The Effects of “Salting” on Razor Clams

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by

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Abstract:

We studied the impact of "salting," the method used to fish razor clams, where concentrated salt solution is used to flush clams from their burrows in sand/mud. Effects of the excess salt on intact clams and clam tissues, and the potential for overfishing are discussed.

Microscopy and Imaging

- A translucent substitute for sand/mud allowed us to document (via video recording) the reaction of burrowed razor clams to salting.
- Concentrated salt solution (fishermen use 100-200 ppt) is deadly to the clams if the tissue is directly exposed: ciliary pumping is irreversibly stopped (determined via video microscopy), and cilia and microvilli shrink and disintegrate (determined by light and transmission electron microscopy).

Findings/Concerns about Salting

- The extra salt added to the estuary does not measurably affect the salinity in Pleasant Bay
- The town of Orleans has 30 licensed razor clammers, up 1000% from five years ago.
- Each razor clammer typically takes 300 pounds (900 to 1500 clams) per day, and there is no limit on numbers or season.
- Beds are usually fished twice before essentially depopulated. Clams take two to three years to mature, (up to 10 years to maximum size), so beds require several seasons to repopulate after being fished out.
- The impact of the razor clam fishery on the horseshoe crab population is undetermined, but horseshoe crabs compete with clammers for this food resource. *Limulus* is itself a resource for bait and biotech uses (up to 400,000 horseshoe crabs are taken annually in Massachusetts alone). These two resources deserve a coordinated management plan.

Acknowledgements:

Special thanks to Albert "Skip" Norgeot and AMAR Labs for providing us a marine biology lab in S. Orleans and for his guidance and support. Thanks to Craig Johnson and Howard Johnson for allowing us video interviews and a wealth of clamming knowledge. A very special thanks to Dr. Daniel Gibson III and the WPI Biology department for his time, energy, guidance and knowledge throughout the entire project. Thank you to Susan Johnson for her excellent video recordings[*]. Thank you to Brian Robinson for allowing me (Joel) to live in his house during the summer. Thanks to the UMASS Medical School for giving us access to the transmission electron microscope.

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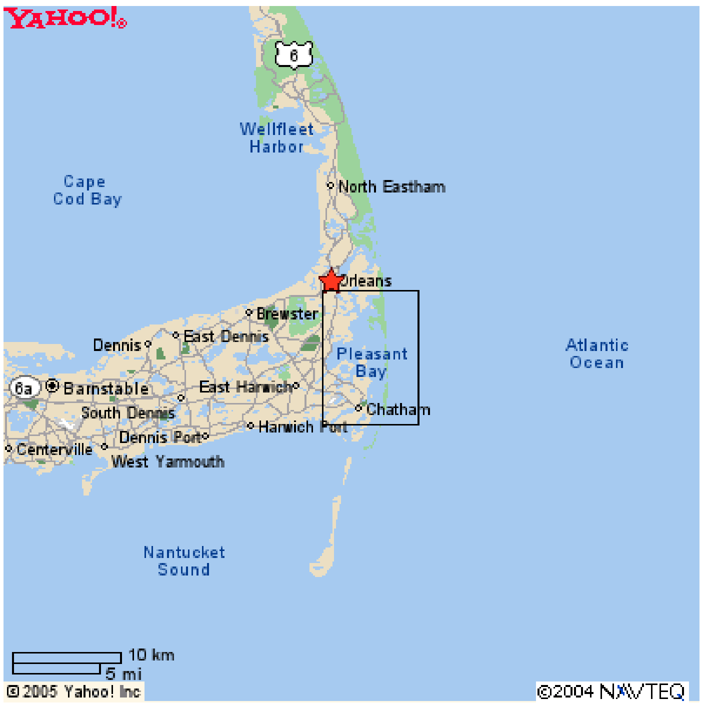
Introduction:

A variety of clam types (hard clams [*Mercenaria*], softshell clams [*Mya*], surf clams [*Spisula*]) are harvested commercially by raking, tonging, and dredging. Salting, i.e., squirting salt into clam burrow to force the clam out, is a technique that was seldom used commercially until lately when it was found to be very effective in harvesting razor clams (*Ensis*), both on Cape Cod and on the Irish Coast (Albert Skip Norgeot, former shellfish warden, Town of Orleans, and Fahy et al., 2001). The growing market for razor clams is mainly overseas and in the restaurant trade (Asian and Italian cooking: personal communication from Craig Johnson, razor clammer, Chatham, MA). Five years ago there were only a handful of fisherman targeting razor clams in the Pleasant Bay area on the "elbow" of Cape Cod. Now over thirty licensed razor clammers ply Pleasant Bay in all seasons (Cape Cod Times, June 2004).

