Shediac Bay Watershed Green Crab (C*arcinus maenas)* Survey in Coastal Waters of the southeast Gulf of St. Lawrence: Shediac Bay 2013-2017

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ABSTRACT

During the 2013 summer - fall sampling season, a total of 150 individual Fukui crab traps were fished for 24 hours in Shediac Bay. Seven repetitions of 10 sites on the inner bay were set twice a month for 2 ½ months. During the summer - fall sampling season in 2014, 2015, 2016 and 2017, a total of 50 individual Fukui crab traps were set from May to September. The second, third, fourth and fifth season were sampled monthly. The amount of marine area covered by the study was 20.16 square kilometers. Green crab was the target species as they have moved into the bay as they were first observed 5 years ago (2012). In 2014, their numbers were observed to have increased exponentially. In 2015, numbers were down significantly, but did show signs of rebounding in September (2015). The numbers showed dramatic and exponential increases in 2016. Numbers held steady just below 2016 levels in 2017.The study for all five seasons was to acquire an idea of their density and distribution in the bay and any trends over the study period. Every fished effort resulted in crab being caught in 2016 and 2017. The green crabs were prevalent in eel-grass habitat and were not found in sandy bottom locations. Males were more dominant than females especially later in the season. Numbers tended to drop off in September as waters cooled by about 2 degrees centigrade. An extra trapping was scheduled for October in 2017.

1.0 INTRODUCTION

In 2011, the first of the invasive green crabs first appeared in Community Aquatic Monitoring Program (CAMP) survey beach seines. The local environmental NGO, Shediac Bay Watershed Association (SBWA) had predicted they would appear as they were known to be migrating up the Northumberland Strait. They had already become prolific in Nova Scotia and Prince Edward Island. In 2012, CAMP surveys saw an exponential increase in the numbers of crab collected in the Shediac bay area. It was after this significant increase that SBWA decided that a more extensive survey would be beneficial to understanding how extensive the green crab population has become. Phase I (2013) was to do an initial survey to determine what the population dynamics appeared to be. Phase II (2014 and onward) would be to repeat the sampling regime to determine any population structure changes. Funding was acquired from the NB Wildlife Trust Fund (NBWTF) in 2015 to continue this important monitoring study. Limited funding meant borrowing funds from other programs to continue this important work in 2016. In 2017, additional funding from both the Environmental Trust Fund and the Wildlife Trust Fund was secured. This allowed a project to incorporate an eelgrass monitoring study to complement the continuation of usual green crab surveys over the usual study season (May to September).

1.1 Background

A native of Europe and Northern Africa, the green crab has invaded the Atlantic and Pacific coasts of North America, South Africa, Australia, South America, and Asia. In North America, the distribution of green crabs now extends from Newfoundland to Virginia and from British Columbia to California.

Green crabs live up to 4-7 years and can reach a maximum size of 9-10 cm (carapace width). The life cycle alternates between benthic adults and planktonic larvae. Green crabs are efficient larval dispersers, but most invasions have been attributed to anthropogenic transport.

The green crab has successfully colonized sheltered coastal and estuarine habitats and semi-exposed rocky coasts. Fecundity was estimated at 140,000- 200,000 embryos per mass. It is commonly found from the high tide level to depths of 5 - 6m. It is eurythermic, being able to

survive temperatures from 0 to over 35 ºC and reproduce at temperatures between 18 and 26 ºC. It is euryhaline, tolerating salinities from 4 to 52 ºoo. It is reasonably tolerant of low oxygen conditions. If the air temperature is cool, green crabs can survived exposed to air for 5-7 days.

Green crabs prey on a wide variety of marine organisms including commercially important bivalves, gastropods, decapods and fishes. Impacts on prey populations are greater in soft-bottom habitat and in environments sheltered from strong wave action.

The species potentially competes for food with many other predators and omnivores. The dominant predators of green crabs include fishes, birds, and larger decapods.
The effects of green crabs have been of particular concern to shellfish culture and fishing industries, as well as eel fisheries. Control efforts have included fencing, trapping and poisoning. Commercial fisheries for green crab have reduced its abundance in parts of its native range.

The European green crab C*arcinus maenas* is considered an aggressively invasive alien species in most of the regions it inhabits. It has spread across the globe by hitching rides on the hulls of ships and possibly as larval stage in ballast water and is now found on every continent except for Antarctica.

This species originated in the northeastern parts of the Atlantic Ocean, particularly the Baltic Sea. However, with the help of global fishing and shipping industries, it has quickly broadened its range and is now found in parts of coastal Canada.

In all regions where green crabs have been found, they were more abundant in protected embayments. Green crabs have been successful invaders of warm, sheltered coastal and estuarine habitats throughout the world.

Green crabs are well-documented to suppress the abundance of bivalve prey, including several species that are commercially fished or grown in aquaculture in Canada: blue mussels *Mytilus edulis*, quahogs *Mercenaria mercenaria*, eastern oysters *Crassostrea virginica*, soft-shell clams *Mya arenaria,* and bay scallop *Argopecten irradians*.

"It must be concluded that the green crab is one of the worst, if not the worst, clam predators we know. Its ability to multiply rapidly, to feed on many varieties of shellfish other than commercial species, and its large appetite for commercially important shellfish, all suggest that it can do enormous damage."

In Atlantic Canada this species is a threat to vital eel-grass habitat that many migratory birds and fish species rely on. By chopping off the shoots of eel-grass right at its base, the crab can easily destroy an entire area. The crabs do not consume these roots, they are searching for food. In fact, this voracious critter is on the One Hundred of the World's Worst Invasive Alien Species List.

This species most distinctive feature is the greenish tinge on its shell. Although it can range anywhere from grey to red, the species is primarily green in most regions. The shell has no bumps on it and extends all the way to the eyes, giving it an almost saucer-like shape. On average, the crab is 60 millimeters long and 90 millimeters wide.

The green crab, otherwise known as the cockroach of the sea, invaded the coast of North America at Cape Cod more than a century ago. By the 1950s, it had colonized in the waters of New Brunswick in the Bay of Fundy. The green crab not only preys on native crabs, clams,

oysters, and mussels and occupies their habitat but also eats the same food as crabs, lobster, and many seabirds. A single green crab can eat 40 clams in a day. It also carries a parasite that is harmful to the eider duck, whose downy feathers have been prized for generations as insulation and bedding material.

The demise of the soft-shell clam fishery in northern New England and Nova Scotia in the mid-1950s was associated with green crab. The green crab is aggressively colonizing along Canada's east coast, putting Canada's clam, mussel, and oyster industries at risk. The landed value of Atlantic clams, mussels, and oysters was about $57 million in 2000. The landed value of Atlantic lobster, which scientists believe may also be threatened, was over $500 million in 2000. The values represented here are dated and their impact in the current decade may be even higher. Eel fishermen livelihood is also threatened as the crabs enter nets and by attacking eels bunched in the eel trap can significantly affect the quality of the eel catch.

1.2 Purpose of the study

The invasive green crab has a history of being very destructive to local habitat and to populations of preferred prey. Once it was verified that they had moved into the Shediac Bay area, SBWA undertook to determine at what population levels we had and to monitor how they would change over the years. SBWA is the first to undertake such a survey. From past experience in eastern Canadian coastal waters, there have been explosive numbers verified for locations in Nova Scotia and PEI. Now that their northern coastal migration has reached us, we hope to determine rough population size and to be able to monitor change during subsequent years. Lacking the resources of government or university agencies allows us to do limited evaluation.

