Making the Deep Sea Atlantic Red Crab Fishery a sustainable and profitable industry for Virginia

Final Project Report
Atlantic Red Crab Company, LLC
Casey's Seafood, Inc.
Graham & Rollins, Inc.

Virginia Fishery Resource Grant Program
Project Number FRGP – 2014-22

Abstract

In the summer of 2015 about 303,000 red crabs were off-loaded in the Newport News small boat harbor. This activity occurred in part because of a Virginia Fishery Resource Grant. The wholesale value of the crabs was a little more than $600,000 for the crabs unloaded at the dock. Many of those crabs were sold directly into the market. However, 48,000 of the 303,000 pounds of crab were put into a live holding facility, which was built at the dock. The Fishery Resource grant funded some of the equipment that went into that experimental construction. The majority of the funds for site work, construction and equipment for the project were provided by industry.

The primary purpose of this fishery resource grant project was to develop the on-shore live holding system for deep sea Atlantic Red Crab caught in off-shore Virginia waters. A live holding system makes crabs continuously available so that both export and domestic markets can develop. Hopefully a live holding facility will assist a Mid-Atlantic fishery to grow to a catch of a million pounds or more.

The capital-intensive on-shore refrigerated recirculating marine water system was built at Casey's Seafood, 807 Jefferson Ave., Newport News. By the time system was completely operating it could hold water at a temperature less than 40° F and keep the water clean in which the crabs were held. The system's capacity was about 10,000 pounds of live crabs.

The biological filters in the system use natural nitrifying bacteria to reduce and eliminate ammonia in the water, which is produced by the crabs. Ammonia must be reduced or eliminated from the water or the crabs will die. Because the bacteria must build naturally in the filters it took most of the summer to condition them. They are now fully functioning and able to remove both ammonia and debris from the seawater in the holding system. The crab boats supplied the initial seawater in the system and subsequent exchange water. The boats took the water on-board when far offshore. Before the filters were fully functioning, the crabs in the system were kept alive through frequent water exchanges. Because the biological filters are now fully functioning, exchanges are less critical but must still be done on a periodic basis to maintain water quality.

Bringing the filters on line required close collaboration between industry and academia. Frequent water quality samples of the recirculating system were done during the summer. Tests for total ammonia, nitrite, nitrate and alkalinity were done in order to ascertain when the filters were coming on line. During this process industry personnel learned how to operate the filters. Industry employees, with occasional university consultation, can now keep the filters running.

Project's Purpose

Create a sustainable year-round Mid-Atlantic deep-sea red crab industry by building out and improving local red crab infrastructure so industry participants can continuously supply domestic and foreign markets with live crab. The primary infrastructure needs are live holding system, which can maintain high quality crabs for extended periods of time. The market has the potential to expand to over 1 million pounds per year as there is approximately that much quota available.

Project Description

A large recirculating marine seawater system, capable of holding in excess of 10,000 pounds of live red crab was built in the Newport News commercial small boat harbor at Casey's Seafood, 807 Jefferson Avenue, Newport News, VA 23607. This system was intended to provide a continuous supply of live crabs to both domestic and international markets.

Construction of the large holding system in Newport News was almost complete when this photo was taken in April of 2015.

With the exception of the deep-water ocean pressure, the holding system is capable of maintaining water parameters similar to the ocean conditions where the crabs are caught. The crabs are caught at depths of 2,000 feet in water that is 40° F. Red Crabs manage the dramatic pressure differential between were they are caught and the ocean surface

without apparent physiological stress. Red crabs have been held in a live holding system at the Virginia Seafood Agricultural Research and Extension Center for as long one year.

A smaller live holding system, which could hold about 500 pounds, was installed at Graham & Rollins, 509 Basset Street, Hampton, Virginia 23669. Its purpose was to supply crabs to the retail operation and also allow Graham and Rollins to experiment with picking red crabs if the supply of blue crabs wasn't sufficient to keep their picking house operating at peak efficiency. However, after a summer's experiment with the system, Johnny Graham, the president of G&R, decided that it wasn't efficient use of his cold room and that the bigger holding system could supply whatever needs he had. He removed his system.