Clams are salted at any time when water is low enough to wade in and clear enough to see the clam burrows, which appear as ~20 mm holes in the bottom, surrounded by a ring of excavated mud and sand. The fishermen fill an insect sprayer back pack with concentrated solution of fish salt (coarse sodium chloride used to salt codfish and herring) and sea water. They spray the salt solution in the clam hole and this causes the clam come out of the mud. Then they walk back over the area and collect the ejected clams (Cape Cod Times, June 2004).

Razor clamming by salting is currently unrestricted except that clammers must have a license. Dawn Farber, the shellfish warden of Orleans is very supportive of razor clamming as long as the resources are available (Cape Cod Times, June 2004). The clam population may not be able to withstand the fishing pressure, the species that feed on the clams may be affected, and the long tem effects of repeated salting on the remaining clams is unknown. We monitored clamming in Pleasant Bay and devised experiments to determine salt effects on intact razor clams and clam tissue.



Pleasant Bay lies on the south eastern shore of Cape Cod. Many parts of the bay fall to less than one foot depth during low tide, which is ideal for razor clamming by salting. Most of our field research was performed using AMAR Labs (Albert Norgeot, Proprietor) as home base. AMAR Labs is located at the Quansett Dock/town landing in S. Orleans

Methods:

1. Obtaining clams:

We obtained clams from Pleasant Bay clammers who had salted them. These clams never fully recovered and died within a few days. We then dug our own from clam beds in Plymouth Bay on the South Shore, and transported them to the laboratory on ice.

2. The Effect of Salt on Cilia and Microvilli function and Structure.

Clam gill tissue was pinned out on a transparent silicone elastomer resin (Dow-Corning Sylgard® - bottomed Petri dishes. Then different salt concentrations were used to find out how they reacted with the tissue. Salt concentrations of ~70 ppt, ~100ppt, 135 ppt, 170 ppt, and fully saturated salt solution. These were concentrations were applied using two methods.

The first method was pumping the salt solutions over the gill tissue to see the cilia reaction vs. time. This was not precise because the salt diffused in the residual seawater and did not give accurate results for the concentration.

The second was securing the tissue to the resin filled Petri dish and submerging it in different concentrations of salt solutions. The best concentration for further experimentation was 100ppt. This was used as standard concentration after when experimenting with gill tissue

We made a 100 ppt. salt solution by adding 70 g NaCl to 930 ml seawater (original salinity: ~35 ppt) and exposed blocks of clam gill tissue to it for 5, 10 , 20 , 30, 45, 60, 90, and 120 sec. to show the damage to the cilia and microvili from the salt.

After the high salt treatment, we mounted the tissues in normal seawater on microscope slides and videotaped its recovery of ciliary movement.

A subset of the treated tissues: (0 sec, 10 sec, 20 sec, 30 sec, 45 sec, 60 sec, 75 sec 90 sec and 120 sec exposure) were immediately dropped into 2% glutatarldehyde in cacodylate buffer (pH 7.8, osmolarity 900 mOs/kg), post fixed in 1% osmium tetroxide, dehydrated, epoxy-embedded (Anderson and Ellis, 1965), and cut into 0.45 um and 70 nm sections for light and electron microscopy, respectively.

3. How intact Razor Clams React to Salt Solution.

We filled a transparent 2 L plastic vessel with clear silica gel beads (~5 mm diameter: Litter Pearls^{TM}) and added natural seawater to provide a substrate for the clams to burrow in that would allow us to observe their movements. We then placed a clam on top and allowed it to dig to a comfortable depth. Finally we observed the clams' reaction to different salt concentrations that were pipetted onto the clam's siphon and onto his foot.

4. How clams recovered from salt exposure experiments.

The clams were exposed to concentrated salt solution by pipetting in the laboratory environment were placed back into their natural environment. They were buried in the mud in a mesh cage to ensure the same clams would be observed at a later date. The clams were allowed to stay in the bay for one week.

Results:

100 ppt salt solution did not prevent cilia from recovery under 45 seconds. At 75 seconds there was moderate to severe decline in recovery and at 120 seconds there was virtually no recovery in cilia function and the gill tissue appeared to be dead.

Table 1.

Time Gill tissue was allowed to set in 100 ppt. salt solution	Ciliary function recovery after being replaced in seawater for 60 seconds
10 seconds	Full Cilia function restored
20 seconds	Full Cilia function restored
30 seconds	Full Cilia function restored
45 seconds	First indication of impaired recovery
60 seconds	Slightly impaired recovery
75 seconds	Moderate/Severely impaired recovery
90 seconds	Severely impaired recovery
120 seconds	Virtually no cilia function restored. Tissue appears dead.