There are fishing industries that experience detrimental effects due to green crab introduction. Decimation of molluscan beds, especially clams, has been well documented. Green crabs that get into eel fishers nets have been known to ruin fresh eel product and in some cases have caused the eel fishery to be non-viable. In the search for food, green crab have been documented to destroy eel grass beds. Destruction of this important habitat will have detrimental effects on the health of the Bay, as it has in other locations. Another study initiated this year will start the process of looking at eel grass quadrates and how they may be changing over time. Any changes that may be attributed to potential habitat destruction due to green crab activity will be documented. The overall health of the eel grass habitat is vital to the health of any inshore marine ecosystem.

In order to initiate any control over the numbers, population data is needed. A possible limited sustainable fishery for green crab is a solution that will not be initiated until valid population data is available to warrant the introduction of such a control method. These decisions are out of our control or jurisdiction. The data we gather through this study may help influence a sooner rather than later need for control measures. This is a problem that will not go away as the green crab populztions migrate up the coast of the Northumberland Strait.

2.0 MATERIALS and METHODS

2.1 Materials required to carry out the trapping survey

Ten Fukui traps (Polyethylene Fish Trap Nets Model FT-100) (Figure 1) were purchased and delivered in the spring of 2013.

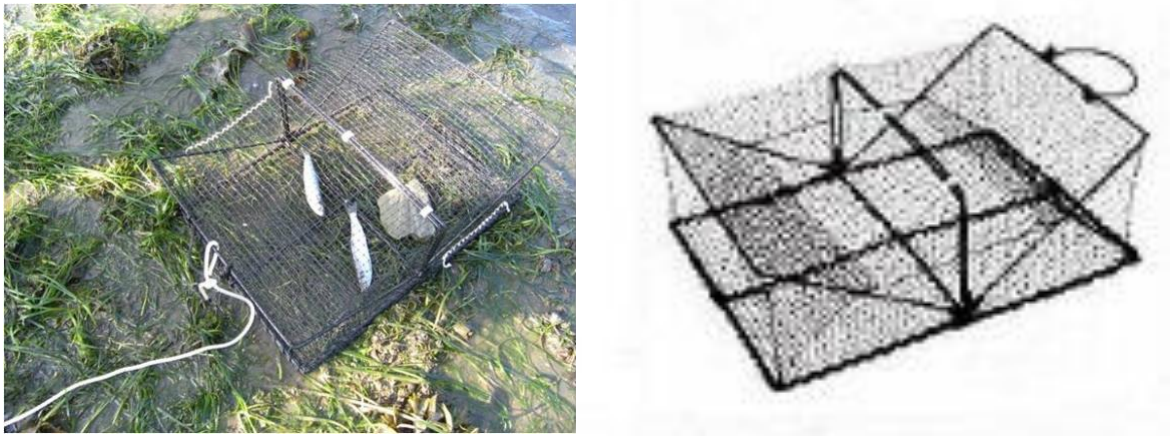


Figure 1. Top view of the Fukui trap used in this study

These are the exact same traps used by DFO for their green crab studies and we expect the same traps will be used in a possible upcoming study to be carried out by a university led NRC group possibly starting next year. Lines and buoys were borrowed from DFO. The lack of water velocity in the bay meant that no extra weight was needed to keep the traps in place. In channels close to the two rivers, the traps were placed just off channel to avoid drift caused by tidal flow and river flow currents.

A loan agreement was reached with DFO to borrow and maintain a boat and trailer to use for this survey in 2013 and 2014. The boat was a 19 foot Boston Whaler with a 90 HP Honda outboard. DFO paid for spring and fall servicing. O and N Sports in Grande Digue did all the service and the cost invoice was paid by DFO (contacts Marie Helen Theriault and Monica Boudreau). SBWA paid for transport to and from the storage facility at the beginning and end of the season and for all the gas expense and daily maintenance. SBWA had hoped the boat would again be available for the 2015 season. However, it was not, so a similar sized boat was rented for the study in 2015, 2016 and 2017.

Figure 2. Boston Whaler with traps loaded to set that day 2013-2014.

Figure 3. Blue Fin Aluminum on land with traps loaded to set that day 2015-2017.

We experimented with different types of bait. In the end it was determined the most cost effective were cans of sardines. We used 10 of the soya oil based (or spring water based) cans for each sampling. We used thick plastic bottles similar to our water sample bottles where several holes were drilled, 3 to 4 sardines put in each bottle and placed in the net bait bag in the trap. One sardine was often put in the bait bag next to the bottle in 2013-2015. In 2016 and 2017, the often was replaced by always

Figure 4. Bottles with drilled holes ready to be baited with sardines from can.

The traps were all set for 24 hours. Weather, especially wind conditions, usually determined the exact date to fish in the middle and at the end of the month during the study in 2013. In 2014, limited funding allowed only monthly sampling. Additional funding from NBWTF allowed this important study to maintain continuity in 2015. In their infinite wisdom, they declined to fund in 2016. But , funding was again secured in 2017. End of month sampling was carried out in 2014 - 2017.

In 2013, the Shediac Bay Marina provide a berth free of charge to the SBWA where we could keep the boat all season which meant we did not have to drop and remove the boat each sampling. In 2014, we had free storage at the O and N boatyard, in-kind launch contribution from the Pt. Du Chene Harbour Authority and in-kind docking for 24 hours at the Pt. Du Chene marina. A similar arrangement from the Harbour Authority was negotiated for 2015- 2017. Storage between trap sets was provided in-kind by First Choice Marine in 2015 and 2016. Money was available to pay first choice marine for seasonal storage in 2017. These were very valuable in-kind contributions and definitely helped in making the project more viable.

2.2 Study Area

A map of Shediac Bay shows the extent of the study area outlined in black and shaded light blue.

The total square kilometers is 22.3 minus 2.14 (Shediac Island) to give us 20.16 square kilometers or 20,160,000 square meters, a number to be used later to determine rough population estimates. The bay is basically shallow with mostly an eel-grass bottom. Shediac Island in the outer middle directs two outflows from the two rivers to the Northumberland Strait.

Figure 5. Total surface area of waters in Shediac Bay included in study area for baseline data collection (outlined in black)

2.3 How sites were chosen

Sites were chosen by the author to represent a valid cross-section of the inner bay. Sites were always in eel-grass beds. They were always above the low water mark and usually close to shore. This was always a challenge at low tide and the engine often needed to be lifted to drop and retrieve the traps. In the past two years, we sampled as close to high tide as possible. Often water sampling was carried out on the same water trip. Coverage along the shore of the inner Bay was a priority as transects into deeper water were also carried out. The previous year CAMP sampling indicated there was green crab close to shore so some locations did overlap though our traps were usually set outside or close to the CAMP locations.

2.4 Locations of the Green Crab sites

After beach seine results in 2012 from the Community Aquatic Monitoring Program (CAMP) surveys, green crab were seen to be present and becoming abundant in Shediac Bay. Funding from SHELL Canada was secured to initiate a survey of waters to determine the extent of green crab population in Shediac Bay. **Figure 5** shows where sample sites were located. The only one off the shore on the inner bay was "D" and it was close to Shediac Island shore in the eel grass beds found there.

Table 1 The exact latitude-longitude location of collection sites repeated bi-monthly during the study 2013.

