteria do consume terrestrial organic matter but not as efficiently as oxygen bacteria. When leaves on land are exposed to the oxygen reduction pathway when at the surface (and why composters today turn over compost deposits) they break down quickly but deep accumulations now favors ammonia generation. When leaves fall into the water oxygen reducers work on them as well – unless it gets hot. In hot water oxygen is scarce (naturally) and sulfur reducing bacteria take over using sulfate as an oxygen source and when they do they now emit toxic compounds, sulfide (which is commonly referred as the rotten egg smell) ammonia and complex heavy metals. Oak leaves are the most damaging as they are naturally acidic – 3.4 have a tannin floculant and contains leaf parrafins a waxy substance that sulfur reducing bacteria cannot consume. As this organic matter builds it forms a "sticky" layer and becomes "greasy" to touch and smells of sulfur sulfide. In time this layer becomes sulfide rich and forms Sapropel. In heat and few storms Sapropel can become deep collecting first in low energy areas subject to leaf fall or organic debris – bark, grass clippings, manure or street run off.

Many fishers have experienced Sapropel on a falling tide in upper reaches of tidal estuaries – they frequently get stuck in it. When that happens the smell of sulfides can become very strong – it is those habitats that are so deadly to fish and shellfish larval stages including blue crab Megalops. That is one of my concerns that the very recent Blue Carbon initiative isn't really telling the whole habitat story – while sulfur reducing bacteria do act to lock up carbon, the byproducts of sulfate reducing bacteria but tends to ignore the negative impacts to fish and shellfish species, this is often "forgotton" and not mentioned. To lock up carbon they need organic matter, stripping off usable compounds and leaving the carbon chain behind. In this process toxic compounds are emitted as by products – that is often not mentioned in blue carbon reports. This is a type of scientific research misconduct termed citation amnesia – the forgetting of references that do not typically support a funding effect or research effort. The 1982-2012 eelgrass funding and protection efforts is the most current example, much information on the cycle of oxygen cool "clean and green eelgrass" was highlighted but forgotten was the "brown and furry eelgrass" when high heat turns eelgrass meadows into natures sulfur killing fields. All to often such research selects short periods upon which to assign permanent habitat values - that process tends to ignore a longer successional habitat history of which our coves have had a series of habitat successional events – lost in time but recorded in the estuarine bottoms themselves. As habitats change so also the populations of seafood that needs them.

Now researchers all over the world are focusing upon the sulfur reducing bacteria – SRB the bacteria that live in Sapropel (it seems for centuries) and under eelgrass meadows that collected organic matter – food for SRB.

That is not to say that eelgrass isn't an important part of habitat succession – it is. However, eelgrass provides some very important research data about the sulfur cycle and a warming planet. In heat it helps bring Vibrio bacteria close to the surface. As it warms and the sulfur cycle returns to the shallows it is under eelgrass that Vibrio can be found. In addition to slowing currents and trapping additional organics eelgrass habitat sucession can change the nature of marine soils themselves, transforming them into pools of stagnant sulfide rich sapropel. That is why the research from peat studies contains many clues about this estuarine biochemical process – the rise and fall of Sapropel.

Fishers have come in contact with Sapropel – it is a very destructive and at times dangerous habitat type. It is simply the rotting of organic matter in the absence of oxygen – it rots with sulfur reducing bacteria. When Sapropel forms it can have very serious consequences for sealife – in heat it can purge ammonia, produce sulfides (sulfur smells) with oxygen very low pH (lethal) and when remixed with oxygen forms sulfuric acid. Sulfuric acids from Sapropel deposits can release toxic aluminum as a normal sulfur reducing activity. It is a very toxic habitat type but that rarely is mentioned today in habitat studies. One of the signs of Sapropel is color – blue/black and odor – this is an 1891 account of a Long Island Sound then bottom survey that appeared in The New London Day newspaper (today called "The Day"). Although this account is over a century old – it fits perfectly the Sapropel descriptions of today – it was very hot in Long Island Sound then and a bottom survey was conducted on behalf of the Connecticut Oyster Industry who had large numbers of oysters perish in the heat. (Thought to be sulfide starvation see The Cycle of Eelgrass and Fish Habitats part 2, The Blue Crab Forum™ fishing, eeling, oystering thread June 11, 2015).

"Long Island Sound A Bottom of Putrefied Things"
The New London Day, March 21, 1891

"His dredge (Captain Platt) in the vicinity of the beds (oyster) brought up from a bottom a foul deposit which save forth such a stench that it was almost impossible to examine it. The water splattered from the dredge coming of the foul matter dissolved paints where ever it struck… where as the hand coming in contact with any of the muck from the bottom of Long Island Sound hours of washing would not rid the flesh from the smell…"

This description is of Sapropel and the high sulfides (smells) associated with it.is as good as any today. Although many articles describe sub tidal habitats very few mention high heat sulfide rich Sapropel. A bias exists that all habitats are good and valuable but clearly some are not – in fact some bottom habitats are very toxic. The impacts of Sapropel has been largely excluded from today's habitat discussions or that marine habitats over time succeed. This habitat succession is often reported by inshore fishers as "cycles."