100ppt salt solution destroys cell membranes when applied directly to gill tissue, this was determined from electron microscopy. The 100ppt salt solution is approximately only half of what the fisherman use. Such a saturated salt solution when applied to the gill tissue caused immediate death. The gill tissue seen in the following 3 figures was soaked simultaneously with the gill tissues seen in table 1. They were preserved in 2% glutaraldehyde on ice, and prepared for fixation and embedding as for *Limulus* (Gibson and Lang, 1979). This protocol was used because the horseshoe crab is also a euryhaline marine invertebrate that can tolerate exposure in the intertidal zone. All fixations and washes were in 100 mM sodium cacodylate buffer, pH 7.8: after initial fixation in 2% glutaraldehyde, tissue was postfixed in 1% osmium tetroxide, dehydrated in ethanol and propylene oxide and infiltrated with EmBed-12-Araldite after a recipe for Epon-Araldite by Andersen and Ellis (1965).

Figure 2:

10 second exposure to 100ppt salt solution
Scale bar: 1 µm
The microvilli are in healthy condition.
The membranes are in good
condition and are clearly defined.

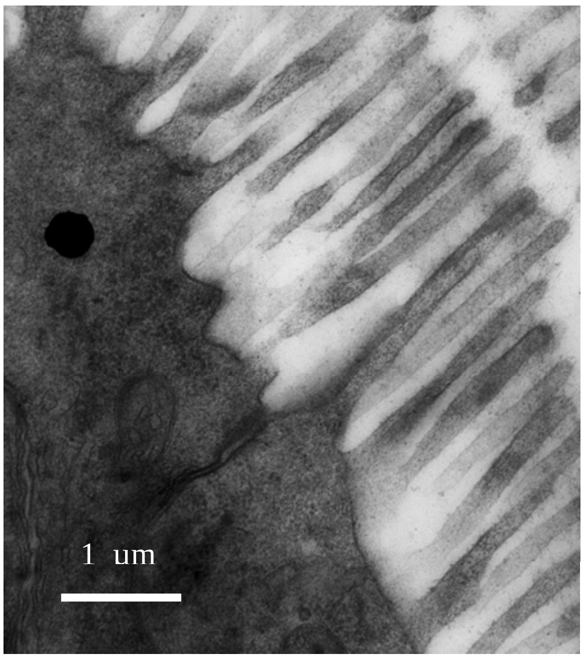


Figure 3:
75 second exposure to 100ppt salt solution
27,500 magnification
The microvilli and cell
membranes are noticeably damaged.
The microvilli have
shriveled due to desiccation.

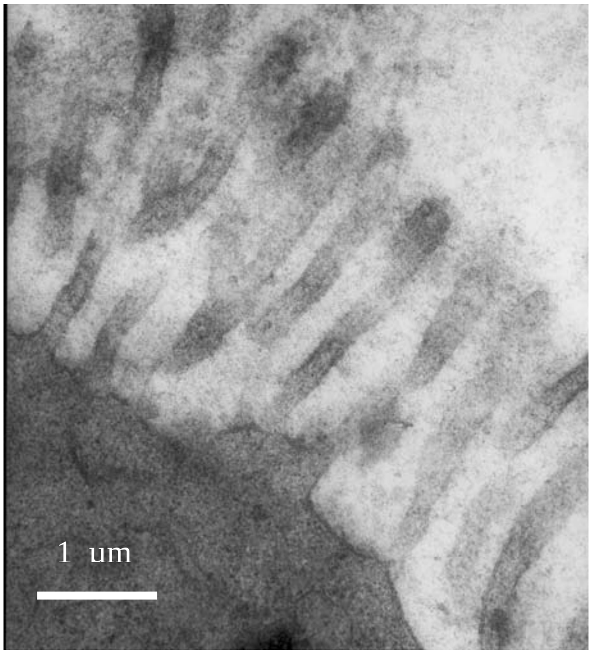


Figure 4.
120 second exposure to 100ppt salt solution
27,500 magnification
The microvilli and the cell membranes are destroyed to the point where they are almost indefinable. What is left of the microvilli has shriveled severely