Site	Green Crabs - Site details (2013)		
A	Pass Under the Bridge Chez Leo (CAMP)	46° 16' 17.52"	64° 34' 32.44"
B	Bridge (CAMP) Chez Leo, left of boat launch point	46° 16' 19.18"	64° 34' 329.01"
C	In front of CAMP site (Oak Point)	46° 16' 22.52"	64° 33' 48.07"
D	Shediac Island (middle) off line of oyster lease buoys	46° 15' 53.72"	64° 33' 00.20"
E	Yellow House, shore before Friars	46° 15' 15.87"	64° 34' 02.86"
F	flag St Martins in Woods Rd	46° 14' 06.84"	64° 33' 38.09"
G	Before crossing bridge Scoudouc River Lobster from Marina	46° 13' 10.98"	64° 33' 16.69"
H	After crossing bridge opposite Shediac Lobster inside next to channel	46° 13' 04.65"	64° 33' 11.76"
I	Close to old SBWA Office, outer Shediac marina opposite crane	46° 13' 34.70"	64° 33' 43.45"
J	Pointe-du-Chêne inner South Cove (eelgrass site)	46° 14' 06.62"	64° 31' 26.75"

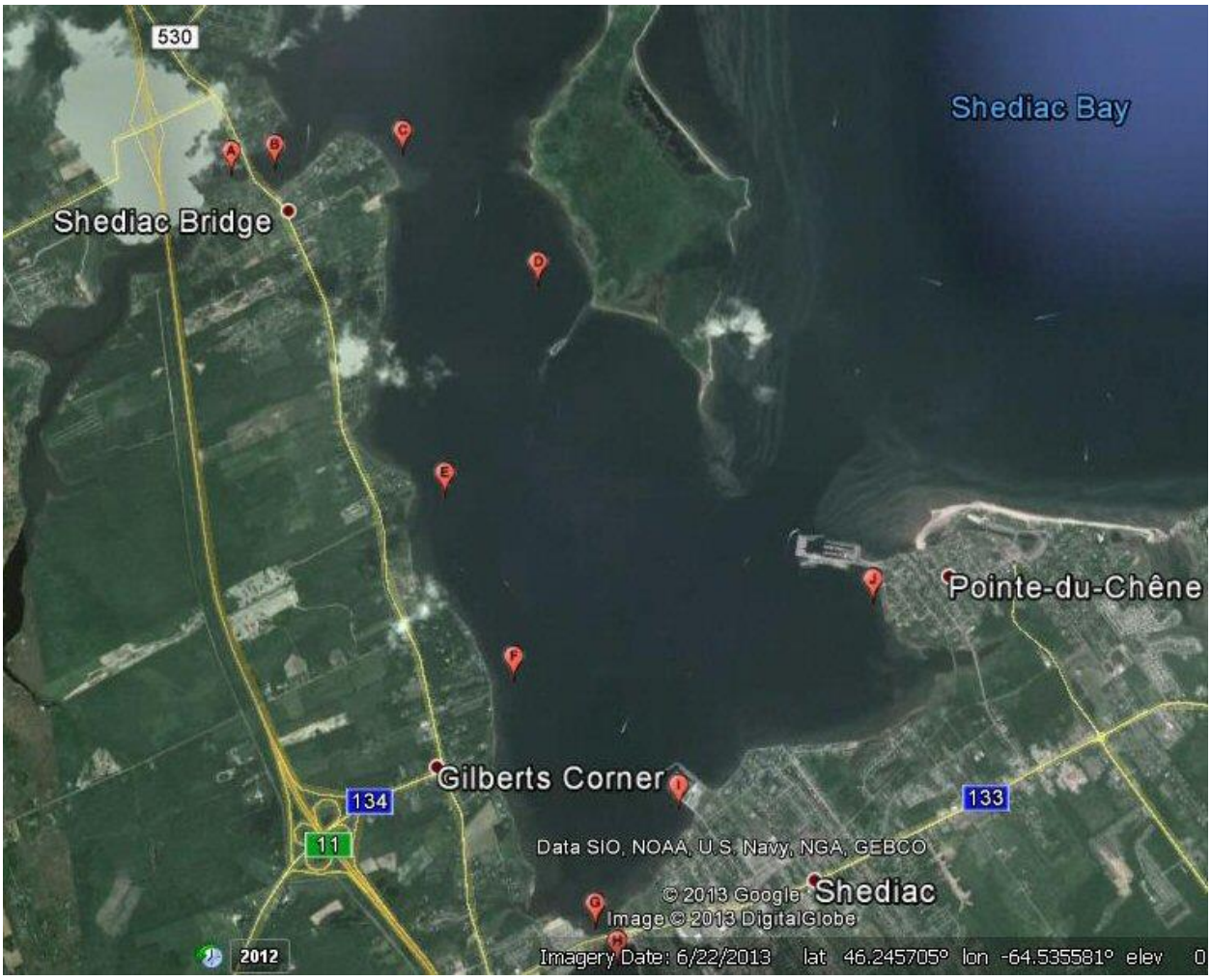


Figure 6. The chosen 10 sites for repeat trapping lettered A to J for the 2013- 2017 spring to fall season in Shediac Bay

2.5 What was in the traps

After 24 hours the trap was brought in and all green crab were counted and sexed. Aging was not done in this survey. All other contents were also identified and counted. Green crabs were brought to shore and the uses are described in the discussion. All other species were returned to the water. Each crab was handled with a thick rubber glove as they can deliver a nasty squeeze with their large claws. The holding and walking claws have sharp ends and can also inflict a pinch. Other fish and starfish were easily removed. Some care was exercised to minimize stretching the opening as over time it can become larger and we speculate crab can wiggle back out. The bait bottle was also removed to be baited again with the next sampling. The bottles and bait were frozen and thawed for future use, i.e. the next sampling. New bait was added to the bottle after two uses and fresh sardines were put in the bag beside the bottle at each sampling.

3.0. RESULTS AND DISCUSSION

3.1 Materials required to carry out the trapping survey

The survey was carried out for two seasons (2013-2014) as this is stipulated in the SHELL funding agreement. Monies had been ear-marked for a duplicate survey in 2014. Funding was secured (2015) from NBWTF to cover part of salary, rental, transportation, education and maintenance costs. Monies for the 2016 survey came from various sources. Other parameters may be involved if a proposed NRC project gets underway. We are an in-kind contributor to their proposed study at this point, though we hope for a more money related role as logistic support. We requested and received a loan agreement for the boat from DFO for both 2013 and 2014. Another boat was rented in 2015, 2016 and 2017 as the DFO boat was not available to us in 2015. We have the ropes and buoys in our storage space and can keep them until we no longer have a need, whereas we have to sign them back into the warehouse. We would have no need of traps. I did sign out an extra from DFO in the event one of ours was lost or removed. Sardines are easily purchased with best price being from Giant Tiger and No-Frills in Shediac. There was a short time to experiment with the most suitable bait. Canned clams worked well. The best bait was dead fresh fish be it mackerel or tomcod. This is harder to come by in early spring unless we wanted to outlay monies to purchase. Fish that entered the trap were attacked by crab and the feeding frenzy would attract even more green crab. Our main cost after the trap purchase was gas for the project boat. For the 2013 season this was approximately 370 dollars. Gas for 2014 season totalled 219.45 dollars. Gas for the 2015 season was approximately 260 dollars. This amount was similar for 2016 and 2017.

3.2 Study Area

The actual bay is reasonable large and does provide a suitable location for 2 marinas and many boaters. On calm sunny days in the summer season, boat traffic can be quite busy. The health of this bay fed by two estuaries is important to the local economy. The majority of the local and temporary residents do not even know what a green crab looks like. Efforts of the SBWA to inform the public have been on-going and our efforts have resulted in an increase in number of people made aware of the issues related to green crab. The health of the bay is one of the association's prime mandates and as such the possible threats to the health of the bay that can be the result of habitat destruction by green crab is a major concern. This initial survey will provide a necessary baseline for our monitoring efforts. Strategies for controlling or maintaining a sustainable healthy state of this marine ecosystem will be helped by studies such as this.