Outfitting the boat that was originally slated to fish for red crabs in the Mid-Atlantic, the Benthic Lady, was not completed. So it was not sent fishing and the research intended to be done on it was not accomplished. Instead another boat, the Hannah Boden, did most of the fishing, in the summer of 2015, for the red crab. In all about 300,000 pounds of red crab was unloaded at the dock from the Hannah Boden and one other boat this summer. All the boats that fish for red crab have Refrigerated Seawater holds.

However, the boat had a catch capacity of 40,000 pounds, which was too large for the systems in Newport News. So it operated at less than peak efficiency. It brought crabs to the dock between May 19 and September 9, 2015.

A smaller boat, the Sea King, with a capacity of about 15,000 pounds and a handling system that will ease unloading is being retrofitted in a boat yard currently. She will have greater water-cooling capabilities than the larger boats and will be outfitted with heat exchangers.

The Hannah Boden supplied crabs to the project in the summer of 2015. She was one to the two boats that survived the "Perfect Storm." A bestselling book and movie detailed that harrowing storm.

This will allow the boat to maintain higher quality since fouled water in the hold because can now be rapidly exhausted while pulling clean ocean water into the hold. The heat

Unloading red crabs from the refrigerated seawater hold of the Hannah Boden

exchangers will enable transfer of the stored cold energy from the chilled exhaust water to the warmer incoming ocean water. Then the increased mechanical chiller capacity of the boat should be able to finish the job of cooling the water to 40° F. Last summer the Hannah Boden sometimes had to idle at the fishing grounds for 18 hours waiting for the chillers to cool the water to the desired temperature. The crew does not start fishing until the water in the hold is cooled to 40°. The improved chilling capacity may increase the rate of water exchange on the trip back to the dock. This should allow the boat to arrive with little free ammonia in the hold water. The on-shore filters can rapidly eliminate the ammonia that is in the water that is pumped off the boat into the land based holding system. None of the red crab boats have room to carry biological ammonia filters.

Specialized Equipment Used

The large holding system in the small boat harbor uses mechanical devices to chill or heat the water, filter solids and microscopic proteins, reduce ammonia and kill bacteria in the water that circulates over the crab. All these water quality control devices are on a "side loop" that is independent of the system that supplies water to the crabs in the trailer. The machines in the side loop are:

1. Two 5-ton heat pumps/chillers.

The pumps were custom built by Larry Yee, Queens, New York. When crabs are in the trailer the target water temperature is 40° F. Depending on the ambient temperature, the pumps can either heat or cool the water. The pumps

are somewhat redundant. If one malfunctions the water can still be cooled, preventing crab loss.

2. Two Aquaculture Systems Technologies Propeller-Washed Bead Filters

The large propeller wash bead filters catch the "solid" debris that accumulates in the system. There is a sight glass in the top of these pressurized filters, which go from white to dark when the filters have accumulated debris. When the filters get dirty a propeller is turned on to agitate and knock the debris from the floating beads. The accumulated debris settles to the bottom of the filter and is exhausted by gravity flow before the tank is put back on line.

When the crabs are in the tank, the filters need to be back-washed once a week. If pressure gauge reading in the tanks increases it is an indication that the filters are becoming clogged. In addition to catching solids, these filters also eliminate some ammonia as nitrifying bacteria clings to the solid beads.