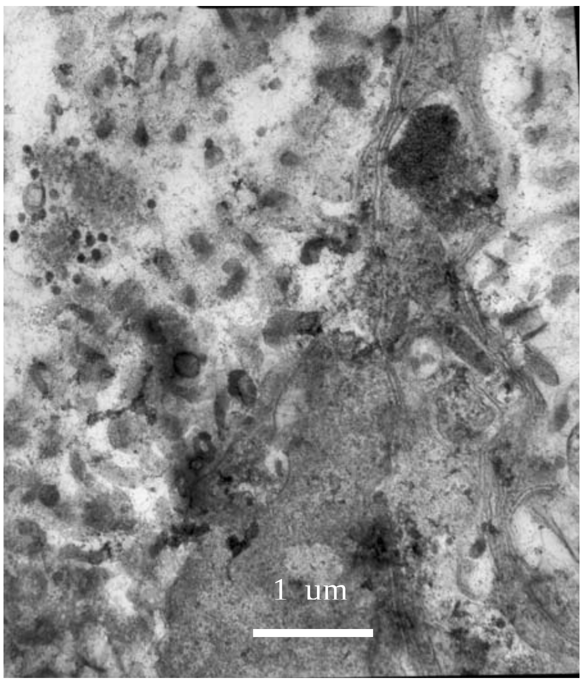
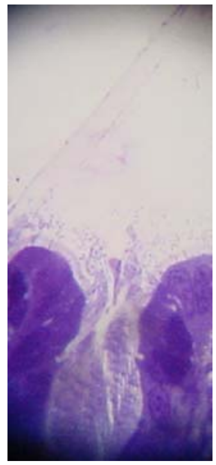


Figure 5
Seen under a light microscope at 400X magnification. This piece of gill tissue was submerged for 10 seconds in 100ppt solution.

The cilia and microvilli can be seen in excellent condition.

Figure 6
Seen under a light microscope at 400X magnification. This piece of gill tissue was submerged for 75 seconds in 100ppt solution.



The cilia and microvilli can be seen with substantial damage

Salting clams in a lab environment.

The clams were dug using conventional methods. They were then transported on ice to the site of experimentation. Concentrated salt solution was then injected into the water on the clams siphon and foot and the effects videotaped. The concentrated salt solution was not applied as forcefully as the clammers' methods and also less volume was used, so we erred on the side of caution in obtaining and interpreting our results.

Figure 7 Salting effects on clams

7.1. Initial introduction of concentrated salt solution. The clam pulls down after 17 seconds. This initial reaction is to avoid the salt, but is not adequate.

7.2. At 28 seconds the clam begins upwards to exit his now hypersaline burrow.

7.3. From 28 to 40 seconds there are three surges upwards.
Note expanded foot, being extended to push clam upward.

7.4. At 51 seconds the clam squirts to eject "inhaled" salt.

7.5. At 63 seconds the clam squirts a second time.

7.6. At 105 seconds the clam, having cleared his gill cavity of excess salt, re-burrows, pulling down hard. More salt is added and the clam pulls down hard a second time, repeating the initial strategy, to flee the salt by drawing further into the burrow. As shown in figures 2-4, pulling into the burrow is not a successful way to avoid salt exposure.

The results above show the effects of salting the clam at the top of the burrow.

Introducing salt at the foot of the clam causes him to draw the foot into the shell and close it (although razor clams cannot tightly close their valves). Putting salt solution on the foot of a clam from which the shell has been removed causes escape responses of the foot, but this is only because the clam is then unable to protect the foot within his shell.

Clams reintroduced to natural environment.

The clams were then reintroduced to a natural environment and allowed to sit in the mud for a week to see if they recovered. It appeared that all clams salted made a full recovery. The clams were then retaken and brought back to the laboratory. They were dissected and compared to unsalted clams. There was no distinguishable difference between the two. Clams salted by the fishermen could probably show similar recovery if less salt was used to flush them out. In fact, salted clams do not recover, most likely because of the higher pressure and volume of salt used. Because salted clams are usually picked up and held in a floating basket, they can pump and flush their gills for long periods after harvest, but the salt load appears to be too much for them.

Discussion:

100ppt concentrated salt solution affects the cilia function in the gills and it also disturbs the cell membranes. This can be seen in Table 1. It shows that after 120 seconds in 100 ppt solution there was no recovery of ciliary function. The progression of damage in Figures 1.-3 shows that the membranes sustained increasing damage from 10 seconds to 120 seconds. Even though fishermen use more concentrated salt solution, we cannot calculate how much salt is actually inhaled because the animals quickly close their siphons and stop pumping. However, the fact that they do not recover long-term even when replaced in a suitable environment indicates that they receive a substantial dose of salt.