Much of the eelgrass research today does not mention the negative aspect of this high heat low energy eelgrass habitat succession – which at times in the historical fisheries literature destroyed both shellfish and finfish habitats and their larval forms as eelgrass meadows act to start Sapropel formation. Within the past century for example, eelgrass control measures have included, cutting boards, drag chains, cutters (and ones used to harvest eelgrass for the first bat insulation) blades and mowers – some powered by gas engines, herbicides and on Cape Cod reference to Agent Orange and in Connecticut explosives. Why these efforts to control eelgrass, because at the end of its habitat succession it (eelgrass) turned deadly – it suffocated shellfish beds, smothered marine soils made them acidic and slowed (stopped) tidal circulation. The end of eelgrass habitat succession did not apparently fit current environmental policy – so it was "forgotten" (my view). (I have suggested in 2014 a funding amnesty where eelgrass research papers can be changed with no reprocessions). We seem to have the same they occurring in blue crab studies – a concentration on the oxygen sufficient clean and green eelgrass (which is correct blue crab megalops and star crab sizes do live here) but fail to mention what happens in heat and low oxygen – the sulfide filled Blue Crab jubilees – great for easy catching larger adult blue crabs but sulfide levels that are now deadly to larval forms – much from organic deposits (Sapropel) held by eelgrass. (The State of Massachusetts Coastal Zone Management office deserves much credit here for releasing all its state 1950-1978 historical fish and habitat reports, we need a full habitat history and discussions associated with them that includes the sulfur cycle - my view T. Visel).

No Sapropel Research?

It is the chemistry of marine soils and its marine compost Sapropel that deserves additional habitat study, after all blue crabs spend up to half their lives in it, burrowed into marine soils over the winter which may or may not have a thick compost or vegetation cover. The seriousness of Vibrio bacteria has also come to the attention of blue crabbers – who come in contact with them while fishing in these warm shallows that contain Sapropel. They are a very dangerous and may potentially contain deadly bacteria types.

Exposure had some crabbers become seriously infected in cuts or scratches from Vibrio strains and now linked to shell disease and fin rot in fish. However researchers pointed to the impacts of winter flounder to Sapropel more than three decades ago – high fin rot prevalence in areas of high coliform bacteria and heavy metals – both signs of Sapropel formation. Winter flounder fin rot was highest in shallow habitats with "muddy bottoms."

The lobster shell disease Vibrio was identified by Malloys (1978) as Vibrio beneckea that produced necrotic shell disease in lobsters. Even the decline of coral reefs has been associated to Vibrio species (Cervino et al 2004). Most Vibrios are connected to the sulfur cycles and as such perhaps the largest habitat modifier of oxygen requiring sea life.

The question of the sulfur cycle and over wintering blue crabs has much to offer (my view) in terms of understanding its abundance. And I draw some familiar conclusions from John Hammond, key to this understanding is temperature and energy. The blue crab population is governed by natural factors – although much of the research emphasis today is upon "us," our impacts to the population (catches) and to its environment by pollution, which at times can be significant. Here I can find hundreds of reports but to as its winter habitat just a few? When it comes to Sapropel, the sulfur reduced acidic marine "compost" in which Vibrio lives almost none. Sapropel is now linked to being the growth medium (food) for some dangerous sulfur reducing bacteria, that can also alter bottom habitats, feeding on terrestrial organic matter washed into estuaries. In our region it is oak leaves, but manure, forest duff, waste sawdust can all support these sulfur reducing bacteria. Over time they complex metal salts, and Sapropel metal content over time increases – naturally.

In fact, EPA did some of the initial research in this area and in some of the 1970s EPA reports mention the fact that these sulfur reducing bacteria need organic matter to live and investigated them as a way to complex heavy metals as they do – naturally from mine wastes (they also complex heavy metals in the marine environment). EPA 670/2-73-080 Sept 1973 Removal of Heavy Metals from Marine Drainage by Precipitation. These bacteria do not need "free" or elemental oxygen in sea water but as a remnant of the sulfur cycle use sulfate as an oxidation electron acceptor. Sulfate is non limiting in coastal waters and these sulfate reducing bacteria will never face a "oxygen shortage." This section from project 3 Mine Waste Technology has this section on a EPA – Sulfate reducing bacteria demonstration if found below, (   ) indicate my insertions. (EPA Activity III Project 3 Sulfate Reducing Bacteria Demonstration).

