Report to Governor Paul R. LePage

Regarding the Executive Order:
An Order Establishing the Governor's Task Force on the Invasive European Green Crab (February 28, 2014)

Report Compiled By:
The Appointed Members of the Governor's Task Force on the Invasive European Green Crab

Chair:
As designated by Patrick Keliher, Commissioner
Maine Department of Marine Resources
J. Kohl Kanwit – Director, Bureau of Public Health
Maine Department of Marine Resources

Members:
Susanne Miller, Department of Environmental Protection
Janine Bisaillon-Cary, Maine International Trade Center
Dan Harrington, Chair of Woolwich Shellfish Commission
Abden Simmons, Chair of Waldoboro Shellfish Commission
Garret Simmons, Freeport Shellfish Dealer (S&S Seafoods)
Fiona De Koning, Aquaculturist (Acadia Aqua Farms)
Rink Varian, multi-fishery harvester
George Seaver, Ocean Organics Corp.
Dr. Brian Beal, University of Maine at Machias and The Downeast Institute
Dr. Megan Tyrrell, National Park Service
Hugh Cowperthwaite, Coastal Enterprises Inc.(CEI)

September 30, 2014

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1. Introduction

a. Invasion History

Green crabs (*Carcinus maenas* [L.]) are native to northwest Africa and western Europe ranging from Mauritania to northern Norway (Barents Sea), and were accidentally introduced to the United States around 1817 in the Long Island area (Carlton and Cohen, 2003). Green crabs have been observed in Maine since about 1905 when they were first noted in Casco Bay (Eagle Harbor, Harpswell and the New Meadows River) (Rathbun, 1905). By 1930, green crabs had been collected at Brooklin (Hancock County), and in 1938, the easternmost specimen was collected at the Sands, near Corea (Hancock County). By 1951, they were observed in Washington County from Jonesport and Machiasport to Cutler and as far east as Lubec (Scattergood, 1952). Although the early life-history of *C. maenas* has a planktonic component, Scattergood (1952) provided a reasonable account of how they were able to spread eastward along the Maine coast (which is in the opposite direction of the net movement of tidal currents):

> "Undoubtedly, man's activities are partially responsible for the remarkable spread of *Carcinides* (sic). The lobster and sardine fisheries probably provide the principal means by which crabs may be transported from one area to another. Since the crabs can live for several days out of water, it is relatively easy for the crabs to be carried in lobster smacks, lobster-carrying trucks, lobster-fishing boats, sardine carriers, and sardine-fishing boats. I have seen live crabs in crates of live lobsters and have noticed them aboard sardine carriers and fishing boats."

The original invasion of green crabs from Europe seems to have been augmented by a more northern genotype as recently as the late 1900s (Blakeslee, 2010). Research indicates that this reintroduction likely began in Nova Scotia shipping ports and has migrated down the eastern seaboard into New England mixing with the naturalized population from the initial introduction. This poses a new threat to native species and habitat assuming that the northern genotype is more cold tolerant and less likely to be killed by severe winters. This secondary introduction of the more northern genotype of green crabs is also impacting Newfoundland (cir. 2003) where green crabs are establishing populations in Placentia Bay thus demonstrating the ability to withstand colder temperatures and expand their foothold in North America.

b. Biology of Green Crabs

Green crabs have a complex life-history that is comprised of four planktonic zoeal stages and a megalopa stage (Dawirs et al., 1986) in which they increase (via molting) from an average carapace length (CL) of 0.5 mm to 1.3 mm (Rice and Ingles 1975). At the end of the megalopa stage, individuals molt and metamorphose into a benthic (bottom) juvenile (1.5 mm CL), known as a first-stage crab (Zeng and Naylor, 1996). In Maine, adults mate between mid-July and mid-October, with a peak occurring in August (Berrill, 1982). However, it should be noted that this mating window is likely larger given the warming trends since these observations were made and recorded. Ovigerous females (typically > 35 mm CL) extrude their fertilized eggs between April and August of the following year. At oceanic salinities (32 o/oo) and seawater temperatures near 18^{o}C, it takes between 4-5 days for larvae to pass through one zoeal stage and about 12 days for the megalopa stage (Dawirs et al., 1986). Working in mid-coast Maine, Berrill (1982) observed first-stage crabs as early as August, and these newly settled juveniles continued to grow until November reaching a mean size of 5.5 mm CL (range = 3-10 mm). Little, if any, further growth occurred between November and the end of the following May (1980). By the following November (going into the second winter), *C. maenas* ranged in size from 13-28 mm CL.

c. Recent Events and Impetus for the European Green Crab Task Force

Late in 2012, shellfish industry members began raising the alarm regarding the devastating impacts they were observing as a result of high densities of European green crabs in coastal Maine waters. DMR convened a meeting with the Maine Clammers Association, research scientists and representatives from the towns of Penobscot and Chebeague in April 2013 to hear concerns and discuss options. The consensus from the meeting was that green crabs were being reported widely but information on the abundance and distribution along the coast was absent. It was also agreed that many municipalities, residents and industry members were unaware of the problem. DMR therefore coordinated and conducted a volunteer, statewide, one-day, green crab trapping study in August of 2013 (see section 12.b.ii of this report). The dual objectives were to increase awareness of the problem and also collect data on the relative abundance and distribution of green crabs coast wide. The trapping study did show that green crabs were present throughout the Maine coast, frequently in staggering numbers. As industry members became more aware of the problem, researchers also noticed precipitous declines in eelgrass beds and rapid marsh bank erosion, both signs of heavy green crab infestations. Bivalve shellfish resource surveys conducted in many areas in 2013 revealed one or two missing year classes of soft-shelled clams and intertidal mussels were observed to be severely depleted. Many municipal shellfish programs initiated mitigation efforts including trapping, netting seed and fencing vulnerable areas in an effort to maintain commercial shellfish fisheries. Shellfish aquaculturists began or continued trapping on their lease sites but reported heavy losses of seed regardless. DMR and Maine SeaGrant partnered with the US Geological Survey and the Coastal Zone Management program to host a Maine Green Crab Summit in December 2013. This event drew more than 200 in-person participants and more than 300 on-line listeners. Clearly the awareness of the green crab population surge and its resulting impacts on native and commercial resources, as well as habitat had increased dramatically. The summit presented what is known about green crabs (e.g. history, biology, genetics etc) and possible mitigation and control measures (e.g. case study in NS, potential markets) that can be employed. The website for the summit hosts all the presentations and can be viewed here: http://seagrant.umaine.edu/green-crab-summit.

In response to growing concerns regarding green crabs and their impact on native resources and habitat, Governor LePage issued an Executive Order in February 2014. The announcement was made at the Maine Fisherman’s Forum. The Executive Order established the European Green Crab Task Force and identified several objectives to be addressed and reported on by the end of September 2014.

With awareness and the desire to effect change at its peak, DMR hosted a Municipal Green Crab Workshop in March of 2014. The objective of this workshop was to provide municipal shellfish programs with the tools to control and/or reduce the green crab populations in their area. Demonstrations on trap modifications were given, regulations were discussed and general information was presented.

Many municipalities initiated green crab control programs in 2014 and were pleasantly surprised by the reduced numbers of crabs in their traps and the apparent increased survival of soft-shelled clam and mussel seed. The winter of 2013/14 was colder than recent years and seems to have depressed the green crab population in some areas. However, green crabs are still present as they have been for over 100 years in Maine waters. It is critical that the research, resource management and industry sectors remain aware of the threat posed by green crab population surges and prepare for additional population increases in order to initiate mitigation early for maximum effectiveness.