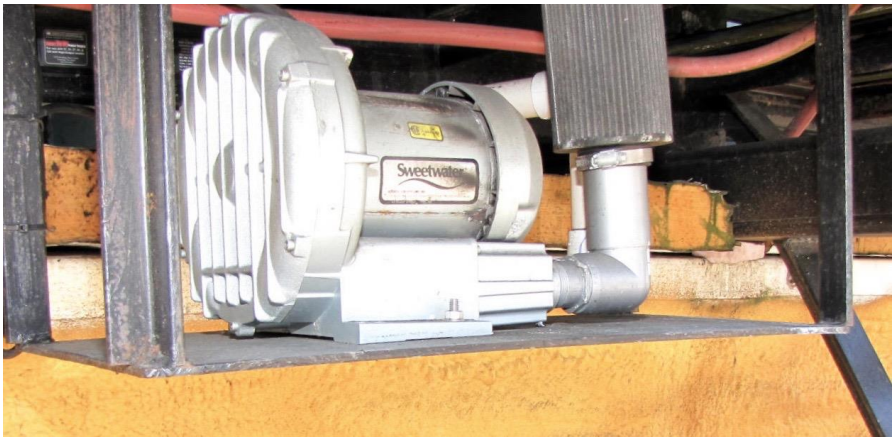
3. One 80 watt UV Sterilizer 45 gpm

The Ultra Violet Sterilizer is after the solids filter because it needs clear water to work. Rays from the ultra violet tube do a non-selective kill of the bacteria in the water that is pushed through the sterilizer. If the water is cloudy the sterilizer is less effective. Most of the beneficial nitrifying bacteria clings to the beads in the filters and is not pushed into the sterilizer. The bulb needs to be changed every nine months or so to maintain peak efficiency. The sterilizer is the last component in the side loop to be fully pressurized.

4. Two fluidized bed ammonia filters

These relatively simple filters do the heavy lifting as far as ammonia removal is concerned. There is an air manifold in them powered by a blower. Air from the blower bubbles through the water and keeps the specialized "Kaldnes" beads, commonly called KMT, in the filters fluidized. KMT, invented in Norwegian universities in the 1980s, have multifaceted surfaces in each bead, which the ammonia (nitrifying) eliminating bacteria can cling to. There are interiorpassages through the bead is that protect the nitrifying bacteria so it can follow a natural life cycle from generation to death and then regeneration. The dead and spent bacteria are constantly replaced with younger heavier feeding bacteria. As the beads tumble in the bubbling water they self clean. Surface area largely determines ammonia removal capacity. The quantities of nitrifying bacteria on the beads move up and down in response to the amount of ammonia in the system.

5. One Regenerative Blower



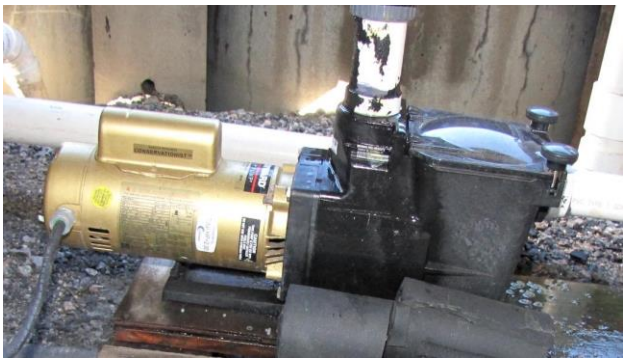
A Sweetwater regenerative blower forces air through the fluidized bed filters with a rotating impeller. This type of blower is much more efficient than a compressor in situations were low air pressure can do the job. The impeller doesn't touch anything as it spins so these blowers last a long time and require relatively little maintenance.

6. **One RK2 25PEm 25-40 gpm protein skimmer with venturi pump**

In addition to the solid waste and ammonia in the system there are organic substances in the water from crab metabolic by-products, algae, etc. These dissolved materials create water turbidity lessening the UV's effectiveness and cause other problems. Venturis in the protein skimmer or foam fractionator inject fine air bubbles into a water column. When that happens the aforementioned microscopic pollutants attach to the bubbles and make foam. This foam can then be skimmed or removed from the water column keeping the water clearer and cleaner. In the RK2, in the picture to the right, air is injected into the water column in the gray canister. Organic substances in the water attach to the bubbles and foam. The foam is then floated off through the clear Lucite canister at the top of the skimmer. Most of the water is returned to the reservoir.

You can sometimes see nature's own foam fractionator at work in the ocean surf. The foam coming off the ocean is created in the same way it is in the protein skimmer.