"For aqueous waste, this biological process is generally limited to the reduction of dissolved sulfate to hydrogen sulfide (this is the rotten egg smell of marshes in the historical literature in the 1890s when it got very hot in CT – Tim Visel) and the concomitant oxidation of organic nutrients to bicarbonate. The particular group of bacteria chosen for this demonstration sulfate reducing bacteria (SRB) requires a reducing environment (more recognized as anoxic or hypoxic conditions – Tim Visel) and cannot tolerate aerobic conditions (good oxygen saturation or oxygen availability T. Visel) for extended periods. These bacteria require a simple organic nutrient."

In heat and low oxygen conditions SRB does fine in fact they excel. The last very hot period saw these populations increase with several negative habitat considerations – the "rise" of Sapropel. The largest concern is that under eelgrass Sapropel or animal fat or grease layers are found some of the more dangerous Desulfovibrio bacterial series.

In the 1980s and 1990s EPA again ran SRB tests and for the "media" for growth they just used cow manure and highlighted that it was also a SRB source,

"Organic carbon is the bacterial food supply and because it was provided in the form of cow manure was included as the SRB source." (Ibid – EPA Activity III project 24).

Many times decayed leaves – Sapropel is the carbon/glucose media source for bacteria. The remaining pools of sulfur reducing bacteria in New England are now likely in deep Sapropel deposits or under eelgrass meadows. Much of the current eelgrass research however "forgot" to mention this SRB connection. As our climate recently now seems to be getting cooler with more strong storms look for eelgrass/Sapropel deposits to disappear as oxygen bacteria reducers displace the sulfate reducers in oxygen sufficient conditions. (That will require benthic Vibrio monitoring).

The European research coming online now post 2014 reflects the very warm period 2002 to 2012. Vibrio bacteria thrived in this hot/low oxygen period. As more researchers in the US examines these organic (Sapropel) deposits – especially held by eelgrass they will also find this relationship. High heat strengthens the entire sulfur cycle and it appears Vibrio bacteria as well.

We recently issued a second warning about these dangerous bacteria, as a caution to those coming in contact with Sapropel – a high heat low energy compost that naturally contains these sulfur reducing bacteria. Those very deep layers are those that have very little oxygen are the most likely to have the most dangerous sulfur reducing bacteria. In more southern waters blue crabbers have had Vibrio infections – some with deadly consequences.

These Sapropel deposits occur in the fisheries habitat history. The 1891 description in Long Island Sound fits today – perfectly especially the strong smells and acidic descriptions. It is the dead bottoms or foul bottoms in which Long Island New York Bayman again described to me at a New York Fishermens Forum – decades ago as large areas of white bottoms, dead clams and sulfur smells. (Arnold Carr communication, T. Visel, Feb. 18, 1983).

In the winter of 1982 I was invited to give a workshop on small otter trawls at the New York Fishermen's Forum. In 1979 I had presented a similar workshop there but by 1983 fishers had already noticed some distinct bottom habitat changes – this is a segment of a letter sent to Arnold Carr from me to then Director of Fishermen's Extension Service of the Massachusetts Division of Marine Fisheries on February 18, 1983.

Dear Arnold:

> "I thought you might be interested in some of the feedback I received after my presentation at the New York Fishermen Forum. I gave a short slide-lecture presentation on skiff trawls in a general "baymens" section. The last time I had the opportunity to attend the forum in Riverhead was in 1979, just after an otter trawl closure for Great South Bay. At that time many fishermen were upset by this law, not only from the loss of income but also the need to "turn the bottom." I know we have discussed this issue many times in reference to the inshore flounder fishery and hydraulic shellfish harvesting.
>
> It seems that in the four years of closure, some areas have gone "sour" after small trawls were forbidden. This was made known to me in a lengthy talk with a half dozen fishermen after my presentation. One fisherman described a "white film" over soft muck in some areas that had been previously hard bottom productive in both fish and shellfish. The hard clams below the soft muck were all dead. I'm not certain, but I think he was explaining some of the problems that many salt ponds and estuaries have been subjected to."

In the continued heat a noticeable decline in the hard shell clam fishery has occurred in Great South Bay. Some of the best hard clam quahog harvests occurred there in the colder and more storm prevalent 1950s and 1960s, but declined in the 1990s and 2000s. Without investigations of marine soil habitat quality – hard shell clam recruitment failure most likely had a sulfur cycle link – first observed by the baymen who fished its waters as they first noticed the beginning of Sapropel (my view) as a white bacterial film on the bottom.

In times of low energy and heat these sulfur tolerant bacteria do quite well, and their habitats as a rule contain much less life than those with sandy oxygen filled bottoms, those that that can sustain shellfish. I witnessed a sulfide kill on Cape Cod in Buttermilk Bay – soft shell clams actually came out of the bottom, the only living soft shell clams were at the edges most likely influenced by tidal/ground water pulses. The "back flushing" by tidal action is now linked to keeping those beach or shoreline marine soils with pore space able to support "life" and as compared to the "sticky" plastic or jelly like Sapropel. Once Sapropel deposits sealed marine soil pores soft shell clams here quickly perished.