2. Executive Order

AN ORDER ESTABLISHING THE GOVERNOR'S TASK FORCE ON THE INVASIVE EUROPEAN GREEN CRAB

WHEREAS, the European green crab population has rapidly expanded in Maine's coastal waters in recent years; and

WHEREAS, the European green crab is a voracious predator known to be causing resource depletion of bivalve shellfish species such as the blue mussel and soft-shelled clam; and

WHEREAS, the European green crab has destroyed eelgrass and fringe marsh habitat throughout the coast; and

WHEREAS, the bivalve shellfish fishery is worth approximately $25 million to the state economy; and

WHEREAS, the eelgrass and fringe marsh habitats are critically important to the health and productivity of Maine's marine resources; and

WHEREAS, the impacts of European green crab predation are unknown with regard to other commercially important marine species; and

NOW, THEREFORE, I, Paul R. LePage, Governor of the State of Maine, hereby order as follows:

The Governor's Task Force on the invasive European green crab is hereby established.

The membership of the task force shall consist of (12) twelve people, appointed by the Governor, including representatives of the following groups:

Department of Marine Resources (1); Department of Environmental Protection (1); Department of Economic and Community Development (1); Towns with municipal shellfish ordinances (2); Bivalve shellfish industry (2); Other marine resource industry (2); Researchers from disciplines such as ecology, marine biology or shellfish biology (2); Researchers from disciplines such as economic or market development (1).

The Task Force shall:

a. Review and consider the impacts of European green crabs on the commercial bivalve fisheries, shellfish aquaculture; intertidal and sub tidal habitat, and other marine resources;

b. Develop recommendations for short-term and long-term solutions in addressing the European green crab population explosion in coastal Maine waters including, but not limited to targeted depletion and directed fishery development;

c. Determine the direct economic impacts of European green crab predation on the bivalve shellfish resources of Maine.

d. Review and consider costs associated with proposed control strategies;

e. Consider anything else necessary to successfully address the European green crab crisis in Maine waters.

The Task Force Chair shall:

a. Identify the process, schedule and information to carry-out the Executive Order.

The Task Force shall submit a written report with recommendations to the Governor no later than September 30, 2014, after which the Task Force shall dissolve.

3. List of European Green Crab Task Force Members

Chair:	J. Kohl Kanwit, Director, Bureau of Public Health, Department of Marine Resources
DEP:	Susanne Miller, Director, Eastern Maine Regional Office, Department of Environmental Protection
DECD:	Janine Bisaillon-Cary, President and Director, Maine International Trade Center
Municipal Representatives	Dan Harrington, Chair of Woolwich Shellfish Commission Abden Simmons, Chair of Waldoboro Shellfish Commission

Shellfish Industry	Garret Simmons, Freeport Shellfish Dealer (S&S Seafood's) Fiona De Koning, Aquaculturist (Acadia Aqua Farms)
Marine Industry	Rink Varian, multi-fishery harvester George Seaver, Ocean Organics Corp.
Researchers of Biology and Ecology	Dr. Brian Beal, Professor of Marine Ecology UMaine and Founder of The Downeast Institute Dr. Megan Tyrrell, Research and Monitoring Coordinator, Cape Cod National Seashore ,National Park Service
Economic Development	Hugh Cowperthwaite, Fisheries Project Director, Coastal Enterprises Inc. (CEI)

<u>Maine Department of Marine Resources Support Staff</u>
Jennifer McHenry, Task Force Coordinator
Carl Wilson, Lobster and Crab Biologist
Les White, Shrimp and Crab Biologist
Denis-Marc Nault, Shellfish Management Program, Supervisor
Hannah Annis, Shellfish Management Program, Area Biologist
Peter Thayer, Shellfish Management Program, Area Biologist
Heidi Leighton, Shellfish Management Program, Area Biologist

<u>Maine International Trade Center Support Staff</u>
Jeff Bennett, Senior Trade Advisor, Food and Seafood Industry
Joe Long, Trade Research Intern

4. Summary of Documented Impacts from Green Crabs

a. Impacts to Commercial Fisheries

Several members of the green crab task force represent various segments of fisheries in Maine. These individuals provided a summary of the impacts of green crabs which they both personally observed and gleaned from working and communicating with other industry members. They have 70 or more years of collective experience in the fishing industry and many of them have participated in several fisheries. They also represent experience and knowledge throughout the entire coast of Maine. The following is a summary of their experience and knowledge of green crabs and their impact on commercial fisheries.

The region most heavily and/or noticeably impacted by green crabs appears to be river and estuary habitats and within three miles of shore. Green crabs are present continually, although their numbers increase in the summer and to a lesser extent the fall. They prefer soft bottom habitat (mud or silt) but can be found in sand and on rocky/ledge substrate if there is seaweed cover. Their depth preference seems to be from the intertidal zone to a 30 foot depth range, however lobstermen report catching them in much deeper water.

The numbers of green crabs dramatically increased in 2013 even from just the year prior (2012). The increasing trend in the green crab population is difficult to track however, because few recognized the signs of an expanding green crab population prior to 2013. The signs of green crab presence such as pock marks in the mud were sometimes misinterpreted as things like sturgeon feeding marks. It was the coincidence of increased awareness and actively looking for green crabs by trapping that made many people identify the problem last year. The numbers of green crabs observed in 2014 have declined significantly from 2013 levels in most, but not all areas.

Green crabs negatively impact most commercially significant species especially bivalve shellfish seed, but also adult bivalves, marine worms, urchins, scallops and lobsters. It would seem that few industry members have changed their harvesting or growing practices in response to the increased green crab population, however many were considering it for 2014 if the numbers of green crabs stayed at 2013 levels. Potential measures include increasing mitigation efforts and reseeding.

The harvest and aquaculture sectors indicated that the relative importance of green crab's impact on marine resources is very high with only habitat loss perceived at a similar threat level. Concerns such as ocean acidification, warming water temperatures and overharvesting ranked lower as significant threats to resources and habitat. However, there seems to be consensus that in the natural world there are always multiple factors influencing populations. While habitat loss, ocean acidification, warming water temperatures, overharvesting and many other influences impact coastal marine habitat and bivalve shellfish abundance and survival; green crab impacts were so overwhelming in 2013 that it was perceived as the most significant threat but never as the sole threat.

The solutions to the impacts of exceptionally large green crab populations now and in the future should rely on partnerships between the government, non-government agencies, municipalities and the industry. Efforts to reduce the population below critical threshold levels can be successful with the right tools and persistence. Trapping appears to be the most effective mitigation method if the traps are tended frequently. More information on green crab population dynamics and movements will help target effective mitigation efforts.

i. Results from Harvester Mail Survey

The Task Force conducted a survey of harvesters and growers to characterize the recent occurrence and impacts of expanding green crab populations in Maine. In early summer 2014, questions were generated from initial task force meetings and the final questionnaire was distributed via state email lists in August, reaching roughly 2000 potential respondents. In early September, responses were analyzed to quantify the knowledge and perception of coastal lobstermen, shellfish harvesters/growers, draggers/divers, and marine worm harvesters. Only 52 responses were received by the deadline for inclusion in the Task Force report so the results should be viewed with this limitation in mind. Unfortunately, no shellfish aquaculturists participated in the survey so they are not represented in the results.

The primary survey goals were to 1) determine how many harvesters and growers currently encounter green crabs, 2) characterize whether harvesters and growers have observed changes or impacts from green crab populations over the last several years, and 3) determine whether Maine harvesters and growers are engaged in successful control measures that could be implemented at a larger scale.