7. Side loop pump for the water cleansing system



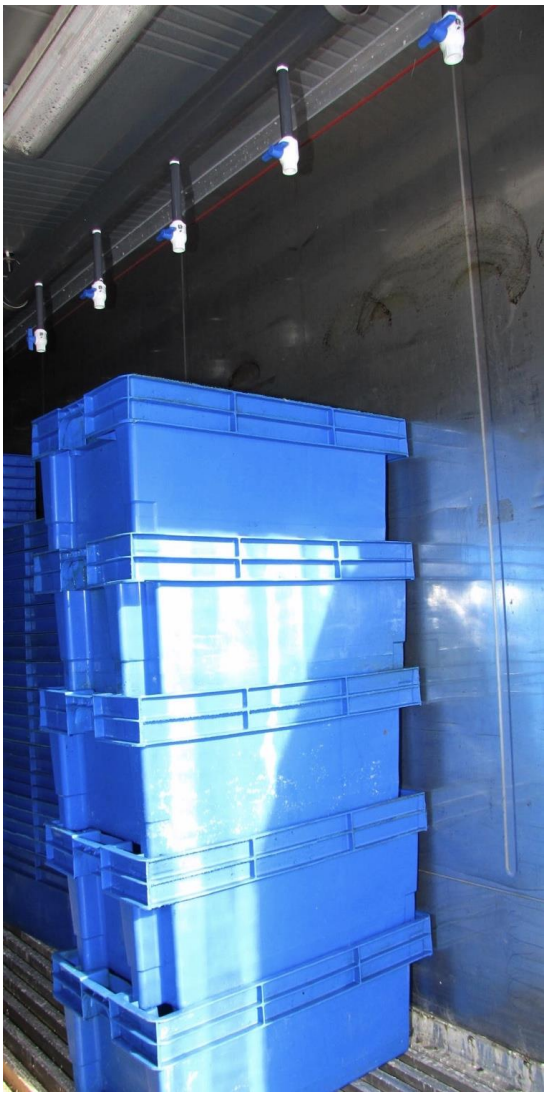
Water is supplied to the cleaning and sanitizing system by a small 2-inch pump. It is the same type of pump that is used in many home swimming pools. Once the water moves through that side loop system it is recirculated into the trailer system.

8. Crab Totes

The crab's claws are banded when they are caught and held in a refrigerated seawater hold. When unloaded and placed in the live holding system trailer, the crabs are packed in stacking fish totes. The totes are constructed so they nest one way and stack, without nesting, when turned 180° on each other. About 40 pounds of crab go into each tote. The totes are stacked four high and under a cascading water stream coming from a manifold attached to the ceiling of the trailer. A fifth but empty tote is placed on top of the "four stack" to protect the crabs in the top tote from the pressurized water cascading in the totes. Each of the totes has a series of holes drilled in the bottom of the tote. The holes allow water to drain to the tote below. However, the rate of water coming from the supply manifold is greater than the drain rate of the totes. Because of this differential each tote eventually fills with water, immersing the crabs completely. Water then spills over the side totes while also continuing to drain through the tote bottoms. The trailer is slightly sloped so water coming from totes goes to a drain to the reservoir below the trailer. That returned water is then cleaned and sanitized in the "side loop" system (described in 1 through 6 above) and then recirculates back through the trailer.

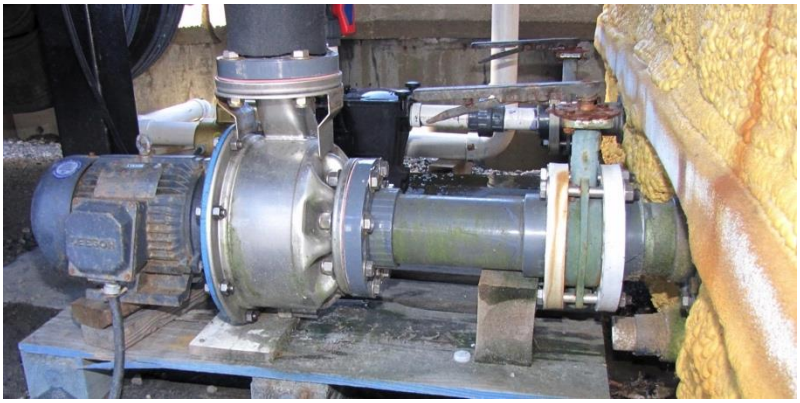
Drain holes in the bottom of the tote

A two-way valve at the front of the trailer can be adjusted to control the amount of water sent to the manifold (the gray pipe in the picture) that supplies the water to the crab totes. The white stopcocks are opened as stacks of crab filled totes are moved below them. Only the stopcocks are opened that have totes beneath them. If there aren't many crabs in the trailer, the valve in the front of the trailer is kept mostly open so that the supply pump does not have to pump against backpressure. Backpressure causes extra wear on pumps and increases electricity bills.