Blue Crabs and blue crabbers enter and move around these Sapropel deposits and many researchers have found a Vibrio association to turbidity – an organic release that has bacteria in it. I don't think anyone will be surprised that bacteria – thrives in heat, but extreme heat (low oxygen) and thick organic deposits help these potentially dangerous bacteria grow. J. W. Davis and R. K. Sizemore in 1982 – Applied and Environmental Microbiology 1982 May 43 (5) 1092-1097 had found Vibrio in Blue Crabs. Some recent research in the Journal of Applied Microbiology 2014 Oct .1198 –209 Rodgers et al. found both Vibrio parahaemolyticus, and Vibrio vulnificus in blue crabs (Callinectes sapidus), Sea Water And Sediments Of The Maryland Coastal Bays and suggested that blue crabs could concentrate these Vibrio bacteria.

The shellfish ISSC has recommended that blue crabs and shellfish not share the same seawater containers and that shellfish be cooled rapidly to slow the growth of all bacteria. The simple matter is that bacteria do better in heat, especially the dangerous sulfur and sulfate reducing bacteria. One of the few historical references I have found about past episodes of shell wasting (Vibrio) bacteria perhaps impacting blue crabs is a 1958 Fish and Wildlife Service Bureau of Commercial Fisheries "The Blue Crab and Its Fishery in Chesapeake Bay by W. A. Van Angle" in part I is found this segment C, (c) indicate my additional comment – T. Visel.

"Crab dredge's report that in winter in the vicinity of Cape Henry crabs are often of strong odor (suspected Sapropel – T. Visel) here shells deeply pitted (again very similar references to the early lobster shell disease in the New York dumpsites T. Visel) and produce a very small quantity of very inferior crab and catches of this kind are quickly dumped overboard."

Winter flounder fishers in the middle 1980s drove adult fish to the Connecticut Sea Grant office for me to examine with wounds, infected fins and missing flesh. All were mentioned over our near bottoms with soft bottoms and the presence of "black mayonnaise" – organic deposits that just reeked of sulfur (Sapropel). This condition became known as winter flounder fin rot, mostly likely a simple scratch provided on entry point and as sulfur reducing bacteria increased these habitats became deadly to winter flounder – the fishery for them soon collapsed as a inshore habitat failure. This condition although much larger in scope is the same which closed system fish aquarium filters fail – See EC #10 Blue Fish Forum™. Crabs shellfish and fish in these situations are then much more susceptible to fungal and bacterial infections.

Shallow Habitats Fail First

Eelgrass lives in this general habitat area and cooler energized habitats support eelgrass and is good for blue crabs and many other species. In cool water this habitat type is very positive. But in time the ability of eelgrass to gather and bind organics works against itself in high heat. It helps Sapropel creation and purge sulfides into the top layers in which eelgrass lives. In times of high heat as the sulfide levels increase it kills the eelgrass itself and in time other organisms near it. Shallow easy to warm habitats these in low energy areas therefore "fail first" they are the ones that exhibit declining habitat quality. Fishers that once reported healthy habitats now experience the transition, bottoms that now become "softer." Some areas that were sandy or contained bits of shell become muck bottom that often "smell."

In all likehood the die off eelgrass is very bad for blue crabs as it signals sulfide formation so intense to kill eelgrass it will most likely kill the megalops blue crab stage as well. In the end Sapropel is now toxic to eelgrass, purges ammonia which feeds dense sea lettuce patches, if in a low current area support HABS harmful algal blooms especially if ammonia levels are retained in low volume low flushed coves and bays. The "clean and green" eelgrass in light sandy soils can use its blades for nitrogen exchange but as organic matter builds up in the soil (as a function of its own biology) it now depends upon root/soil interactions. The cycle of eelgrass and Sapropel may hold important clues for the blue crabs. We should look at the influence of terrestrial organics and the increases in tree leaves settling on bay bottoms would be a good start – my view. It is the shallows the areas to have the warmest waters that often fail first, killing larval stages and driving those that swim out. We can "see" the Blue Crab jubilees as crabs walk out of the water or the adults that die, what often isn't seen is the larval deaths. The return of the sulfur cycle has immense consequences for inshore fisheries.