From preliminary analysis, there are three main conclusions (see Appendix c. for full report). First, the majority of respondents (84.6%) encounter green crabs regularly. In many areas, commercial lobstermen and shellfish harvesters have seen drastic increases in local green crab abundances since 2012. Second, some harvesters are seeing negative impacts to their target species or habitat (36.5%), including evidence of predation on shellfish, degradation of eelgrass beds, and spatio-temporal displacement of American lobsters. However, most either have not or are unsure of the short and longer term impacts of green crabs. Third, although many respondents were unsure of the extent of recent impacts, most respondents (51.9%) are already taking steps to control, avoid or prevent potential impacts from green crabs, including trapping to kill, shifting target areas, or even pursuing other economic options. Overall, 69% of respondents are in favor of Maine agencies, industries or other groups collaborating to develop solutions for controlling, reducing or capitalizing European green crabs.

b. Competition and Predation

Green crabs have a wide, opportunistic diet. They have typically been characterized as a molluscan predator (Ropes 1955) but a wide variety of prey, including crustaceans, has been recorded in their stomach contents (Grosholz and Ruiz 1995). In laboratory experiments where green crabs were matched with Asian shore crabs by biomass, green crabs had lower consumption rates on medium (~10 mm) and large (~14.5-21 mm) mussels (*Mytilus edulis*) than *Hemigrapsus sanguineus* (DeGraff and Tyrrell 2004). Juvenile green crabs that live in the shell hash found between rocky shore cobbles and boulders, impose a substantial predatory hurdle for newly recruiting shellfish, barnacles, crustaceans and even fish.

Ropes (1968) studied the feeding habits of green crabs from 1954-1956 that he caught at the edges of salt marshes in Plum Island Sound, Massachusetts, and Hampton Harbor, New Hampshire by “opening caves in the banks of cordgrass (*Spartina alterniflora*) and searching through seaweeds at the upper edges of the banks and beneath sods that had fallen onto clam flats.” In addition, he collected crabs from the subtidal zone using a scallop drag at the edges of channels in Plum Island Sound. Of 3,979 crab stomachs sampled, 31 food items were identified (3 species of polychaete worms; 10 species of bivalves; 4 species of gastropods; 4 species of crabs, 3 arthropod species; a barnacle; 2 species of plants; and, four other groups ranging from fish and insects to foraminiferans and colonial hydroids). Bivalves (particularly blue mussels, *Mytilus edulis*, and soft-shell clams, *Mya arenaria*) were most frequent in crabs ranging in carapace length (CL) from 30-59 mm. The feeding habits were regulated by the time of day and tidal cycle. Crabs sampled at night and at high tide had the greatest frequency of food in their guts. Another study of green crab diet was conducted in Port Hebert, Nova Scotia (Elner, 1981) that showed the most important items by volume and frequency were bivalve mollusks such as blue mussels and soft-shell clams.

Neither Ropes (1968) nor Elner (1981) found evidence that *C. maenas* was a predator of lobster; however, multiple lines of evidence suggest otherwise. First, several laboratory trials have demonstrated that green crabs consume juvenile lobsters (Barshaw et al., 1994; Rossong et al., 2006; Haarr and Rochette, 2012; Sigurdsson and Rochette, 2013). Second, videos taken from shallow and estuarine sites in mid-coast Maine of tethered juvenile lobsters (< 20 mm CL) showed green crabs as a common predator (Wahle and Steneck, 1992). Third, parts of juvenile lobsters have been observed in the guts of green crabs from the Harraseeket River, Freeport, Maine (22 July 2014; B. Beal, pers. obs.).

Green crabs prey on commercially important bivalve species in soft sediments such as soft-shell clams, *Mya arenaria*. Dramatic increases in *C. maenas* populations occurred in New England during the early 1950's, and was correlated with declines in commercial soft-shell clam landings in Maine, Massachusetts, and the Canadian Maritimes (Glude, 1955; MacPhail et al., 1955; Smith and Chin, 1955; Ropes, 1968; Welch, 1969; Dow, 1972). Green crabs have been shown to limit experimental populations of cultured and wild juvenile clams in eastern Maine (Beal et al., 2001; Beal, 2006). In addition, Whitlow et al. (2003) and Whitlow (2010) tested experimentally in the Little River Estuary near Wells, Maine, how crab foraging affected clam burrowing, and how depth in the sediment affected clam survival. Flynn and Smee (2010) conducted similar studies in the Damariscotta River. Collectively, those studies demonstrated that soft-shell clams change their behavior in the presence of green crabs and dig deeper into sandy sediments presumably to escape predation. That is, crabs induced a greater burrowing response from clams than did clams not exposed directly to crabs. Also, sediment depth, not clam size, provided a refuge from green crab predation in those studies.

i. Observations on Winter Mortality of Green Crabs During Periods of Unusual Cold Weather

Throughout their life-history, green crabs have varying physiological tolerances to salinity, temperature, and dissolved oxygen, that affects everything from respiration and osmoregulation to foraging behavior and predation rate. These tolerances have been well-studied under laboratory conditions (Spaargaren, D.H. 1977; Taylor et al., 1977a, b; Nagaraj, 1993; Anger et al., 1998; Robertson et al., 2002; Bravo et al., 2007; Kelley et al. 2013). Under field conditions, observations from both North America and Europe suggest that unusually cold winter temperatures are correlated with decreases in green crab abundance, particularly affecting adult crabs and these decreases affect the dynamics of soft-bottom and other marine communities.

After their historic population explosion in northern New England during the early 1950's that was associated with dramatic declines of soft-shell clams, *Mya arenaria* (Glude, 1955; Smith and Chin 1955), green crab populations dwindled along the coast of Maine during the late 1950's and into the 1960's with a concurrent increase in commercial clam landings (Welch, 1968). The decline in green crab populations was attributed to a series of cold winters (Glude 1955). For example, during the winter of 1955-56, mean monthly seawater temperatures at Boothbay Harbor, Maine in December (4.9^{o}C) and January (3.4^{o}C) were the coldest in eight years. Lobster fishers, clammers, and state biologists reported large numbers of dead green crabs washed up along the shore in Blue Hill Bay, Herrick Bay (Brooklin), and Sams Cove (Bremen) (Welch, 1968). During the winter of 1958-59, biologists from the federal laboratory in Boothbay Harbor observed another winter kill in southwestern Maine. At that time, winter seawater temperatures between January and March were the lowest for all three months since 1948. Monthly mean air temperatures for December 1958 and February 1959 were also the lowest for those months since 1917 and 1934, respectively. Welch (1968) found in the banks of *Spartina* sod in the tidal marshes in Wells, Maine "hundreds of dead crabs of all sexes and all sizes." Subsequent trap catches in those marshes during the summer of 1959 resulted in lower overall catch biomass, with the proportion of small crabs in the catch being much higher than observed in previous years. Another example that unusually cold weather has a disproportionate effect on large vs. small green crabs occurred in North Wales, England, during the winter of 1962-63. Crisp (1964) noted that sea ice accumulated along the shores of the intertidal zone near the marine science laboratory at Menai Bridge, Anglesey, and that ice floes 15 cm thick (ca. 6 inches) and several square meters drifted down the Menai Straights, and caused "severe mechanical scouring" of the shores (Crisp, 1964). Crisp (1964) noted that the unusually cold weather resulted in dead or moribund adults "all around the coast, but smaller individuals were less affected and dominated the population surviving in March-April."

Observations from several European studies have shown exceptionally heavy recruitment of soft-shell clam juveniles and other bivalves species after a severe winter. For example, in the western Wadden Sea (Balgzand, a 50 km^2 tidal flat) Beukeuma (1982) noted that four bivalve species, *Mya arenaria*, *Mytilus edulis* (blue mussel), *Cerastoderma edule* (common cockle), and *Macoma balthica* (the Baltic tellin) each had higher than usual recruitment in 1979, after a severe winter. Similar observations were made by Beukema (1992) and Beukema et al. (2001) who remarked that following relatively mild winters, recruitment in *M. arenaria* was negligible. Beukema (1992) noted that particularly mild winters favored certain groups of infaunal predators, including the green crab, *Carcinus maenas*. Strasser (2002) used a caging experiment on an intertidal flat in Königshafen Bay in the north of the German island of Sylt, North Sea during the summer and fall of 1996 (following a severe winter), 1997 (following a moderate winter), and 1998 (following a mild winter) to examine the effects of predation on wild recruits of Mya and two other bivalves. Significant predation effects occurred only after the two mild winters but not after the severe winter. Two predators, *Carcinus meanas*, and the sand shrimp, *Crangon crangon*, were largely responsible for preying on *Mya* recruits; however, densities of both epibenthic predators were reduced after severe winters suggesting that high bivalve recruitment after severe winters is due to reduced epibenthic predation (Strasser and Günter, 2001).