Only the bottom four totes contain crab. The top tote is to catch water coming from the pipe above and let it drain down through the lower totes.

9. 4" trailer supply pump



It takes a large pump to pull chilled and cleaned water from the reservoir and push it up to the manifold in the trailer above. The pump motor is five horsepower.

10. One 39x8X3 foot fiberglass water reservoir

The approximately 7,000 gallon capacity reservoir tank is fully insulated and holds temperature well. It is not filled to capacity when operating.

This picture shows how the chillers, filters, UV and skimmer, which are discussed above, are hooked together.

Results

The system received its first crabs from the Hannah Boden on May 18, 2015. Between then and September 9, 2015 a total of 13 trips were made with a total weight of 302,884 pounds packed. Of that total 47,815 went into the holding system. The dates and total pounds packed and pounds into the holding system for each trip are reported in Table One. Subtract the live system quantity from the total landings for each trip to determine the quantities sold across the dock on the day the boat landed. The quantities in the live system were then sold in subsequent days before the boat landed again with more crabs. This allows for a more continuous availability of the red crabs to the market.

Table One.
Newport News 2015 Red Crab Landings in LBS.

Date	Total	Live System
5/18/15	25,175	11,140
5/26/15	28,422	7,790
6/2/15	29,913	5,200
6/9/15	31,250	5,950
6/24/15	20,310	2,085
7/1/15	15,532	1,992
7/8/15	16,545	1,190
7/20/15	17,720	2,200
7/27/15	11,710	1,500
8/12/15	20,033	1,300
8/19/15	32,018	1,500
8/26/15	19,358	1,200
9/9/15	34,898	4,768
T'tl LBS.	302,884	47,815

Wholesale prices vary depending on quality, quantity purchased, sort, whether delivered or picked up, etc. Accounting for those variables, industry participants estimated wholesale value of red crabs packed in Newport News during the summer of 2015 at a little more than $600,000.

Red crabs packed in Newport News this past summer were sold in both domestic and foreign markets. Most of the domestic sales were along the East Coast from Virginia to Florida. Virginia markets did not develop to the extent expected because it turned out to be the best blue crab seasons in some time. Blue crabs were less expensive than they had been in previous seasons. Newport News live crabs were successfully shipped to China this summer by a wholesaler purchasing the crabs at the dock.

Since the filters are now actively and quickly reducing ammonia, it is hoped even better red crab markets can develop. It took more than three months for the nitrifying (ammonia eliminating) bacteria to build in the tanks. When crabs are constantly being added to the system and removed it can't be accurately determined how well the ammonia filters are working. That is because the quantity of ammonia the crabs are putting into the system is unknown.

However it is clear that initially the filters were not eliminating much ammonia. Attempts to condition the ammonia filters, prior to installation, were not successful. It required time for them to condition naturally.

At first the crabs in the holding system were kept alive mostly by water exchanges from the landing boat. Each time the boat landed, the reservoir in the holding system was pumped down and new, higher quality chilled ocean water from the hold of the boat was

pumped into the system. Crustaceans can handle higher ammonia levels than fish. However initially ammonia levels in the holding system were not well controlled. On June 22, 2015 the Total Ammonia Nitrogen (TAN) was measured at an unacceptable 41 parts per million. (TAN is made up of NH3 and NH4. It is the NH3 that kills marine life.) This high TAN level necessitated shipping some of the crabs to New Bedford for processing before they died. Subsequently less crabs were put in the holding system and gradually the ammonia filters began functioning. On the last big load into system crabs lived in the system without water exchange for three weeks until they were all sold. Ammonia levels were reduced but not low as desirable. The filters have continued to strengthen since that time. (See appendix for a report of all the water quality tests taken.)