Almost no studies (at least I can locate) are looking today into Sapropel – the marine compost that forms under eelgrass or under sticky wax and fat/grease layers. For Sapropel to form it needs to be hot and low dissolved oxygen as the Vibrio and sulfate reducing bacteria now replace oxygen bacteria as they die off. The wax from leaf parrafins seal pore water exchanges and sulfur reducing bacteria slowly begin to break down organic matter releasing toxic ammonia, sulfides, and aluminum. A New Jersey publication – The Peats of New Jersey and Their Utilization by Selmon A. Waksman – Dept of Conservation and Development –

State of New Jersey Agriculture Experiment Station – Rutgers University 1942 – 151 pages reviews the chemistry of muck soils used for fertilizer reuse – including Sapropel. On page 68 describes the tendency for a wax jelly like consistency. "The fats, waxes, or the so called bitumens have received most consideration. This group is frequently designated as the ether and alcohol soluble fraction. In view of the fact that different plants vary considerably I these constituents, it is essential to know the composition of the original plants, as compared with the same constituents in the resulting peats (tables 10-12).

Either extracts from plants and plant residues, ethereal and fatty oils, oleoresins and resins, certain wax like substances and nitrogenous fats. Alcohol extracts from plant materials, various waxes, tannins, resins, bitter substances, alkaloids, chlorophyll, certain pigments, and soluble carbohydrates. The wax extracted from peat with alcohol or benzol-alcohol can be divided into two or more fractions; some are dark brown, having the odor of beewax, and soluble in ether; their melting point varies from 46 to 87.5º C" (1942 Waksman).

The tannin signature of oak leaf wax can be a factor in source analysis. Connecticut now has a return of its forest canopy including large areas of red oak (Quercus rubra) trees. And offers (1942 Waksman) an explanation of oak leaf deposits being hard to digest, on page 76-77. "Under the anaerobic conditions prevailing in peat bogs, lignin is more resistant to decomposition than are cellulose and some of the other plant constituents; hence, it accumulates. The fact that the methoxyl content of the lignin in peat and coal is always considerably lower than that of the lignin in plant material (table 13) has been explained by a partial loss of some methoxyl in the process of decomposition of the plant material (184). The relation of lignin to peat formation has received considerable attention in recent years (32, 285, 307). Systematic study of chemical composition of peat. To be able to understand the chemical nature of peat as a whole, as well as to be able to follow the processes leading to the accumulation of larger quantities of organic matter in the form of peat, it is, first of all, important to adopt a definite system of analysis. This can also be applied to the study of the composition of the plants from which the peat originated, and thus allow a comparison between the chemical composition of the plants and that of the resulting peat. The system can be only proximate."

They (SRB) are slow to break down organics so in hot periods, organic matter can build up (or behind dams or other tidal restrictions) what was once firm bottoms become foul smelling and soft as the blue – black Sapropel build up. This is assisted by a cycle of energy, low energy does not "turn the compost" so in heat Sapropel builds up even faster. Fishers that fish in shallow waters can notice this change as they did here in Connecticut in the 1980s. It also mentions the problem of sulfuric acid – the hurt full acidity highlighted in IMEP #26 Blue Crab Forum™. Nichols 1920 provides a terrific description of Sapropel nearly a century ago and its tendency to be largely devoid of life. Nichols 1920 The Vegetation of Connecticut pg 525, Torrey Botanical Society states. "At ordinary low tides flats present a surface of soft blue black ill smelling mud."

This sulfur cycle also can be seen in salt marshes, out of sight sulfate digestion occurs beneath the cord grass and depends upon organic debris (mostly leaves) entering to match this burning into the sulfur cycle – the marsh surface turns soft, the "race is on" the reduction of marsh below, or the accretion on top. Salt hay farmers noticed a century ago in heat (1880-1920) they could now not get three cuttings of salt hay sometimes only two. They noticed the marsh itself started to sink - and now put a top dressing of Sapropel to enhance salt hay yields (marine mud to bring the surface above the tides) once pools formed they can get hot and burn into a hole called salt pannes. The sulfides in these pools are so high only a few plants can live here in high sulfur – it is also home of the killifish, one of the most sulfide tolerant species in shallow waters.

What farmers and fishers did not know is the impacts of sulfate reduction on submerged soil habitats – it destroyed them. A new habitat soon emerged the oyster reef, and shells buffered the acidic conditions allowing blue crabs to hibernate in marine soils with an oyster shell cover. A long cold winter is deadly to hibernating blue crabs as it allows Sapropel to purge sulfides and kills crabs in the mud itself. Some do not have enough stored food perhaps but I suspect as many shellfishers confirm the benefits of working marine soils, the scattering of oyster shell and mixing in oxygen into the top layer of marine soils. This chemically may help blue crabs survive in this "cultivated" material. Many cases in the historical fisheries literature mention the benefits of soil disturbance (including hand hauled trawl nets) as long as it did not create habitat instability – in other words working the same bottom day after day does contain instability – periodic is "good" but of habitat succession large storms do the same thing as if you did not cut your grass every day. It is also easy to see the negative habitat impact of continuous forest fires or what happens when lawn care (mowing) is stopped for long periods, but that habitat change is difficult to "see" that in the marine environment.