Recent observations (May - September, 2014) from trapping studies in the Harraseeket River, Freeport, Maine have shown that since the severe winter conditions of 2013-2014, green crab biomass trap^{-1} is approximately 90% lower than over the same period during 2013. In addition, smaller crabs are being caught compared to 2013, and there are signs that soft-shell clam recruitment (in some areas) is higher than in 2013. These observations are similar to those observed in the Wadden Sea. Sampling for recruits of *Mya* (Beal, 2014) from a number of field experiments during November 2014 will allow an unambiguous assessment of the importance of predation by *C. maenas* and other predators on soft-shell clams following a severe winter.

c. Impacts to Habitat:

In Maine and elsewhere, individuals of *Carcinus* have a diverse habitat range. They inhabit rocky shores living within beds of knotted wrackweed, *Ascophyllum nodosum* (Rangeley and Thomas, 1987; Bertness et al., 2004), or in the interstices of cobbles, rocks, and ledges (Ellis et al., 2007). They are found in salt marshes (Glude, 1955; Young et al., 1999; Konisky et al., 2006), eelgrass beds (Mattila et al., 1999; Schmidt et al., 2011), and in unvegetated soft sediments (Larsen and Doggett, 1991; Beal et al., 2001; Gregory and Quijón, 2011). Green crabs can live both intertidally and subtidally; hence, they can influence the dynamics of many marine ecosystems.

i. Soft Bottom Intertidal and Subtidal Ecosystems and Habitats Including Eelgrass

Green crabs are omnivores, and play a major role as an ecosystem engineer in soft sediments. Their predatory exploits have been studied in a variety of soft-bottom habitats both in Europe (Klein-Bretler, 1976; Scherer and Reise, 1981; Jensen and Jensen, 1985; Sanchez-Salazar et al., 1987; Richards et al., 1999; Baeta et al. 2005), where they are native, and in Maine (Glude, 1955; Beal and Kraus, 2002; Whitlow et al., 2003; Whitlow, 2010; Beal, 2014).

Green crabs use structurally complex habitats in soft sediments such as submerged aquatic vegetation (eelgrass – *Zostera marina*), mussel beds, shell debris, and mats of ephemeral algae (sensu Vadas and Beal, 1987) as habitat (Thiel and Dernedde, 1994; Heck et al., 1995; Sprung, 2001; Moksnes, 2002; Almeida et al. 2008). However, as population densities increase, crabs also can have a negative impact on eelgrass beds.

Eelgrass provides essential habitat, refuge, nursery and feeding grounds for fish and shellfish. It also reduces turbidity, removes dissolved carbon, increases pH, and oxygenates surface sediments. Eelgrass coverage has been declining, and it is thought that while the causes may vary, one of the primary causes in coastal Maine may be European green crabs. Other causes may include: climate change, ocean acidification, and eutrophication.

Juvenile green crabs use eelgrass primarily as nursery habitat. Juveniles don’t preferentially eat eelgrass, but they may occasionally utilize it as a food source. Typically juveniles have a negative effect on eelgrass beds by causing sediment disruption as they dig for clams and other invertebrates. Adults may also eat eelgrass although it is not part of their typical diet. Adults will destroy eelgrass by digging for other food sources, and will uproot, expose, clip or weaken the eelgrass shoots or rhizomes (Malyshev and Quijon 2011). Green crab foraging activity was responsible for disturbing a large-scale transplant experiment in Great Bay Estuary, New Hampshire resulting in survival rates of plants between 1-5% (Davis and Short, 1997; Davis et al., 1998). Sometimes green crabs may tear or cut the eelgrass shoot sheath bundle causing the shoots to have a "frayed" appearance (Davis *et al.* 1998). In turn, these weakened roots and rhizomes are often more susceptible to damage caused by waves and currents (Malyshev and Quijon 2011). An indicator of green crab impacts on eelgrass is floating or detached, clipped shoots.

A laboratory study showed that green crabs destroyed up to 39% of eelgrass transplants (Davis *et al.* 1998). In Tracadie Harbour, Nova Scotia, green crabs have been estimated to be able to remove up to 87,000 eelgrass shoots day^{-1} (Garbary et al., 2004). Malyshev and Quijón (2011) provided experimental evidence as to how crabs destroy eelgrass shoots and underground portions of the plants. Using a combination of both field and laboratory experiments, they showed that the deleterious role of green crabs is mediated by at least two mechanisms that depend on the size/age of the crabs: uprooting by adults and direct grazing on shoots by juveniles. Garbary et al. (2014) used a variety of techniques (direct observations of changes eelgrass beds and bare patches through time, caging experiments, tagging individual shoots and following their fate) to determine unambiguously that declines of eelgrass beds in Antigonish Harbour, Nova Scotia (1.1 to 4.1 shoots m^{-2} day^{-1}, with a rate of shoot deposition on the shore of 81,300 shoots day^{-1}) were caused by green crabs. In Benoit Cove, Nova Scotia, a recent invasion of green crabs resulted in a drastic decline in eelgrass beds. (Garbary *et al.* 2014)

In 2013, DEP coordinated and completed a survey to determine eelgrass bed acreage in Casco Bay, Maine. The purpose was to compare with 1993/1994 and 2001/2002 Department of Marine Resources mapping efforts, and to determine future monitoring needs and locations. As part of the surveys, DEP staff also assessed water quality at ten selected locations throughout the Bay. Results showed a 58% reduction in eelgrass area Bay-wide from 2001/2002 until 2013, and most notably, 4,392 acres of dense eelgrass lost along the Freeport, Brunswick, and Harpswell shorelines. In this central Bay area, higher levels of chlorophyll, greater light attenuation, and poorer water clarity were observed compared to elsewhere in Casco Bay (Brewer *et al.* 2013). This study did not assess the specific role of green crabs, but it should be noted that in 2013 there were a significant number of green crabs observed and trapped around coastal Maine, especially in Brunswick and Freeport.

Also in 2013, USGS established six experimental eelgrass transplant plots in Maquoit Bay, Brunswick (this area was included in the mapping described above). Three plots were protected from green crabs and three adjacent plots were not. Over a 26 day growth period, eelgrass survival was significantly higher in the protected areas, suggesting that green crabs were a primary cause of eelgrass loss. However, other stressors likely played a role in conjunction with green crab impacts (Neckles 2013).

ii. Salt Marsh Ecosystems and Habitats

Salt marshes occur in a narrow elevation band in wave-protected environments. Salt marshes are particularly important for: supporting higher trophic levels, absorbing storm surge and upland flooding, removing nutrients, building peat and sequestering carbon. Green crabs are common salt marsh inhabitants and with their quick burrowing ability, they are able to seek refuge in the soft substrates, such as creek bottoms. Green crabs also use the marsh platform, salt marsh pools, under the fucoid algae and culms of *Spartina alterniflora* - anywhere where they can burrow or otherwise be protected from avian or fish predators.