Then pumps had to be disconnected from the reservoir because of the threat of saltwater flooding from the strong offshore winds produced by Hurricane Joaquin. The storm system put five inches of water over the office floor where the holding system is located. The pumps would have been submerged in saltwater had they not been disconnected.

The disconnected slightly hurt the filters because no water was being pumped through them. However, air continued to be bubbled through the two fluidized bed filters as the regenerative blower did not have to be disconnected. The filters built strength rapidly after the pumps were reconnected. With no crabs in the system, chemical ammonia had to be added to the system to feed the nitrifying bacteria that took so long to build. Sodium bicarbonate also needed to be adjusted to between 140 and 180 parts per million in order to keep the filters healthy. Greg Casey was trained in how to do this.

With no crabs in the system, TAN was boosted artificially to 10 ppm three times. The filters reduced the TAN level to almost zero in two days. It may even be sooner than that because water tests have been spaced out for at least two days. In this relatively controlled environment, the filters eliminate ammonia. The real test will be when a full load of crabs is placed in the trailer.

Conclusions

Deep-sea red crabs can be successfully kept alive in an on-shore holding facility once the filters are successfully conditioned and maintained. The on-shore facility appears to be fully functional. That should make crab continuously available to markets, once the Sea King gets out of the boat yard and starts to supply the facility with crab. Water quality in the holding facility is high which should allow the holding of very high quality crab. Dependable availability should allow both domestic and international live markets to expand and the red crab industry to become more firmly established in Virginia.

Acknowledgments

The collaborating companies wish to recognize and thank the valuable expert assistance provided by scientists at the Virginia Institute of Marine Science and staff at the Virginia Tech Area Seafood Research Center in Hampton. Virginia. In particular we wish to thank Dr. Dan Kaufmann for his assistance in preparing this final report.

Appendix
Record of water quality tests taken during the summer of 2015

Water Quality Analysis									
Date	TAN	NO_2	NO_3	ALK	pH	PPT Salt	Lbs Bicarb added	Lbs. NH3 add	Comments
5/18/15	4.5	0.242	10.2	170					
5/19/15	7.6	0.264	18.9	200					
5/20/15	11.3	0.220	18.4	220	7.8				
5/21/15	19.32	0.264	18.4	260	7.2				
5/26/2015 Boat AM	0.69	0.019	1.6	160	NA				Memorial day weekend
5/26/2015 Tank AM	26.25	0.168	4.4	320	NA				water dark almost opaque
5/26/2015 Tank PM	14.7	0.124	4	260	7.9				crabs added
5/27/15	17.25	0.129	4.8	340					
5/28/15	13	0.117	4.3	300					
5/29/15	14.25	0.109	3.6	340					
6/2/2015 Fore	1.88	0.026	2.2	130					
6/2/2015 Aft	5.35	0.059	2.4	160					
6/2/2015 Live	8.45	0.265	2.2	160					crabs added
6/3/15	7.95	0.108	3.7	200					
6/4/15	9.63	0.077	2.9	220	7.9				rained torrentially
6/5/15	12.5	0.056	1.7	200					
6/8/15	11.25	0.046	1.7	200	8				
6/9/2015 Fore	4.13	0.03	4.9	180	7.8				
6/9/2015 Aft	9.4	0.076	25	200	7.4				boat came in with foam
6/9/2015 Live	13.75	0.051	2	220	8.2				Crabs added
6/10/15	15.63	0.036	2.4	220	7.8				
6/11/15	22	0.03	1.9	240	7.9				64 oz of nitrifying bacteria added
6/12/15	18	0.028	2.1	260	8				reservoir loaded with foam
6/15/15	36.25	0.034	4.7	300	8.1				foam coming out of the reservoir
									Urick did 6/15/15 sample
6/16/15	26.75	0.042	1.7	340	8.05				Bucket test for alkalinity 6/16
									Student did H20 test 6/16
									Skimmer not skimming A.M. 6/16
6/18/15	45	0.042	5.9	360	8.21				Urick did test
									skimmer working, water and foam with black organics
6/19/15	37.5	0.045	2.8	360	8.2				less foam water appeared better
									salinity 27.5
6/22/15	40.75								before dilution urick did test
6/22/15	28								added water with sump on incoming tide after dilution urick did test