Over cultivation can occur and a series of hurricanes in a short time can create much habitat instability. That is why the best quahog sets occur after the last cultivation event – allowing the soil to then stabilize.

Periodic cultivation events (hurricanes) does remove and "turn" Sapropel deposits now releasing a sulfuric acid wash – crabbers may notice this after a serious storm or flood of organic matter, metal crab traps may dissolve, the same thing happens to mooring chains in New England they turn black and disappear. Mooring mushroom anchors in deep muds may in time be eaten at this sulfuric acid interface. It is this sulfuric acid/sulfide wash that can also "winter kill." Sapropel when exposed to oxygen purges sulfuric acid – farmers a century ago who harvested Sapropel for land fertilizer applications (it replaces important soil metals from acid leached soils) soon found out that when exposed to air sulfuric acid levels soared. Regional New England Agriculture Experiment Stations quickly advised farmers to cut in oyster shell (lobster shell to the north) to offset this "hurtful acidity" on terrestrial soils. When they blended in bivalve shell the productivity of Sapropel soils soared.

Marine Soils and Nitrogen

Most likely the best situation to study Sapropel is with the Winter Dredge Blue Crab Survey of Chesapeake Bay – I also suspect that some of the best over wintering soils are not the blue-black deep Sapropel compost but marine soils with a thin organic deposit mixed with bivalve shell. When you look at oyster and blue crab fisheries, they both do better in moderate heat following a cold period that is in the historical fish records (extreme heat however brings die offs and oyster diseases and higher bacteria counts as well).

Many blue crabbers have experienced this blue-black deposit Sapropel as I have. When you get stuck in it and need to put your outboard on lift or churn your way out of it chances are you also smelled sulfur – that is the result of bacterial sulfate reduction – it can stain your hands and the sulfur smell sink into your skin (the "Ticky" blue crabs). That is the material in so many historical references referred to as having the smell of "rotten eggs." High heat alters the nitrogen cycle as well – turning cold water nitrate bacterial process to those of sulfate that produce ammonia. Many shallow areas had ammonia levels soar in high heat as organics (black mayonnaise) Sapropel deposits overwhelmed the oxygen/nitrate pathway – when this happens bottom habitats become deadly to oxygen requiring sea life.

We have had a dramatic change in habitat conditions recently after a long hot period with few hurricanes 1972-2012- we have had several hurricanes and colder winters – the Polar Vortex and sub tropical jet battle now and intensify these coastal storms. The impacts will be felt in the marine soils – but very few researchers are looking at Sapropel (black mayonnaise) area much I believe from an existing research bias and funding effect policy dilemma – for so long the public and fishers were told it the bottom "was all good" when it fact it is not. Sometimes its beneficial to dredge and remove Sapropel before it becomes deadly – we may need to adjust dredge windows for ammonia and sulfide rather than times. In time Sapropel naturally increases heavy metals, even mercury and discharges aluminum the most toxic substance into the marine environment. Much of it from salt marsh digestion of organic matter by sulfate reducing bacteria.

Now with some overseas research (sadly I add here) we are learning that eelgrass/Sapropel is unhealthy to fish and shellfish but now – as a potential source of dangerous Vibrio bacteria. Some Vibrio bacteria have been identified as specific only to eelgrass, and eelgrass but its natural ability to bind organic matter is considered a vector for Vibrio diseases – even to coral reefs (black band disease) has been linked to Vibrio species. (See J. M. Cervino et al 2004 Relationship of Vibrio Species Infection and Elevated Temperature to Yellow Blotch/Band Disease in Caribbean Corals).

Climate Change and Habitat Failures

As winters grew longer in the 1930s Sapropel deposits shed its sulfides built up in the heat of the 1890's and after storms oxygen created acids – sulfuric acid that terrestrial farmers also learned to be harmful unless treated with shells. These organic deposits that eelgrass helped create now turned against it them as well – the acids causing "root failure" and patches of eelgrass could be cast up even by weak storms then with the remains of root tissue still attached to it (blades). By 1931 the eelgrass habitat failure became known as the wasting disease. Although much information has appeared in the literature linking eelgrass populations to high bay scallop catches, over time and in the catch statistics they appear to have an exactly opposite relationship – the cold and stormy periods destructive to eelgrass meadows have the best bay scallop catches. As eelgrass populations died off Bay Scallops crops increased. The Poquonnock River in Groton is an excellent example of the 1950s –1960s bay scallop "return." In the high heat when eelgrass meadows grow thick, (1890s) bay scallops declined and until the 1970s many New England states conducted eelgrass control, or direct removal programs it was so destructive to shellfish habitats. Massachusetts had the best historical references to these eelgrass "problems." (IMEP The Blue Crab Forum™ Quahoggers Final Stand Against Eelgrass In Chatham Oct 9, 2014 fishing, eeling, oystering thread). Now we are leaning that eelgrass assisted the sulfate reducing bacteria commonly known as the Vibrio series – some of them identified in blue crabs intestinal tracks. The increase of Vibrio into southern New England waters came after years of heat, and the build up Sapropel organic deposits – its "food."