Green crabs are commonly found in vegetated intertidal salt marshes. They are encountered both during the day and night when the marsh surface is exposed to air, and when it is flooded. Although they have been known to take refuge within and under peat banks during Maine winters (Tyrrell, pers. obs.), their abundance in Maine salt marsh banks appears to have dramatically increased in recent years. In some cases, they can be found in “swarms” that burrow both vertically and laterally into the marsh peat (Deveraux video in Belknap and Wilson, 2014). Green crabs can rapidly burrow into soft sediments such as mud or sand. When peat is present, they can excavate tunnels (Barshaw *et al*. 1994), leading to destruction of the marsh bank (Belknap and Wilson 2014; Glenn 2014).

If green crabs contribute to accelerated loss of marsh peat, it could have devastating impacts for NE salt marshes. This topic is currently being investigated by Dan Belknap (ME Geological Survey) and colleagues. Of particular concern is the diminished wave absorption capacity of marshes behind barrier beaches. With accelerated sea level rise and increased frequency and severity of storms, salt marshes are currently under several climate change related threats such as increased frequency and severity of storms and accelerated sea level rise. If warmer winter water temperatures, combined with cold-tolerant green crab haplotypes lead to sustained, high green crab abundance, salt marshes could be in even greater peril due to green crab facilitated bank erosion and vegetation dieback.

In contrast to their potentially devastating effects on salt marshes where they are the only crab species, green crabs are credited for salt marsh re-vegetation in Cape Cod, MA. Excessive herbivory on salt marsh cordgrass (*Spartina alterniflora)*, by the native purple marsh crab, *Sesarma reticulatum,* led to wide unvegetated patches in southern New England salt marshes (e.g. Holdredge *et al.* 2009; Smith *et al. 2012*). Green crabs have been credited with facilitating vegetation recovery after they eat *Sesarma*, displace them from burrows and slow their effectiveness of consuming salt marsh cordgrass (Bertness and Coverdale 2013). *Sesarma reticulatum* is not yet present in Maine. The current northward extent of this species is the northern portion of Cape Cod (e.g. Wellfleet, MA).

Pitfall traps effectively sample the relative abundance of non-swimming crabs in salt marshes and soft sediments. Extensive pitfall trapping in NE salt marshes reveals that green crabs are the major component by biomass and number of individuals in salt marshes ranging from Maine to Massachusetts (ME- Lindsay Whitlow unpub. obs.; MA- Tyrrell unpub. obs). Pitfall traps are an inexpensive method to detect and record the relative abundance of other crab species, such as *Sesarma reticulatum*. This sampling method, combined with intensive manipulative research and monitoring of green crab contributions to salt marsh demise, are important tools for assessing the impacts of this invasive species on Maine's salt marshes. The myriad ecosystem functions of salt marshes such as: protection from storm surge, absorbing flood waters, nursery functions, carbon sequestration, trophic support for commercially exploited species, removing nutrients, etc. underscore the importance of thoroughly documenting the impacts of green crabs on this critical habitat type in the Northeast US.

iii. Rocky Intertidal and Subtidal Ecosystems and Habitats

In addition to soft sediment habitats, green crabs are common inhabitants of intertidal and shallow subtidal rocky habitats. The depth distributions of green crabs span from the upper mean high water mark to approximately 30 m depth. Because of the suitable shelter that they provide, green crabs are most common in areas dominated by cobble or boulders (Tyrrell 2002). Smaller grain sizes (e.g. pebbles) are prone to dislodge and crush crabs during storms. Conversely, solid rock bench, which is the most storm surge resistant substrate type, does not provide shelter from predators or harsh environmental conditions and thus has lower densities of green crabs. Rock bench that is covered w. thick macroalgae (e.g. *Ascophyllum nodosum or Fucus sp.*) such as typical of wave sheltered north temperate rocky systems, will harbor green crabs.

Green crabs have not caused widespread economic damage in northern New England's rocky habitats and it is unknown whether their populations have increased in this habitat in recent years. Green crabs have been implicated in apparent competition for food with rock crabs (*Cancer irroratus;* Miron *et al.* 2005), and they have similar prey preferences as rock crabs and juvenile lobsters (*Homarus americanus;* Sungail 2010).

iv. Sandy Intertidal and Subtidal Ecosystems and Habitats

There is little documented or anecdotal information related to green crabs and impacts on sandy intertidal and subtidal ecosystems and habitats. Information provided to the Task Force indicated that it is the least preferred habitat and therefore also the least impacted.

5. Summary of Ongoing Research and Control Efforts in the Region

This section summarizes information provided by request to the Green Crab Task Force by researchers, managers and teachers in Maine, Canada and other New England states. A request was emailed to anyone in the scientific, education and management community whom the Green Crab Task Force members were aware was currently or recently conducting green crab work. Individuals were asked to submit one-page summaries on the work they were conducting. References to authors in the following sections are made to the one page summaries included in Appendix b.

Awareness of the green crab population increase along coastal Maine in recent years led to extensive research, mitigation and education efforts in 2013 and 2014. Summaries submitted to the Green Crab Task Force fell into four broad categories: genetic research, population dynamics, mitigation efforts and education.

Several researchers are tackling the question of green crab genetics and introduction of multiple genotypes to North America. Blakeslee et. al. have documented the reintroduction of a more northern genotype into Canada in the late 1900s and its apparent mixing with the original green crab genotype introduced in the early 1800s. Williams et.al. further documented the occurrence of the northern haplotype in Maine populations of green crabs. While Badger et. al. found that the presence of the northern haplotype in the Mount Desert Island region did not result in more damage to the ecosystem (eelgrass). They concluded that it is more likely that factors such as green crab abundance or water quality are contributing to the declining health of eelgrass beds along the Maine coast.

Other researchers are focusing on green crab abundance and trap efficiency. Steneck et. al. trapped crabs in the Damariscotta River using methods employed by Welch (1969) in the early 1960s. These researchers found that the patterns of abundance and decline did not vary significantly between trap designs or bait used. Further, making historical comparisons with Welch's study, they found that the catch rates from a comparable area (Southport, Maine) in 1953 to 1966 were about four times higher than those recorded in the Damariscotta River in 2014.

Hilary Neckles of the USGS is overseeing a broad partnership that has come together to investigate whether eelgrass loss is continuing in Casco Bay and to better understand factors that may exacerbate or mitigate damage by green crabs. To determine if eelgrass change is correlated with patterns in green crab densities, they are monitoring green crab abundance in the vicinity of each eelgrass transect as biweekly catch-per-unit-effort. Results from this effort are not yet available.

The towns of Brunswick, Harpswell and Freeport are engaged in several mitigation projects. All three are participating in Predator Protection Pilot Projects as authorized under LD1452. These projects aim to determine if fencing, netting and trapping can be effective tools to mitigate green crab predation especially on soft-shelled clams. Brunswick is also monitoring green crab impacts to coastal shoreline and erosion as well as collecting genetic data and developing a long-term monitoring plan. Dr. Brian Beal has a massive research project going on in cooperation with the Town of Freeport testing the survival of wild and cultured soft-shelled calm seed, effects of acidification on seed survival and survival of juveniles and adult soft-shelled clams in exclosures and under predator nets.

In the fall of 2013, the Island Institute engaged in a green crab monitoring and education project with five island schools in Maine through its National Science Foundation funded WeatherBlur Project. The fall investigation with the Maine island schools (North Haven, Cliff, Chebeague, Long, and Peaks islands) involved working with island lobstermen to deploy ventless lobster traps. The original objective of the project was to study what other marine life lives with lobsters on the sea floor and how this has changed over the life times of the participating fishermen. After the first couple hauls, the investigation quickly turned into a "green crab investigation".

The Eastern Maine Skippers Program (EMSP) which consists of 45 students throughout 8 high schools will be studying the green crab issue in their cumulative project this academic year (2014/15). The EMSP is coordinated by Penobscot East and offers student fishermen an authentic learning opportunity. The project "The Green Crab Invasion" will have students asking "How can (the impact of) the green crab population be controlled in a way that conserves (sustains) our marine ecosystem and encourages new industry(s) from the green crab products."