3.3 How sites were chosen

After choosing the sites, they had to be re-visited and fished on a set schedule. There was some consultation and discussion with DFO, but the final locations were determined by SBWA staff. The determined trap line could have been more extensive but our staff worked within the parameters of the resources available. Trap delivery was an issue as they were not in stock in Canada and had to be shipped from Japan. This delayed our trap set to mid-July,

rather than the first of July in 2013. As the study will be repeated each year various staff and volunteers, mainly Board members, did get experience with the methodology of the study.

3.4 Locations of the Green Crab sites

Getting back to the same location was not a major issue. This was taken into account when sites were initially chosen as the first visit was at a low tide. It seemed every two weeks when we went back to sample it was always low tide again. This was the case in 2013. In 2014, 2015, 2016 and 2017, we set the traps at or near high tide. This was much more friendly to the propellers. These chosen sites had to have eel-grass as this is known to be a preferred feeding location. At each visit the sampler was always looking at the state of the eel-grass beds to determine if a major eel-grass removal might have occurred. This was a visual examination only as a more detailed transect diving regime would have to be put in place to determine if this was occurring. This type of study was initiated in 2016 and will be repeated in 2017. This was beyond the scope of this survey, so only anecdotal observations were made. Overall, there were no obvious patches of removed eel-grass bed material observed over the four years. In 2016 there seemed to be more floating green eel grass, but what was the cause can only be speculated. No observable change in eel grass present as loose material in the bay was seen in 2017.

3.5 What was in the traps

The area of influence of a baited trap of the type used in the southwestern Gulf of St. Lawrence snow crab fishery was studied by releasing tagged snow crabs at increasing distances from the bait and noting recaptures after fishing periods of 24 and 48 hr. For the shorter fishing period, the recapture rate decreased with increasing distance of released crabs from the trap. The radius of the prospected area was estimated to be in the range of 100-140 m, with the radius of the effective fished area being about 50-70 m. We cannot find any reference to distance that green crab will come to a baited trap.

Traps often had no other species other than green crab. When other species were present they were primarily mummichogs, rock crab, flounder, snails, starfish and mud crab. Occasionally, the traps might retain a tomcod. In 2017, we had canner lobster in one trap, same location on two occasions which was a first.

3.5.1 Total crab catch over the repeated sample sites for the 2013 season

The table below summarizes the catch at each site and the totals for the bi-monthly sampling in 2013.

Table 2. Summary of total green crab catch for sites A to J for each monthly sample 2013

Site	July 17	July 31	Aug 15	Aug 30	Sept 16	Sept 29	Oct 15
A	0	4	0	1	3	4	0
B	10	10	7	2	19	0	0
C	0	2	4	0	15	15	3
D	0	0	1	1	3	2	0
E	4	1	3	19	16	4	2
F	0	0	0	10	1	1	0
G	0	2	3	1	1	2	3
H	1	1	1	1	1	0	0
I	0	8	2	2	2	1	0
J	0	0	1	6	0	1	4
2013	**15**	**28**	**22**	**43**	**59**	**30**	**12**

In 2013, catches were fairly consistent over the sampling season with a slight rise in September. This September rise was probably due to an input of seasonal recruitment as the young hatched in the spring reached a size that would be able to get into the trap and remain. Also more live fish were in the traps later in the season and once inside could be easily attacked by the crab and this dead fish acted as additional bait thus probably attracting more prey, i.e. green crab. On August 30, the traps were in the water for 48 hours as stormy weather preventing lifting traps. This double catch time reflects a doubling of catch for this one time 2 day catch period. Lower numbers in July probably reflect less activity as this is the end of the mating season where crabs might have been less active. Colder water may have been a factor in the October sampling. These are just author speculations, further hypothesis that would require more detailed experimentation. An October sampling was repeated in 2017.

3.5.2 Total crab catch over the repeated sample sites for the 2014 season

The table below summarizes the catch at each site and the totals for the monthly sampling.

Table 3. Summary of total green crab catch for sites A to J for each monthly sample 2014

Site	May 29	June 28	July 30	Aug 27	Sept 25
A	0	0	4	5	10
B	0	0	0	42	4
C	0	11	5	12	1
D	0	0	12	8	1
E	3	27	9	5	6
F	1	7	4	5	5
G	1	0	21	18	6
H	0	0	0	2	3
I	0	2	8	0	7
J	0	0	4	9	3
2014	**5**	**47**	**67**	**106**	**46**

In 2014, traps were only fished at the end of each month. Numbers were low in May which corresponds to spawning time when crabs appear less active. Numbers continued to rise all summer and dropped off again in the fall. Younger crabs were more dominant in the early spring, thus if any could escape the trap, the smaller ones would have this ability. With summer growth, and the obvious number increase, more were caught. Decreasing temperature of the water in the fall could explain the drop in numbers observed in September.

3.5.3 Total crab catch over the repeated sample sites for the 2015 season

The table below summarizes the catch at each site and the totals for the monthly sampling.

Table 4. Summary of total green crab catch for sites A to J for each monthly sample 2015

Site	May 26	Jun 30	July 30	Aug 27	Sept 29
A	0	0	2	0	3
B	0	0	0	2	8
C	1	1	3	2	1
D	1	0	0	0	0
E	0	0	0	2	4
F	0	0	0	0	0
G	0	0	0	2	10
H	0	0	0	0	27

I	0	0	0	0	6
J	1	0	0	1	0
2015	**3**	**1**	**5**	**9**	**59**

Again in 2015, traps were set near the end of the month. Compared to the previous two years, numbers had dropped off significantly. By September, numbers were back to levels close to what existed in 2013 and 2014. There was a significant drop in numbers over the season compared to previous years. The most probable explanation is that the harsher than normal winter created conditions that were detrimental to over-wintering survival. Thicker ice in the bay, colder temperatures, longer winter that delayed spring temperature increase and the subsequent delay in available food are probable causes of this dramatic population decrease. Also the large number in 2014 could have reduced available food supplies for the spring crop in 2015. Additional studies could be initiated to help shed some insight on these and other possible causes of the observed population decline. Anecdotal conversations with fishermen did help determine that more shell remnants were present in the early spring that indicated winter mortality being higher in 2015. The population structure did show a big increase in numbers by September, when compared to still quite low numbers in August.

3.5.4 Total crab catch over the repeated sample sites for the 2016 season

The table below summarizes the catch at each site and the totals for the monthly sampling.

Table 5. Summary of total green crab catch for sites A to J for each monthly sample 2016

Site	May 26	Jun 23	July 20	Aug 31	Sept 21
A	1	13	8	23	14
B	2	34	41	11	33
C	7	15	24	49	25
D	0	13	8	1	5
E	3	25	27	57	14
F	14	10	1	30	14
G	48	2	17	8	3
H	6	6	101	68	3
I	30	29	35	9	4
J	8	7	6	7	2
2016	**119**	**154**	**275**	**263**	**117**

What a difference a year makes, again we suspect the milder winter resulted in enhanced survival and the dramatic rise in numbers, a trend that continued all through the summer months with a slight drop in September.

3.5.5 Total crab catch over the repeated sample sites for the 2017 season

The table below summarizes the catch at each site and the totals for the monthly sampling.