6/23/15	32.5								Urick did
6/24/15 Fore	9.5			140	7.35	31.1			salinity 31.1
6/24/15 Aft	8.6								Urick did all 3tests 6/24
On Shore 6/24/2015	20	0.055	5.3	200	8.18	28.3			tank salinity 28.3; boat water pumped on shore but no crab in system when sample drawn white foam
6/25/15	16.63	0.050	6.2	180	8.0	29.0			salinity 29. More boat water added after 2,000 lbs of crab were put in the system. Foam on tank. Foam still white but black organics on top of foam. Urick
6/26/15	21.5	0.043	3	240		27.3			Rain the previous night. Squadrito
6/29/15	24.13	0.044	1.8	240	8.3	26.5			Rain over the weekend. Squadrito
6/30/15	23.75	0.046	2.2	220	8.4	25.6			Fair amount of foam in tank. Black organics in it. Student did test
7/1/15 Fore	7.30				7.38	32.1			Squadrito-Urick (salinity/pH)
7/1/2015 Aft	6.00		8.6		7.5	31.7			Squadrito-Urick nitrate ph salinity
7/1/15 shore skimmer	16.50		4.5	200	8.1	29.2			Some Boatwater already in tank when sample drawn @ 8:15 a.m Squadrito-1992 lbs into Trailer-total 2500
7/2/15 sk'mmr	15.37			160	8.15	28.9			foam below bottom of deck; white but with black flecks; Urick
7/6/15 sk'mmr	18.63			220	8.3	27.6			little foam on the tank; 1,000 lb crab in tank, Squadrito
7/7/15 sk'mmr	21.88								
7/8/2015 sk'mmr	14.13				7.9	29.6			sample taken at 8:10 a.m. after boat pump
7/8/2015 Fore	7.38				7.5	29.6			Boat samples early a.m.
7/8/2015 Aft	8.63				7.4				Water still being pumped from boat
7/9/15	14.13			200	8.0	29.5			Squadrito, little foam in the tank. Water clarity good 1100 lbs in trailer
7/13/15	20.75			200		29.2			Squadrito, No foam, Water clarity good 200 lbs in tank
7/17/15	22.5			160					Urick, a little foam in tank,no crabs in trailer
7/20/15 shore tank b4 any boat water	20.25								Urick
7/20/15 fore tank	6								Urick
7/20/15 sk'mmr after boat water	14.5					30			Urick, but crab not yet added
7/21/15 sk'mmr	15				7.6	30			Urick, little foam, 1700 lbs in trailer, no water exchange subsequent to sk'mmr tan measurement 7/20 crabs added 7/20

7/24/15	16.75				7.8	30			Urick, thin layer of foam some black flecks in it, 900 lbs in trailer 1500 yesterday
7/28/15 skimmr	10.75				7.7	29			Urick, slightly more foam with black flecks, 1900 lbs of crab added to tank (7/27) with 400 still in there from last week. Crabs added 7/27
7/31/15 skimmr	17				7.8	28			Urick, about 1500 lbs in tank. Water clarity excellent, tan up more than during similar period last week. Possibly cuz of weak crabs
8/7/15 skimmr	25.75				8	27			Squadrito, very little foam in the tank, water clarity good, 150 lbs crab left in trailer & all of that will go out today. Next crabs not until next Wed.. Aug 12
8/11/15 skimr	19.25	0.209			8.1	27			Urick, no crabs in system for 4 days. 6.5 drop in TAN first solid indication filters are kicking in. NO2 4 times higher than previous best (confidence in tests)
8/12/15 skimr	12.25					30			Urick, boat water exchange,1300 lbs of crabs into trailer, boat caught 20,000-all shipped except for those in trailer
8/26/15 skimmr	15.75	0.348	9.4	180	7.7	27			Urick, 1500 lbs in trailer on 9/19. 900 still there on 9/26. Data indicates filters are cycling
9/9/15 fore tank	8.75								Squadrito. This TAN was turned around quick enough that red crab participants used it to make real time shipping decisions
9/9/15 aft tank	14.38								
Date	TAN	NO_2	NO_3	ALK	pH	PPT Salt			Comments
9/9/15 skimmr	12.38	0.313	11.6						Sqadrito. Reading after exchange from the boat but no crabs in the trailer. Shore tank water better than aft tank, but not as good as fore tank. Indicates should not do further exchange from aft. Boat landed with approximate 30,00. About 5,200 in shore trailer system but probably some of those will be taken out.
9/11/15	22	0.43	27.7	170	7.8	28.7			Urick. Boat in on 9/9. As many as 5700 lbs of crab were put in the trailer while boat unloaded and by the end of the day 4800 in the trailer. On 9/10 another 1000 were sold so this reading was taken with about 3800 lbs in trailer