The Green Crab Mitigation Competition, sponsored by the Goldfarb Center of Public Affairs and Civic Engagement, and CEI, is designed to showcase student plans to ease or eradicate the green crab problem. It will be held at Colby College in February 2015, and will be open to undergraduate students from throughout Maine. Each individual or team will develop a detailed plan at their college or university, and pitch the proposals to a panel during the completion day at Colby.

In Newfoundland, researchers (McKenzie et. al.) and managers are actively working on monitoring, mitigation and research. Green crabs were first discovered in North Harbour, Placentia Bay in August 2007. Since that time they have spread throughout Placentia Bay, along the west coast of Newfoundland. The spread has been quite spectacular over the six years and the numbers in some areas are very high. Following the discovery in 2007 and the survey, DFO held a green crab mitigation workshop in early 2008. They decided on mitigation through trapping and have recently received funding to conduct a targeted mitigation in Placentia Bay to remove green crabs. Researchers in Newfoundland have published several papers on green crabs and their impacts on native ecosystems and resources in recent years.

McCarthy et. al reported problems at Kejimkujik National Park Seaside (NS) that have resulted from a recent invasion of a new strain of invasive European green crab from northern waters off Iceland. This crab is known as an ecosystem engineer and can cause major, cascading effects in ecosystems. In this case, it resulted in the mass destruction of eelgrass beds and other native biodiversity including soft-shell clams. In 2010, Kejimkujik began a coastal restoration program to control green crab numbers in collaboration with its partners and volunteers. Green crabs were fished to below thresholds for ecosystem recovery (less than 15 crabs CPUE) and eelgrass was successfully transplanted to enhance restoration of the estuary.

The Massachusetts Division of Marine Fisheries (MADMF, Whitmore et. al.) will administer and oversee the Great Marsh Green Crab Depletion Program to remove European green crabs (*Carcinus maenas*), with the goal of improving shellfish, eelgrass, and fishery resources along Massachusetts' upper North Shore. Several fishermen will be contracted to trap and remove green crabs from locations such as Plum Island Sound, Essex Bay, and Annisquam River estuaries. The program includes a pilot effort to develop the green crab bait market to prospectively enhance in-state utilization of product in the conch and tautog fisheries. Other research being conducted under the program includes identification of factors important for improving success of Great Marsh eelgrass transplant efforts in the presence of green crabs, as well as examination of trapping efficiency, trap use by sex and reproductive condition, and catch by depth to improve trapping efficacy. Young et. al. is also conducting trapping experiments in Salem Sound and looking for indications of molting status.

In New Hampshire, researchers (Fairchild et. al.) discovered that green crabs were to blame for high post stocking fish mortality (winter flounder) and repeated efforts to mitigate or provide alternate fish release strategies to avoid high concentrations of green crabs proved near impossible. This led to a concerted effort to understand and document green crab populations in NH waters, and how they affect other economically and ecologically important species such as lobster, oysters, clams, eelgrass, and juvenile estuarine fishes. In 2009-2010 a dedicated green crab trapping study was conducted in the two NH estuaries, Great Bay and Hampton-Seabrook to document temporal and spatial crab distribution as well as to understand the timing of the molt cycles.

There are undoubtedly researchers, managers and educators who were not included in the one-page summery request or who were unable to respond in the time allocated. However, Appendix b. iii. contains a great deal of information on recent and current green crab research, monitoring, mitigation and education going on in Maine, New England and Canada. These submissions can guide and inform any future research and control efforts. The authors were happy to share the information and encouraged further coordination of efforts and information sharing.

6. Summary of Market Development and Research, Existing Markets and Uses

A subgroup of the Green Crab Task Force worked on exploring potential uses for green crabs based on the current price paid for green crab. The following is a summary of potential uses and markets for green crabs and their by-products. Any food and pet food use will most likely provide the highest return, at least in the current market conditions. The Fishmeal/Chitin and Fertilizer markets are probably the lowest return (initially) for the raw product which is being currently provided as a waste product for little or no cost.

a. Price Point

One of the key questions to address in looking at potential markets for green crabs is the price point. In the current seafood market, if a buyer can pay a harvester at a minimum of $0.30 cents per pound (preferably more) than it may be worth pursuing. If a buyer can't pay this, then it's not likely for a fisherman to leave the dock to target the species (in search of a profit). Having said that, there are other reasons for targeting green crabs as a nuisance species, with the goal of reducing the population in order to save/preserve other marine resources. Green crabs are causing harm to Maine's shellfish industry and marine environment. With or without a profit in the green crab resource itself, a sustainability plan is needed for the health of Maine's current shellfish industries and resources. A small license fee for shellfish harvesters could capitalize a dedicated eradication fund.

b. Higher Value Potential

i. Human Food

Crispy Crab (Best potential market: Asia). There are currently some experimental trials underway in Maine for a baked green crab item (for the smaller crabs). Naturally salted, considered a health food in Asia.

Drunken Crab (Best potential market: Asia). There are currently some experimental trials underway in Maine for a crab item pickled in alcohol (for larger crabs). Eaten whole if the shell is soft or the consumer removes the shell if it's too hard.

Seafood Stock and bouillon (Best potential market: Europe, possibly domestic and Asian potential). Freezing and shipping bouillon made from lobster shell waste has been exported from Maine in the past.

Crab paste/filler (Domestic/export market possibilities). The University of Maine at Orono College of Natural Sciences, Forestry, and Agriculture–Research & Development has experimented with a mechanical process to extract bits of meat from shells to produce crab mince or paste, which is typically used as a filler or flavor enhancer in the restaurant industry[1].

Meat picking, if proper equipment can be found (Domestic/export market possibilities). Green crabs can be quite small and extracting the meat for food products (without shell fragments) can be very challenging. Larger green crabs could likely be cooked and picked similar to how Jonah or rock crabs are processed. Some machinery exists that produces mincemeat that can be used as crab product filler. Mince machines are intended to provide a shell-free mince which can then be used for filling. There is at least one lobster processor in Maine that has this capacity. Maine currently has markets established for Jonah and rock crab. Costal Enterprises Inc (CEI) has assembled a list of raw crab products and value added crab products that are available for sale in Maine. These include seafood markets, processors and distributors. The list can be found in the Appendix d. listed as "Maine Crab Products and Suppliers".

When the green crab resource is at extremely high levels it may make sense to seek out machinery that sorts live crabs by size. A high speed sorting machine that would

[1] http://umaine.edu/nsfaresearch/research-spotlight/agriculture-foods/you-want-a-piece-of-me/

separate larger crabs for picking and smaller crabs for value added opportunities could be useful from a market perspective. Asian markets are particularly interested in live seafood products. Green crabs are quite hardy in their ability to be shipped. The Maine International Trade Center has recently researched seafood processors and the machinery available from Iceland, China and Taiwan. Some of these manufacturing products (machinery) could be useful as Maine explores uses and markets for green crab. This information can be found in Appendix e. listed as "China and Taiwan Fish Processing Equipment Producers" and Appendix f. "Icelandic Fish Processing Equipment Producers".

ii. **Pet Food (Domestic and foreign markets)**

Channel Fish located in Boston is one of the premier producer's and providers of frozen seafood ingredients to the pet food industry. They currently purchase and transport (out of state) a large portion of the shellfish waste generated in Maine.