Table 6. Summary of total green crab catch for sites A to J for each monthly sample 2017

Site	May 25	Jun 23	July 25	Aug 27	Sept 21
A	1	5	17	9	7
B	0	4	41	33	31
C	12	13	13	27	20
D	1	lobster	5	12	2+2lobster
E	9	14	15	27	8
F	5	10	3	24	24
G	11	8	11	24	19
H	5	7	5	20	23
I	21	5	2	17	19
J	0	6	4	5	5
2017	**65**	**72**	**116**	**197**	**158**

The numbers in 2017 exceeded all years except 2016. Populations remained high, increased all summer with a slight drop in September. Notable was a catch of canner sized lobster near Shediac Island site. This had never occurred before. Their presence in a trap may have discouraged green crab from entering the trap, so that none in June and only 2 in September were found in trap "D".

3.5.6 Total crab catch of monthly totals for all sample sites for all five years 2013-2017

year	May	June	July	August	September
2013	**15**	**28**	**22**	**43**	**59**
2014	**5**	**47**	**67**	**106**	**46**
2015	**3**	**1**	**5**	**9**	**59**
2016	**119**	**154**	**275**	**263**	**117**
2017	**65**	**72**	**116**	**197**	**158**

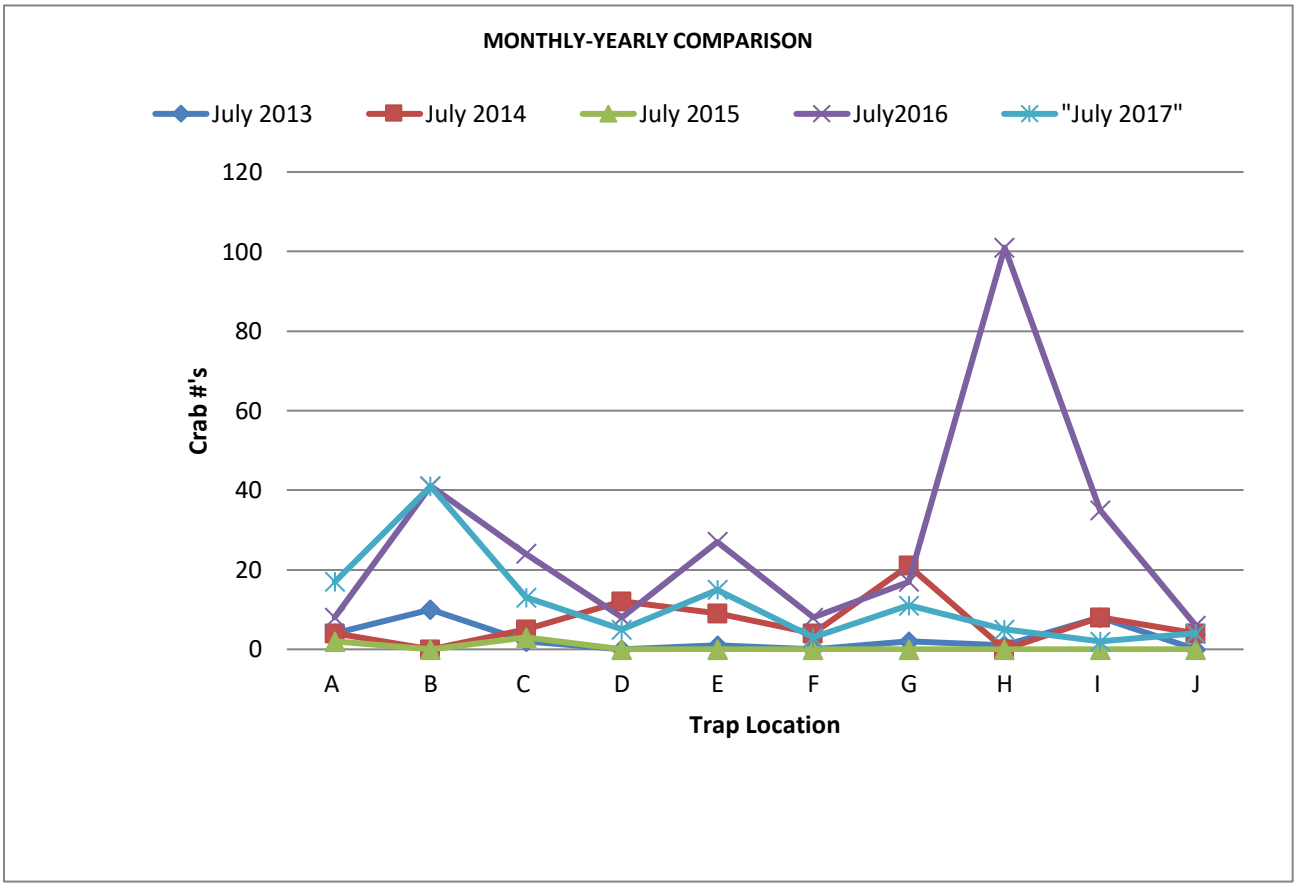
These monthly/yearly comparisons provide a overview of yearly changes. 2016 was the expodential year, 2017 had roughly half the numbers of 2016, except for September. Except for July (2016), August had higher number each year than July. Numbers generally dropped in September, except for 2013 and 2015.

3.5.7 Comparison of 2013, 2014, 2015, 2016 and 2017 catch results for the same month.

The tables below summarize the catch at each site and the totals for the bi-monthly sampling for a monthly comparison. The results are also represented graphically.We only used July, August and September as some years we started late and had no data.

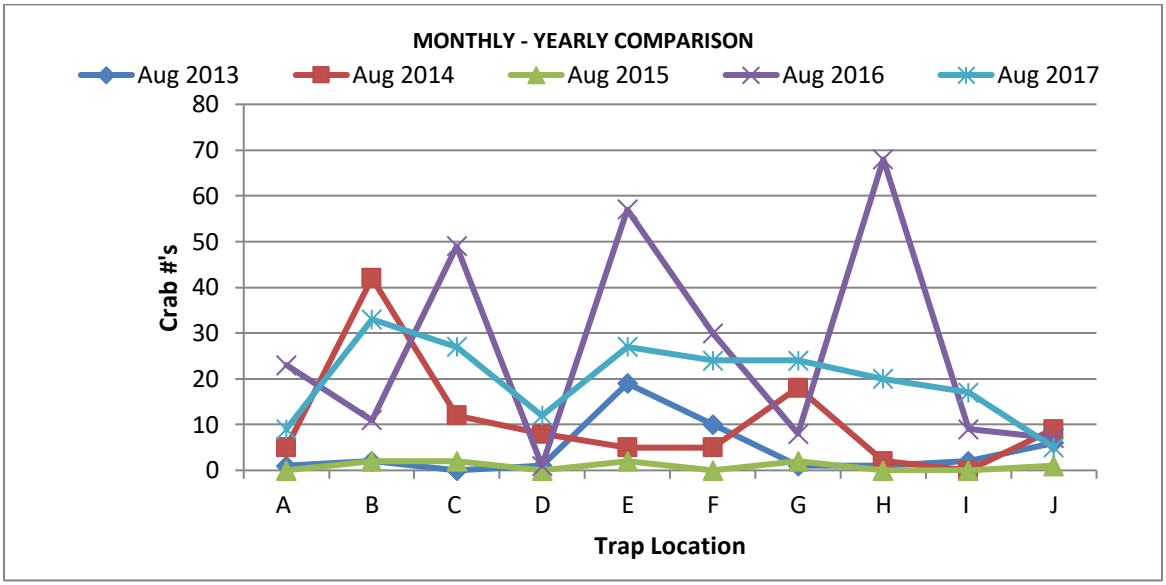
Figure 7. These figures numerically and graphically compare catch results for three months for all 10 sites for the five years of the study.