In the heat deep organic Sapropel deposits that can contain the Vibrios – dangerous to seafood and at times us. How can what seems to be so good at times contain these harmful bacteria? I suspect that blue crabs have developed ways to counter act these bacteria even perhaps to neutralize them as suggested by some research (overseas mostly), Horseshoe crabs a survivor from the age when sulfur ruled also appear to be uniquely suited for these bacteria rich habitats they don't have a oxygen/iron blood base. An entire research effort has developed around the horseshoe crab and its ability to inactivate bacteria by sticky bio films.

Blue Crab Population Cycles

While many blue crab studies continue to focus upon reproductive capacity models – traditional fisheries management is "weak" at predicting such wide swings in estuarine habitat quality – we just don't have the basic foundation for habitat quality information and why predictive models are often described as "brittle." There was nothing anyone would have done to prevent the loss of New England oyster setting capacity after 1920 it just got colder here with powerful storms. The best year for shad returns was 1959 – why, because stream energy and cold waters made returning fish feel "welcome" here (the late 1950s are not known as being pollution progressive). In high heat and low energy streams can emit bio/bacterial chemical sulfide and aluminum blocks, low oxygen and chemical residues meant that many fish simply passed us by in the very hot 1990s, shad and alewife runs now diminished. The habitats here no longer welcomed them. It was hot and organic matter emitted toxic compounds. Could the ratio of oxygen reducing bacteria to sulfur reducing bacteria be not only an indication of climate cycles but also inshore habitat quality for many species including the blue crab? I believe so and that this relationship could tell us much about the bio chemical aspect of inshore habitat quality – oxygen levels influencing nitrogen relationships and toxic algal blooms. These damaging algal blooms seem to be increasing as inshore habitats warm and become hot. Blue-green algae strains Cyanobacteria that can use hydrogen sulfide as part of a respiratory process can yield neurotoxins in high density blooms.

As southern New England temperatures warmed again after 1972 a declining lobster habitat quality meant the blue crabs would return again. The cycle of eelgrass/sapropel did mirror the rise of blue crabs and also the increase of bacteria that live in them. Clean new growth eelgrass meadows protect the blue crab megalops and star crab sizes – it gives them protection and feeding opportunities. Soft organics allow them to hide. But as eelgrass habitats age, they can turn deadly. Increasing warmer tides in heat bring sulfate and now life to dangerous bacteria. This is the sulfur/sulfide cycle part of bacterial reduction of organic matter this is missing from so many current studies.

It will most likely take decades of research to clearly represent what inshore fisheries face with sea level rise and warming. The past climate cycles give us a look at what happens, John C. Hammond told me once on Cape Cod if I wanted to follow the climate – look to the fish, he suggested the 1880-1920 hot period in which southern New England lobster fisheries collapsed to be replaced with a surprising surge in blue crabs, we have had the same thing occur again – at the same time we have an advantage as we can now examine these cycles and issue habitat quality indices. We can learn much from the information that fishers see themselves every time they fish (my view).

The Future?

Many of the same research institutions that heavily promoted eelgrass as an ideal or preferred habitat type (even promoting the planting of eelgrass culms into sulfur rich Sapropel deposits) are now gearing up for a massive "Blue Carbon" initiative. As more research about habitat cycles is available there is time to prevent the same "snap shot" approach or bias which surrounds much of the eelgrass research. While in cold and oxygen sufficient times eelgrass provides several "positive" habitat services, and to blue crabs and other species but in heat and covering deep organic deposits it becomes deadly. The Blue Carbon initiative appears ready to repeat the snapshot approach. The study of the blue crab offers as a chance to see which marine soil conditions that helped or hurt blue crabs, because contrary to lobsters or quahogs they have relatively short life spans. Sadly as much as my modest research has revealed to date we know very little about the habitats in which blue crabs spend half their lives. A closer look at these eelgrass habitats may also reveal important information about the role of bacteria in them and also the aspect of "Blue Carbon" from them.

Finally, for those "Blue Carbon" researchers please give a balanced approach to the science – provide the public both sides of blue carbon process in shallow water organics and its long term habitat changing consequences. Sulfur reducing bacteria do act to store carbon but in the process create some of the most negative shallow water habitat conditions for fish and shellfish - Sapropel. Fishers need to know about the sulfur cycle and its bacterial impact to their inshore fisheries habitats – unfortunately as the eelgrass case now illustrates the inshore sulfur cycle has been sometimes hard to find – my view.