Bay City Crab, a North Carolina-based seafood processor, was purchasing green crab from the Boothbay Harbor-area and selling it to an unidentified cat food company. When the price paid per pound dropped below $0.25 cents the harvesters stopped selling to Bay City Crab as it was not worth their time and effort[2]. Bay City Crab was hoping to purchase up to 40,000 lbs. of green crab a week from Maine to replace blue crab and shrimp ingredients for pet food. This market could be worth visiting again in the future if Maine has an overwhelming abundance of green crabs.

iii. **Aquaculture Feed Component (Domestic/export market possibilities)**

Beth Fulton a student at the University Of New Hampshire conducted a study looking at the whole green crab protein and its suitability for finfish feeds. She concluded that meal made from whole green crab would likely be palatable to many species of finfish. Whole green crab is a good candidate for partial fishmeal replacement for ash tolerant species like Cod or cobia[3].

iv. **Bait for Recreational and Commercial Fishing (Domestic/export market possibilities)**

Recreational Fishing Bait:

Whole live green crab is desired for use as bait for the tautog and striped bass fisheries (to name a few). The demand depends on the season and the different species of fish recreational harvesters are pursuing. It is a difficult market to break into primarily based on green crab regulations that vary from state to state and the target fishery season and species regulations that also vary from state to state. For example, a shipment of green crabs across some state boundaries requires all crabs to be frozen prior to transport. Some areas also require green crabs to be cut in half before use as recreational fishing bait to avoid introducing green crab to other environs. Recreational fishery seasons tend to be short and isolated along the coast. Some buyers do not provide much lead time for the harvester to catch and ship the product when it is needed. There are a

[2] http://www.mainebiz.biz/article/20140818/NEWS0101/140819960/cat-food-market-exists-for-maine's-invasive-green-crab

[3] http://www.seagrant.umaine.edu/files/2013MGCS/Fulton%20MGCS%202013.pdf

number of businesses online that provide guidance on using green crab as bait so there are a few seasonal opportunities to export green crab. The Commonwealth of Massachusetts, Division of Marine Fisheries, Green Crab Trapping Program indicates prices paid range from $8.00 a gallon to $16.00 a quart depending on the time of year and location of the bait shop. The average price paid is approximately $12.00 a gallon.

The unpredictable availability of green crabs themselves makes it difficult to establish a steady supply for the recreational bait markets. For example, the numbers of green crabs were unprecedented in 2013 with daily, single trap catches in the thousands of animals. Preliminary catch reports from 2014 in the same areas are 1/10th of last year's levels. Other states such as New Hampshire already supply crabs to east coast markets on a steady basis making the market harder to break into simply because the availability and shipping costs are hard to compete with. As green crab populations are volatile depending on winter water temperatures, continued efforts will be made to encourage the establishment of Maine based shipping markets.

Commercial Fishing Bait:
Several people have explored using green crabs for commercial lobster bait. In Canada, this market has apparently experienced limited success. Some lobstermen are paying as much as $100 for a crate of large green crabs (McCarthy pers. com.). They spear the crabs and string them on as fresh bait. The use of green crabs for lobster bait in the US has not been widely reported. However, Maine lobstermen who encounter catching green crabs as bycatch do occasionally report crushing the crabs and using them to augment their preferred bait (usually herring, redfish, menhaden etc). In southern New England, green crabs are being actively trapped and sold for channeled whelk (conch) bait. The whelk fishermen have reported paying between $20 and $40 a bushel[4]. In 2013, Massachusetts dealers reported purchases of 186,648 pounds of green crabs worth an estimated $66,648. These crabs were sold for both commercial and recreational bait.

c. Lower Value Potential

i. Fishmeal for Agriculture Feed (Domestic and foreign markets)

This market has a very low return price for the crab. There is a potential for poultry and swine livestock.

ii. Chitin Processing

Wide range of end-use applications available here with a quickly growing global market. Asia dominates this market and the Chinese pricing is very inexpensively priced making it difficult for Canada/others to be competitive. Chitin has good horticultural properties and a derivative Chitosan has antibacterial qualities or use for organic coatings. In a highly purified form it has good pharmaceutical uses. Setting up a chitin processing facility would be a huge investment. There have been a few chitin processing facilities in North America (Newfoundland and Quebec) that went out of business. If Maine were to consider building a facility, it would be critical to research (in depth) why others have

[4] Commonwealth of Massachusetts, Division of Marine Fisheries, Green Crab Trapping Program, page.11

failed. Chitin and chitosan are directly dependent on the availability of large quantities of shellfish waste product. Shipping Maine lobster to Canada for processing is also reinforcing Canada's ability to operate and maintain chitin processing facilities. A recent announcement was made by the Canadian Government highlighting investment in processing shellfish waste: http://www.releases.gov.nl.ca/releases/2014/fishaq/0924n02.aspx#.VCL3xLB8xKA.email. Maine would be challenged to go directly to high-end markets for chitin and chitosan but lower level products could provide entry into the global market. Generally the raw material is a waste product which the chitin producers receive without providing compensation. The Maine International Trade Center has recently researched global chitin producers and an analysis of the global chitin market. This information can be found in the Appendix g. listed as "Chitin Producers and Market Report".

iii. Fertilizer (crustacean or crab meal)

Most shellfish waste is currently provided for free or the supplier might even pay a pick up charge to the collector.

Green Crabs could be the catalyst for all shellfish waste in Maine. Because green crab populations appear to fluctuate greatly from one year to the next it is important that green crab be considered a resource to supplement the waste stream. Green grabs or green crab waste could be combined with lobster, crab, and shrimp waste to produce a premium fertilizer ingredient. We are aware of one Maine business that is currently importing fishmeal from Mississippi at a price of $1,200 a ton. The same business recently reported receiving a pallet of Canadian crab meal bags in Maine with Chinese writing on the bags. This highlights the fact that Canada is shipping a significant amount of crab waste from Canada to China and is routinely using bags and labeling for the Chinese market. Most crab, lobster or shrimp waste currently ends up being composted. This is one of the lowest uses with basically no value added except the freight costs to move it to a location to be composted. Crab and lobster meal is an internationally traded commodity. If a Maine waste processor could produce crustacean or crab meal, they could likely sell all that they produced. One of the long standing barriers to setting up a crab or lobster meal processing plant are the logistics of moving the waste from potentially many locations with relatively small "piles"- and to do it often and quickly enough to move it before it rots. One solution to this would be to chill, cook, or "pickle" (salt) the waste as it is produced to prolong its useful life.

Maine is in need of a facility to dry shellfish waste. Shellfish waste has very high water content and it is not cost effective to transport wet shellfish waste for any significant distance. If Maine could effectively dry shellfish waste, we could likely then source some of Maine's shellfish waste for other uses. Other seafood products could potentially utilize a drying facility including the growing wild and cultured sea vegetable industry. The Maine International Trade Center has recently researched major crab producing countries, crab meal producers, major fertilizer markets and fish feed. This information can be found in the Appendix h. listed as "Crab Market Info - Worldwide".

iv. Composting and Agronomic Utilization of Shellfish Waste in Maine

In Maine, composting and applying “residual” waste to land is governed by DEP’s solid waste rules starting at Chapter 400. Green crabs may be composted or land-spread with or without a license depending on the quantities stored and to be applied (*see below*). If the trigger thresholds are met, a license will be necessary, and parameters will need to be met for siting, monitoring, planning, and recordkeeping in order to ensure compliance with license requirements.

Chapter 400 (1)(Ss) defines "Residual" as: solid wastes generated from municipal, commercial or industrial facilities that may be suitable for agronomic utilization. These materials may include: food, fiber, vegetable and fish processing wastes; dredge materials; sludges; dewatered septage; and ash from wood or sludge fired boilers.

Chapter 400 (1)(Yyy) defines a Type IC residual as: a residual from a known source that does not contain hazardous substances above risk based standards in Appendix 418.A and that has a carbon to nitrogen ration of 15:1 or less, such as fish wastes.