Razor clams cannot tolerate the highly concentrated solution so they are forced to move to an area of less concentration. They do this by leaving their burrows to escape to normal seawater. This was seen in the fishery and in the lab. The clams in Pleasant Bay left their holes after being salted. The clams in the lab left there holes to clear their siphon before burrowing back down. We believe the clam only burrowed back down in this case because it came out of the water and was able to clear itself before it had to completely evacuate. Exposed clams are at increased risk of predation and therefore leaving their burrows would be maladaptive. Nevertheless, there are anecdotal reports of razor clams migrating to new beds on rising tides (Skip Norgeot, former shellfish warden, town of Orleans, personal communication).

There is no evidence that there is a lasting effect on the environment due to the salt.

Samples were taken from the water shortly after the fisherman had passed by and the salt concentration had dropped to normal almost immediately. Salinity readings were taken with a refractometer, which measures absolute solute concentration, as opposed to a hydrometer, which measure density and gives readings that fluctuate with temperature.

Peter Krzyzewski looking through a refractometer

An example of a refractometers reading.

The salting is usually done in about two feet of water and there also usually is a current. The water depth and current is enough to clear the salt away and allow it to diffuse effectively. Also the clams prefer a sandier type of mud so there is more water flow underneath the bottom to clear the salt away. A simple mathematical model demonstrates the minimal effects of salting on the environment: If a fisherman makes up 10- 5 gallon tanks of 200 ppt. salt solution, that is 40 kg of salt. To dilute this to 40 ppt. (just slightly more than the 35 ppt of seawater) would require 1000 L. 10,000 L of tidal flux would dilute this salt, mixed with seawater, to 39 ppt. 10,000 L, to envision the volume, would fill a swimming pool just 1m deep, 2m wide, and 5m long. With tidal flushing, this amount of salt is in fact insignificant in the long term, but undoubtedly affects other organisms near the site of direct application.

Future experiments and further questions

We found that 100ppt. salt solution had a detrimental effect on clam tissue as seen in the experiments mentioned previously. If the clams the fishermen collect never recover it may mean they are not getting to market in as good condition as possible. If they could use a lesser salt concentration and find it still effective they could be helping themselves out in terms of: attractiveness of their catch to buyers, expense of buying salt, and less osmotic water (and therefore, weight) loss by the salted clams.

Another question and concern is the growing number of fisherman in the Pleasant Bay area. Over the past 5 years there has been a 10 fold increase in the number of clammers (Cape Cod Times, June 2004). With a conservative average of 300 pounds a day being taken per clammer, a 9,000 pounds of clams per day are taken from Pleasant Bay. This may be more pressure than the fishery can support. If the fishery collapses this would hurt the fisherman involved in clamming, but paradoxically, the price of clams would rise as they got scarcer, and this might actually lure *more* fishermen into razor clamming at the very time when pressure on the resource should be eased, instead. Two factors mitigate against this, however. Because fishermen go through dealers, the prices may not follow supply and demand directly, and when rate of return per unit effort declines, the slack may be taken up by clamming in other locations, so that the price might not rise at all.

The clams salted by the fisherman did not fully recover. The clams salted in a simulated environment fully recovered. What was the cause for this? Some possible explanations are that the fishermen used a more forceful method of salting. Once bought, the clams are refrigerated but not re-immersed in seawater, so while they are protected from overheating, they are also prevented from clearing excess salt from their bodies. Clammers salt many clams at a time before they collect the ejected razors. They go back and pick up the ones they see out of the holes. Sometimes the clammers miss some they have salted. The clams that we took from them never fully recovered. As seen in previous experiments salt has the ability to kill clam tissue when directly exposed in high concentrations. If the reproductive organs are exposed to this they may be damaged and the clam may not be able to reproduce.

In other heavily fished species the size of often goes down over the course of years showing that many of the organisms do not reach adulthood or full maturity. It would be helpful to analyze the size of the clams being caught annually to see if a decrease is occurring. This is an indicator that there could be a potential collapse of a population if individuals are not reaching sexual maturity, or barely reaching it before being taken. Studies on razor clam species in the Irish Sea indicate that the clams require *ten years* to achieve maximum size and *two or three years* to reach sexual maturity (Fahy et al., 2001). This is a longer generation time than many commercial fish species, and it is difficult to know when a break-even point is reached in a fishery like this.

What effect will a decrease in clams have on predators such as horseshoe crabs and the rest of the ecosystem? Ecological studies of razor predators could be performed to see how they would survive in the absence of razors.

Appendix

back to text Craig Johnson.wmv back to text CLams coming up.wmv back to text Horseshoe crabs.wmv back to text Selling and liscencing.wmv back to text H:\add salt.gif

back to text H:\add salt2.gif saltin in lab.wmv back to text goin to flats.wmv

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