	2013	2014	2015	2016	2017
Site	July 31	July 30	July 30	July 16	July 25
A	4	4	2	8	17
B	10	0	0	41	41
C	2	5	3	24	13
D	0	12	0	8	5
E	1	9	0	27	15
F	0	4	0	8	3
G	2	21	0	17	11
H	1	0	0	101	5
I	8	8	0	35	2
J	0	4	0	6	4
	28	**67**	**5**	**275**	**116**



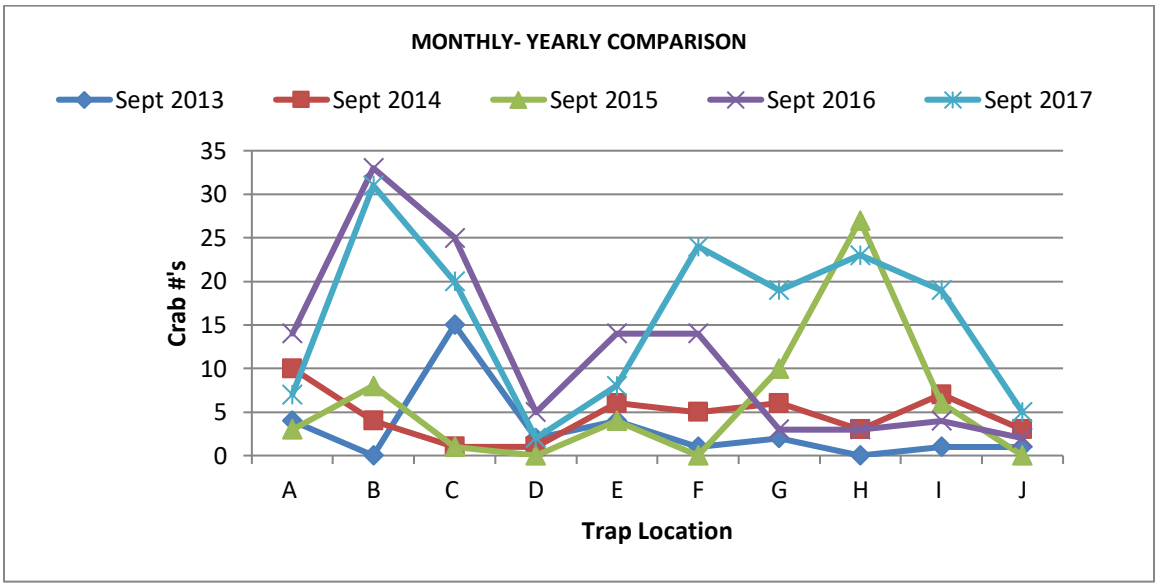
In July, number of green crab caught was highest in 2014 for all sites except **B** (10 vs 0) and **H** (1 vs 0). Site **I** had 8 green crab for both years 2013 and 2014. Numbers were considerably lower (only 5 crab total) for early summer in 2015 for possibilities previously outlined. Eight of 10 sites had no crab at all for the 24 hour trapping time frame. This is a very significant drop compared to previous years. Now in 2016, the numbers have jumped, recovered, rebounded, exponentially increased to exceptionally higher numbers per comparison period and year. Low numbers inside the big lobster "**H**" show the most drastic increase. July had the highest numbers recorded in four years (275) which was only slightly higher than August (263) of 2016. Except for a couple of incidences, numbers in 2017 were higher than 2014 levels, but lower than 2016.

	2013	2014	2015	2016	2017
Site	Aug 30	Aug 27	Aug 27	Aug 30	Aug 27
A	1	5	0	23	9
B	2	42	2	11	33
C	0	12	2	49	27
D	1	8	0	1	12
E	19	5	2	57	27
F	10	5	0	30	24
G	1	18	2	8	24
H	1	2	0	68	20
I	2	0	0	9	17
J	6	9	1	7	5
	43	**106**	**9**	**269**	**198**



As in July, the same pattern of more crab in 2014 was evident (106 vs 43 total), though locations **E** and **F** had more crab in 2013 than 2014.Numbers remained low in August in 2015, though a slight increase from July is evident. Now we again come to the second highest numbers recorded for a sampling (2016) in the first four years of the study. Green crab at every station, no zero's, and again high numbers at station "**H**". In 2017, we had higher numbers at stations B,D,G and I than were recorded in 2016. Overall, the totals were down, but more uniform throughout the whole bay.

	2013	2014	2015	2016	2017
Site	Sept 30	Sept 25	Sept 29	Sept 21	Sept 26
A	4	10	3	14	7
B	0	4	8	33	31
C	15	1	1	25	20
D	2	1	0	5	2
E	4	6	4	14	8
F	1	5	0	14	24
G	2	6	10	3	19
H	0	3	27	3	23
I	1	7	6	4	19
J	1	3	0	2	5
	30	**46**	**59**	**117**	**158**



In September, numbers show decreasing trends for 2013 and 2014 compared to the previous months. Temperatures are decreasing and activity seems to be slowing. But in 2015, the opposite is evident; numbers are up to their highest level compared to the whole sampling season. This is probably attributable to green crab recovery from the previous severe winter. In 2016, numbers are down from previous months but still much higher than the 3 previous years. Station "**A, B** and **C**" at the mouth of the Shediac River had the highest counts.

Overall, most sites show that more green crabs were caught in 2014 than 2013. This leads to an obvious pattern of crab population increasing in Shediac Bay compared to the previous year. But, the significant drop in numbers in 2015 was surprising. We have speculated as to the reasons that influenced this drop (see 3.5.3), but it could just be a normal population fluctuation. Though hard to verify, we have had anecdotal reports that certain diving ducks have been seen consuming green crab. Could the slower recovery than what was normal in the previous two years in the early spring-summer been influenced by these winged predators consuming the young and/or moulting crabs? More than likely it was the harsh winter of 2014-2015, resulting in thicker ice cover crushing the hibernating crabs as the tide rose and fell. The big surprise was the huge recovery and increase in 2016. This followed a milder winter in 2015-2016. The numbers in 2017 were also higher than 2013-2015, but slightly less than 2016, except in the later part of the season where they were higher (September).

Table 7. Breakdown of male to female green crab catch for each site A to J for each bi-monthly sample 2013.

Site	July 17		July 31		Aug 15		Aug 30		Sept 16		Sept 29		Oct 15	
	M	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
A	0	0	3	1	0	0	1	0	2	1	4	0	0	0
B	10	0	10	0	7	0	2	0	14	5	0	0	0	0
C	0	0	1	1	4	0	0	0	15	0	7	8	2	1
D	0	0	0	0	0	1	1	0	3	0	2	0	0	0
E	4	0	0	1	2	1	14	5	15	1	2	2	0	2
F	0	0	0	0	0	0	6	4	1	0	1	0	0	0
G	0	0	2	0	3	0	1	0	1	0	2	0	2	1
H	0	1	0	1	1	0	1	0	1	0	0	0	0	0
I	0	0	5	3	1	1	1	1	2	0	1	0	0	0
J	0	0	0	0	0	1	6	0	0	0	1	0	4	0
sub-total	14	1	21	7	18	4	33	10	52	7	20	10	8	4
2013		**15**		**28**		**22**		**43**		**59**		**30**		**12**

Overall numbers of male crab always exceeded those of female crab by a ratio of at least 2 to 1. This tells us that the male population far exceeds the female population. Early in the season, several females would be in the traps with eggs attached thus probably less active in searching out food. The fecundity of the females has been noted at a possible production rate of 160,000 eggs a season, often with more than one event if conditions are ideal. It is assumed the females are less active especially early in the season. We also note in aquarium observations that the males are more active and more aggressive, aggressiveness being a trait shared by the crabs in general. We have seen crabs catch swimming silversides in the aquarium, rare, but it has been observed.