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Appendix (1)
Treatment of Muck Soils

Sulfur Toxicity 1909, Washington, DC
US Dept of Agriculture July 27th 1909 Experiment Station Work

In a 1909 US Department of Agriculture Farmers Bulletin 366 Experiment Station Work (prepared in the Office of Experiment Stations – A. C. True Director of Experiment Stations Washington Government Printing Office 1909). The problem of "sour" or acid bottoms (a term that is used in the historical fisheries literature many times) is mentioned in a report titled "Treatment of Muck Soils" from the Florida Experiment Station – Bulletin 93, 1908.

"Muck soils are generally acid or sour, and this acidity must be corrected before they will be productive."

And mentions the bacteria change in them as “useful micro organisms” and the impacts of air (oxygen) to make these “soils” able to be fertile. These are much the same aspects to marine soils only here the natural “cultivation” is a storm event.

The similarity between them and the impact of oxygen is remarkably the same explanation a century later, page 5 of this report.

> “Cultivation should be deep, especially at first, in order that the air may thoroughly penetrate the soil. Muck soils often contain substances that are injurious and even poisonous to plants. When these poisonous, substances are exposed to the air they are probably oxidized to a considerable extent and thus destroyed. A free circulation of the air also improves the conditions for the development of the useful micro organisms.”

And further -

> “The importance of destroying the acids can be better appreciated when we remember that the micro organisms that convert organic nitrogen into a form that can be used by plants cannot develop in a highly acid soil, and gives the explanation – muck soils.
>
> “are so strongly impregnated with acids that the bacteria which would otherwise convert the inert nitrogen of the organic matter into soluble nitrates cannot live” … nitrate of soda may be used to good advantage as may also stabled manure as it introduces beneficial bacteria.”

Farmers a century ago were well aware of the “good” and bad “bacteria” and many of the impacts of each. And compare David Beldings description of subtidal soils influencing soft shell clam growth in the 1920s in the State of Massachusetts (Reprints are available from the University of Massachusetts Cape Cod Extension Service).

David L. Belding – A Report Upon the Soft Shell Clam Fishery of Massachusetts 1920.

Under the section on unproductive flats –

“Organic material: clams (soft shells) are usually absent from soils containing an abundance of organic material. Even if the slimy surface does not prevent the set, the clams that take lodgment soon perish. Organic acids corrode their shells and interfere with the shell forming function of the mantle. Such a soil indicates a lack of water circulation within the soil itself as indicated by the foul odor of the lower layers of soil, the presence of hydrogen sulfide decaying matter dead eelgrass, shells and worms. If such a soil could be opened up by the deep ploughing, or resurfaced with fresh soil to sufficient depth, it would probably favor the growth of the clam."

And further - Belding Comments -

"The surface of a soft mud flat may be made firm by covering with sand or gravel, either through the agency of a storm or by manual labor. Instances of good clam flats being formed in this way by dredging deposits are on record."

Some very heavy clam sets that occurred after dredging in the 1960s which perhaps broke the sulfur cycle in soils with sulfur reducing bacteria.

The salt marshes are perhaps the best place to study this bacterial/sulfur conflict. In high heat salt marshes are bathed in sulfate (not limiting in coastal sea water) and now subject to the impact of collapse as root tissue (peat) is consumed deep below the marsh surface.

In the extreme heat the same sulfur cycle – sulfide toxicity will impact salt marshes at the surface – sulfide levels that can cause yellowing as the root rizophere collapses as sulfide levels build. Much more plant energy is utilized in moving oxygen to plant roots weakening the plant and making it more susceptible to fungal infection. It is interesting the note that the 1928-1931 die off eelgrass occurred after the warmers 1880 to 1920 period had ended. It is suspected that colder water had allowed sulfides to rise and weaken the roots. As energy levels increased into the late 1930s (storm intensity increased) these weakened eelgrass meadows were no match for these storms and the sulfuric acid washes that followed them. These long buried and "putrified" soils now released sulfuric acid when exposed to oxygen much like muck soils.

In high heat sulfate digestion by sulfur reducing bacteria can create sulfide levels so high that vegetated mud flats turn into a blue-black substance that Nichols (1920) describes where areas were unable to support any plant life. At lower tides "present a surface of soft blue black ill smelling mud an area in which, except for local colonies of eelgrass or salt marsh grass (Spartina) seed plants and attached algae are practically absent." This is an early description of Sapropel – one still appropriate today – my view, T. Visel. See George E. Nichols, Torrey Botanical Society 1920 Vol47 #11 The Vegetation of Connecticut VII.

Salt marshes themselves may disappear as sulfate digestion consumes them slumping or even sinking below tide levels. Sulfate digestion is now linked to flood wall failure in the tragic flooding of New Orleans during Hurricane Katrina.