9/16/15	14.75	0.58	26		7.6	29			Urick. The 3800 lbs remained in the trailer 6 days. This morning (9/16) another 1,020 sold. Death loss 144 (12% of those pulled). After morning sales about 2600 in the tank. 3 or 4 inches of foam on the tank.
9/22/15	19.1	0.656	40.5						Squadrito. 800 lbs sold yesterday, leaving about 1200 in the trailer. Out of those 800, about 25 lbs were found dead or about 3%. If that ratio applies to the remaining crabs in the trailer, there are about 40 lbs of dead crabs in the 1200. Tomorrow this group of crabs will have been in the trailer for 3 weeks.
9/30/15	5.75	2.02	60.25						No crabs in tank. Jim removed both the main 4"pump and sideloop 2" pump last Thursday because of coming high lunar tides. Reconnected the 2" pup on Monday. Will probably have to take it down again because Joaquin. Lowest TAN reading since May 18
10/8/15 skimm	0.86								Joaquin and strong offshore winds led to 12 consecutive high tides. Both pumps had to be disconnected. Casey's had 6" water in the office. Two inch pump reconnect on 10/6
10/9/15 tank	1.18								Tank water at 42F & skimmer water at 61. Always had some differential but not that big. Need to scope out. Also will start feeding the tank ammonium chloride to keep the nitrifying bacteria alive.
10/9/15	1.26								Just a little ammonium chloride added to tank-about 12 grams
10/10/15									Added two small scoop of ammonia
10/12/15	0+								Measure with strips
10/12/15	3								Added two small scoops of ammonia
10/13/15	>.5--<1								Strip measurement a.m.
10/13/15	0.86								Spectophometer Measurement
10/16/15	2.7								Spect measurement. 860 grams of ammonium cloride added to tank
10/19/15	0.25								Strip measurement a.m.
10/20/15	3								Strip measurement after 250 grams of ammonium chloride added

23-Oct	7.74								SpecAnother 250 grams ammonium cloride & plenty time to mix. Spec measurement subsequently.
10/26/15	8.9			<20					Spec added ~5 lbs sodium bicarb subsequently
10/27/15	7.9			50					spec a.m. reading added five pounds of sodium bicarb subsequent to 50 reading
10/27/15	7.8			120					spec p.m. reading
10/29/15	6.55			110					spec; a.m. reading added 2.5 bicarb after reading
10/30/15	5.4		>100 spec out of range	120					spec a.m reading added another 2.5 lbs of bicarb after reading
10/31/15									spec added another 2.5 lbs bicarb
11/2/15	1.2		75.5	120					speca.m reading added 500 grams ammonia in p.m.
3-Nov	4.85			180					spec; added 5 lbs bicarb @ 6a, sample taken @11a
11/5/15	0.21			150					a.m. sample spec
11/6/15	10			180			3	2	I added bicarb and ammonia at 10 a.m. Sample taken at 1.
11/9/15	0.54		>155.5	100			5	1	sample 8:30 a. Greg added 5 lbs bicarb and 1 lb ammonia at 2:30 p. yesterday Guesstimate yesterday p.m150 Alkalinity and 5 tan
11/11/15	1.14			120					sample taken at 2:30
11/13/15	0.19			140			8	2	Greg added 8 lbs bicarb, 1.5 lb ammonia after sample taken
11/16/15	0.11			180			1	2	Greg adds 2 lbs ammonia and 1 lbs of bicarb in p.m.
11/18/15	0.19			100					
11/30/15	0.21			180					