Table 8. Breakdown of male to female green crab catch for each site A to J for each monthly sample 2014.

Site	May 29		June 28		July 30		Aug 27		Sept 25	
	M	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
A	0	0	0	0	4	0	4	1	10	0
B	0	0	0	0	0	0	40	2	3	1
C	0	0	7	4	5	0	12	0	1	0
D	0	0	0	0	10	2	8	0	1	0
E	3	0	7	10	6	3	4	1	6	0
F	1	0	5	2	3	1	5	0	5	0
G	1	0	0	0	8	13	18	0	6	0
H	0	0	0	0	0	0	2	0	3	0
I	0	0	1	1	7	1	0	0	7	0
J	0	0	0	0	2	2	9	0	2	1
sub-total	5	0	20	27	45	22	102	4	44	2
2014		**5**		**47**		**67**		**106**		**46**

In May, there were no female crabs caught probably because of their egg laying activity. In June, they were more numerous than males as illustrated by their increased activity most likely related for their need for additional nourishment after egg laying processes were completed. Why the female numbers were so low in August and September is interesting and would be a valid question to explore.

Table 9. Breakdown of male to female green crab catch for each site A to J for each monthly sample 2015.

Site	May 26		June 30		July 30		Aug 27		Sept 29	
	M	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
A	0	0	0	0	0	2	0	0	3	0
B	0	0	0	0	0	0	2	0	8	0
C	0	1	0	1	3	0	2	0	1	0
D	0	1	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0	1	1	3	1
F	0	0	0	0	0	0	0	0	0	0
G	0	0	0	0	0	0	2	0	8	2
H	0	0	0	0	0	0	0	0	23	4
I	0	0	0	0	0	0	0	0	4	2
J	0	1	0	0	0	0	1	0	0	0
sub-total		3		1	3	2	8	1	50	9
2015		**3**		**1**		**5**		**9**		**59**

This season was more than unusual. The extreme low numbers at the beginning of the season has been referenced. What few crabs caught early were females with no males captured until the end of July. Then in August and September, patterns similar to previous years was evident, that being more males. But, compared to previous years, numbers did not drop in the fall, rather they were higher at the end of the season. This indicates a late start to the crab population recovery from the stressful winter.

Table 10. Breakdown of male to female green crab catch for each site A to J for each monthly sample 2016.

Site	May 26		June 23		July 20		Aug 31		Sept 21	
	M	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
A	1	0	12	1	7	1	23	0	14	0
B	0	2	30	4	36	5	9	2	30	3
C	3	4	9	6	21	3	48	1	25	0
D	0	0	13	0	7	1	7	0	5	0
E	2	1	20	5	20	7	53	4	14	0
F	6	8	5	5	1	7	26	4	12	2
G	21	27	0	2	11	6	5	3	3	0
H	6	0	3	3	85	18	64	4	2	1
I	11	19	19	10	31	4	9	0	4	0
J	0	8	5	2	5	1	7	0	2	0
sub-total	50	61	116	38	224	53	251	18	111	6
2016		**119**		**154**		**277**		**269**		**117**

Three apparent trends are evident here. More females are active in the spring as they feed more vigorously to support egg production though it appears to be mostly over by late May. Another trend is there are more males for the rest of the season. And the final trend is that numbers begin to drop off as cooling temperatures result in less activity in September.

But the over all observation is that green crab populations have exploded in numbers in 2016. This therefore adds extra impetus for another year of collection to see what the population dynamic is in 2017.

Table 11. Breakdown of male to female green crab catch for each site A to J for each monthly sample 2017.

Site	May 25		June 28		July 25		Aug 27		Sept 29		Oct 23	
	M	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
A	0	1	3	2	15	2	7	2	2	5	12	7
B	0	0	3	1	34	7	25	8	10	21	36	26
C	8	4	13	0	11	2	25	2	14	6	11	5
D	1	0	0	0	3	2	10	2	2	0	1	2
E	4	5	10	4	13	2	20	7	5	3	14	9
F	3	2	5	5	3	0	17	7	16	8	14	7
G	10	1	8	0	10	1	20	4	7	12	16	6
H	3	2	7	0	4	1	11	9	8	15	18	21
I	11	10	5	0	2	0	15	2	15	4	5	5
J	0	0	3	3	4	0	5	0	2	3	3	0
subtotal	40	25	57	15	99	17	155	43	81	77	130	88
2017		**65**		**72**		**116**		**197**		**158**		**218**

A couple of trends for 2017 include higher numbers than all years sampled except 2016. The total is still high but overall less than 2016 (608 vs 936). Here are the totals for 2013, 2014 and 2015: 167 vs 271 vs 77. These comparisons totals are for all months except October that were only sampled in 2013 and 2017. Numbers were high in August as they usually are for all years. In 2017, October numbers were higher than expected and there were a lot of females in the system. We will see how this translates into numbers next spring.

3.5.8 Green Crab catches from the Shediac Marina (2016)

We set up one of our crab traps in the Shediac marina for 2 months (August and September) and baited mostly with mackerel from a deep freeze. The substrate in the marina is muck and mud, no eel grass lives here. The number of crab caught was phenomenal. A local volunteer counted the catch every day or two for most of the summer boating season. This is another example of the huge numbers that were present in the bay. For crab to be found in what is considered an undesirable environment i.e. no eel grass meant there was some type of food there. There are mussels on attached posts, docks and boats, some oyster on the rocky borders and other small crustaceans and molluscs, but preferred eel grass beds are not present.

Various other baits were used and these included sardines, lobster bodies and salmon leftovers. The volunteers noted a significant depletion of starfish from previous years.

They also caught a 3 year old lobster which was released of course.

These numbers are phenomenal in that we caught 936 in 10 traps fished 5 total days and they caught 950 in one trap fished for 60 days. T heir one trap would be in the water for 2-6 days fishing continuously until checked.

Table 12. Total number caught and breakdown of male to female green crab catch for two months of trapping in Shediac Marina 2016

DATE TRAP CHECKED	TOTAL # CAUGHT	MALE	FEMALE	DATE TRAP CHECKED	TOTAL # CAUGHT	MALE	FEMALE
04-Aug-16	**77**	**59**	**18**	03-Sep-16	**15**	**11**	**4**
07-Aug-16	**19**	**18**	**1**	05-Sep-16	**80**	**55**	**25**
08-Aug-16	**7**	**5**	**2**	08-Sep-16	**11**	**7**	**4**
10-Aug-16	**123**	**67**	**56**	09-Sep-16	**46**	**24**	**22**
11-Aug-16	**12**	**8**	**4**	12-Sep-16	**51**	**34**	**17**
15-Aug-16	**56**	**33**	**23**	13-Sep-16	**98**	**87**	**11**
22-Aug-16	**20**	**8**	**12**	17-Sep-16	**27**	**25**	**2**
24-Aug-16	**35**	**21**	**14**	27-Sep-16	**19**	**12**	**7**
27-Aug-16	**7**	**5**	**2**	06-Oct-16	**57**	**45**	**12**
28-Aug-16	**112**	**61**	**51**	**TOTAL**	**404**		
30-Aug-16	**78**	**57**	**21**				
TOTAL	**546**					total	**950**

3.5.9 Green Crab catches from the Shediac Marina (2017)

The same volunteer recorded catches as they did in 2016. Again the numbers were very high. They did fish in July also but for comparison we just presented the August and September months. In 2016 they recorded catches for 20 days. In 2017, they recorded catches for 26 days. The average catch in 2016 was 47.5 crabs per day and in 2017 it was 75 crabs per day. So it seems the population in the marina is alive and well and has increased overall since last year.

Table 13. Total number caught and breakdown of male to female green crab catch for two months of trapping in Shediac Marina 2017

DATE TRAP CHECKED	TOTAL # CAUGHT	MALE	FEMALE	DATE TRAP CHECKED	TOTAL # CAUGHT	MALE	FEMALE
03-Aug-16	**31**	**30**	**1**	05-Sep-16	**32**	**28**	**4**
06-Aug-16	**20**	**17**	**3**	07-Sep-16	**101**	**57**	**44**
08-Aug-16	**11**	**7**	**4**	12-Sep-16	**41**	**41**	**0**
09-Aug-16	**34**	**17**	**17**	16-Sep-16	**100**	**33**	**67**
10-Aug-16	**98**	**35**	**63**	17-Sep-16	**113**	**38**	**75**
12-Aug-16	**17**	**6**	**11**	18-Sep-16	**27**	**14**	**13**
14-Aug-16	**22**	**9**	**13**	22-Sep-16	**56**	**39**	**17**
16-Aug-16	**102**	**28**	**74**	25-Sep-16	**29**	**27**	**2**
19-Aug-16	**75**	**37**	**38**	26-Sep-16	**126**	**72**	**54**
26-Aug-16	**48**	**26**	**22**	27-Sep-16	**85**	**46**	**39**
28-Aug-16	**39**	**27**	**12**	28-Sep-16	**153**	**54**	**99**
29-Aug-16	**44**	**20**	**24**	29-Sep-16	**50**	**50**	**0**
30-Aug-16	**98**	**27**	**68**	30-Sep-16	**127**	**94**	**33**
TOTAL	**639**			**TOTAL**	**1040**	total	**1679**

3.5.10 Incidental catches for monthly sampling

The traps usually had other occupants besides green crab. Species observed included the following: rock crab, mudcrabs, starfish, snails, mummichogs, tomcod, flounders, silversides, and cunners. The fish that came into the trap looking for food was unexpected, but became the norm after the first samples were counted. Sometime the fish predators became the prey of green crab in a confined trap. A lot of snails got into the trap and starfish, slow moving as they are, could be quite numerous after only 24 hours. One trap had

six starfish. Another interesting note was that rock crab and green crab would often be found in the same trap. Obviously they are competitors being attracted to the same bait and occupying the same niche. However the numbers of green crab far outnumber the rock crab. We do not know if rock crab numbers are the same or on a decrease or increase. We do know that, since their arrival in the Bay, green crab now far outnumber the indigenous rock crab. Other species recorded in 2017 included a striped bass, ocean perch and more lobster of just under canner size.

3.6 Non statistical estimations of the green crab population in Shediac Bay

Applying statistical extrapolation to population dynamic structure is beyond the scope of this survey. However, a rough estimation of population size will be presented based on average catch per trap and chosen square meters that the crab might travel to get at the bait in the traps.

From the bi-monthly catch data there were 209 crabs caught. There were 7 times 10 or 70 traps put in the water. The average number of crabs per trap 209 / 70 equals 2.9857 or let's say 3 per trap. The number of square meters was 20,160,000. But this number includes outside Shediac Island where no green crabs were caught. It also includes in front of Parlee beach where no crabs were caught. So we will use 20 million square meters for this rough estimate.

Now how far will a green crab travel to get to a bait source. Let's assume several radii distances. **Table 14** below provides such predictions.

Table 14. Non-statistical estimates of possible population size in Shediac Bay for 2013

Distance from trap	Number of square meters	water area 20,000,000 m^2	Divided by square meters	Number of units	Times 3 crabs per unit
1 meter	3.14	20,000,000	3.14	6,369,426	19,108,280
2 meter	12.56	20,000,000	12.56	1,592,356	47,77,070
3 meters	28.26	20,000,000	28.26	707,714	2,123,142
4 meters	50.24	20,000,000	50.24	398,089	1,194,267
5 meters	78.50	20,000,000	78.50	254,777	764,331

So, if all three crabs only came from a one meter distance away, there might be 19 million crabs in the bay. If they travel from 5 meters away in 24 hours, then only ¾ of a million are

in the bay. Chances are they travel more than 5 meters away, but not knowing the distance from which they can sense the bait and make it to the trap, makes this only a best estimate.

If we now compare the low numbers in 2013 to high numbers in 2016 and 2017, we could up these estimates many fold. But in 2013 we did transect studies and set traps in sandy habitat where no crab were found. This caused our density estimates to be lower. Just taking into account the 10 traps in the inner bay in eel grass habitat, our density estimate would be much higher and our area of coverage would be lower.

3.7 Summary of Objectives subsequent to NBWTF requirements

Funding from NBWTF had two main components, one being the actual monitoring of the green crab population dynamics and the other was the educational aspect of the green crab program. As outlined in our proposal, we did duplicate the sampling protocols from the previous two years. As mentioned, the unusual decrease in population numbers was not expected. This would not have been determined if funding had not been awarded.

Our student staff gave presentations at the Homarus eco-center all summer season. These included educational seminars, visitor discussions on crab life cycle, impact scenarios of green crab on local populations of molluscs and the actual population study itself. Each Sunday, staff manned a booth in the Sunday in the Park market. Live green crab at the booth was always a fun thing for residents and tourists.

Social media plays a more important role in getting information out to those who access our website or follow new stuff on facebook. Also our newsletter describes all project in a briefer form that this report. We always get inquiries just loading and un-loading the boat full of traps, a great opportunity to do the interpretation related to the project.

4.0 CONCLUSION

This survey was carried out because the population of green crab in Shediac Bay had yet to be documented by any government agency. This was not the case in 2016/2017 as DFO staff did set some traps and catch some crab. I do not have those results for this report. Up until 2016, there had been no government sponsored scientific investigation since the green crab migrated into the bay.

Ten locations were chosen and sampled twice a month for 3 ½ months in 2013. The same sites were fished exactly the same on a monthly basis in 2014, 2015, 2016 and 2017 from May to September (October sample in 2013 and 2017). Crabs were found in all locations that had an eel-grass substrate. Sandy substrates did not produce any crab catches. Winds are usually an issue in Shediac Bay so sampling was generally carried out in the mornings. In-kind support from DFO allowed SBWA to carry out this study within an acceptable budget for the first two years. In the last three years, a boat was leased.

Male green crab were always more abundant in the traps. All age classes were trapped over the course of the study. The very young were less numerous or more likely, they could escape back out of the trap, or be eaten by adult crabs when confined in the trap. Females with eggs were mostly not present in any catches. However we did catch one late egg bearing female in 2016. The only change in methodology from 2013 was that traps were

only set monthly in 2014, 2015, 2016 and 2017. This 5 year study did allow the determination of notable changes in population structure as the 5 year comparisons did illustrate. Overall, there seemed to be a higher population density in 2014. It was the 2015 year that yielded un-expected results. Seeing numbers drop rather stay the same or increase would not have been picked up if NBWTF had not granted funding to continue this study in 2015. Then there was the exponential increase in 2016 which was to say the most dramatic. In 2017, numbers remained high, but slightly less that 2016, Funding will be sought for a continuation of this study in subsequent years.

Using processed sardines may not be the best bait but it works, especially those processed in oil. Testing other baits such as fresh fish, clams and dead mackerel was done outside the study, but these sources are not always reliably available.

There is a large population of green crab in Shediac Bay. The need for a removal program to keep the population at an acceptable yet sustainable level will reduce the threat to the health of the local littoral ecosystem in the bay. There is a thriving quahog and eel fishery in the bay and if green crab populations are not controlled in some manner, they are the most likely fisheries to suffer.

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