Green crab wastes would qualify as a Type IC residual.
Under Chapter 410, pertaining to composting facilities, Type IC residuals will require a license unless the facility can demonstrate:

- Less than 5 cubic yards of Type IC residuals are received for composting in any 30 consecutive day period [Chapter 410(1)(A)(1)(c)];
- A total of between 5 and 60 cubic yards of Type IB and IC residuals are composted by Agricultural Composting Operations in any 30 consecutive day period, and operations are in accord with a Compost Management Plan approved by the Maine Department of Agriculture Food and Rural Resources [Chapter 410(1)(A)(4)]; or
- At least 70% of the finished compost product is used at appropriate agronomic rates on the farm that produced the compost within 2 years after it is produced by Agricultural Composting Operations that compost any volume of Type IA, IB, or IC residuals, and operations are in accord with a Compost Management Plan approved by the Maine Department of Agriculture Food and Rural Resources [Chapter 410(1)(A)(5)].

Under Chapter 419, pertaining to the agronomic utilization of residuals (e.g., land application), Type IC residuals will require a license unless the facility can demonstrate that a specific volume limit is met:

- 50 yds^3/yr or less of Type IC residual such as fish by-products, provided the IC residual is applied at a generally accepted agronomic rate between April 15 and July 1 and the waste is incorporated within 24 hours. The volume limit applies to the amount one generator may distribute for utilization in a calendar year, or that may be received for utilization at any one site in a calendar year [Chapter 419 (1)(B)(5)(c)]

d. Beneficial Use and Processing of Green Crabs in Maine

For green crab wastes that are not composted or used in agronomic utilization (*see above*), other solid waste rules may apply including: Chapter 409 Processing Facilities and Chapter 418 Beneficial Use.

Under Chapter 409 (1)(A), A processing facility is any land area, structure, equipment, machine, device, system, or combination thereof, other than licensed incinerators, that is operated to reduce the volume or change the chemical or physical characteristics of solid waste. More specifically, the following activities constitute processing:

- Aerobic digestion, anaerobic digestion, air drying, heat drying, heat treatment, lime stabilization, pelletization, chemical treatment, irradiation, pasteurization, or otherwise reducing pathogens or stabilizing residuals, including dewatering septage, to render the residual suitable for agronomic utilization in accordance with the standards of Chapter 419
- Processing solid waste to render the waste suitable for beneficial use in accordance with the standards of Chapter 418

This means that green crabs that are collected and intentionally changed in any way prior to distribution are being processed (e.g., stored for a length of time to allow the meat or shells to decompose; ground up; crushed, into another form; heated or dried etc.), and thus a processing facility license may be required.

In some cases, green crab wastes may be used for purposes other than in composting, agronomic utilization, or in processing. In these instances, a beneficial use license for such use might be required. As an example, green crab wastes that are used as one of the materials in the manufacture of concrete may require a beneficial use license. Beneficial uses of secondary materials are regulated by Chapter 418 of the solid waste rules. [5]

7. Taskforce Recommendations

The initial meeting of the Green Carb Task Force concluded with a brainstorming session on short-term and long-term recommendations. This was a specific objective set for the Task Force as outlined in the Executive Order. The following list includes the short-term and long-term recommendations that were generated by the Task Force members and reviewed and perfected over subsequent meetings. Several of the recommendations already have activity associated with them either through the Task Force's direct efforts or those of outside entities.

[5] Secondary material is defined as a solid waste, separated from other solid wastes that may be suitable for beneficial use. [Chapter 418 (1)(A)] Solid wastes are defined as useless, unwanted or discarded solid material with insufficient liquid content to be free flowing, including but not limited to rubbish, garbage, refuse-derived fuel, scrap materials, junk, refuse, inert fill material, and landscape refuse, but does not include hazardous waste, biomedical waste, septic tank sludge, or agricultural wastes. The fact that a solid waste, or constituent of the waste, may have value, be beneficially used, have other use, or be sold or exchanged, does not exclude it from this definition [Chapter 400 (1)(Hhh)] Beneficial use means to use or reuse a solid waste or waste derived product: as a raw material substitute in manufacturing, as construction material or construction fill, as fuel, or in agronomic utilization. [Chapter 400 (1)(T)]

The Task Force did not recommend state sponsored funding of green crab mitigation and/or research, but did discuss this concept. Many Task Force members felt that the funding of solutions to the green crab problem should be found within the private sector if they are to be long-term. However, some public participants at the Task Force meetings did advocate for a state funded program. There is no doubt, government funding of mitigation and research could be effective if were selected as a course of action. A state fund could be developed through license fee supplements and allocated through a competitive process to municipalities or researchers. The concept of a bounty was also discussed and discarded based on historic experience of funding running out long before meaningful depletion of green crabs is achieved. However, it was mentioned that a supplemental bounty price per pound could be considered to encourage the development and ultimate success of low value markets (e.g. a $0.10/lb bonus to whatever commercial value can be obtained by harvesters, currently around $0.25/lb). Funds could also be raised at the local level through an increase of town license fees specifically for green crab mitigation or in lieu of mandatory conservation time as a license requirement. Finally, it was acknowledged that government funds (subsidy) could be used as seed money to initiate private industry such as purchasing a drier or meat picking machine.

It is important to note that there was legislation in 1977 that approved a fencing program to exclude green crabs from soft shell clam growing areas. When the Commissioner determined that a soft shell clam growing area was adversely affected by green crab predation, he could provide funds, materials or expertise for the construction and installation of fencing to municipalities.[1977, c. 661, §5 (new).]. There was no specific source of funding (budget) associated with this statute. The law was repealed in 2011, through a prioritization and legislative mandate review process conducted by DMR.

a. Short-Term Recommendations (one year)

- **Hold priority setting meetings along the coast to identify and direct funding and research**

  A group of researchers is convening a meeting on October 8th through the Casco Bay Estuary Partnership and the chair of the green crab task force has been asked to attend and present the report findings. DMR co-hosted a green crab summit in December 2013 with Maine SeaGrant, USGS and CZM. More than 500 people participated in this event either in person or via the web. The presentations are available on the summit webpage: http://seagrant.umaine.edu/green-crab-summit. DMR will continue to facilitate meetings to further coordination of green crab research and assist other groups that wish to do the same.

- **Identify and develop a network of researchers, industry and businesses doing green crab work and developing fisheries solutions**

  This was partially developed by the forming of the Green Crab Task Force. A spin off of the task force will be a culinary challenge group led by Jen Levin of the Gulf of Maine Research Institute and Hugh Cowperthwaite and Janine Bisaillon-Cary both members of the task force. Further networks are being developed through a Maine Technology Institute Planning/Feasibility/Pilot cluster project looking at "Under-Utilized Shellfish Products with Emphasis on Green Crab" led by John der Kinderen. This Green Crab Task Force report will also serve as a point of linkage between many groups pursuing green crab research/development.

- **Continued support of current municipal efforts to depress or exclude green crabs**

  Many municipalities have undertaken trapping, fencing and netting efforts to mitigate the impact of green crabs. It is critical to support these efforts with permitting assistance, letters of support for grant proposals and staff and expertise. DMR will continue to coordinate and host targeted workshops, lend trapping gear and assist with coordination of study efforts. Other groups are also supporting coordinate efforts such as the Casco Bay Estuary Partners. DMR will be holding a summit in January to talk about results of LD1452 predator control pilot projects. The four towns that were issued permits and that will be asked to present information are Brunswick, Freeport, Harpswell and West Bath.
- **Commercial review of processing and markets**

  This was done as a major section of the green crab task force report by experts from industry, non-profit organizations and state government.
- **Recommendations for market, processing and distribution**

  This was done as a major section of the green crab task force report by experts from industry, non-profit organizations and state government.
- **Integrate other resource users into the process (e.g wormers, aquaculturists, land trusts, homeowners experiencing erosion etc.)**

  The task force sent out a survey to a wide group of marine industry members potentially impacted by green crabs. Members of the DMR Advisory Council, Shellfish Advisory Council, Urchin Council, Scallop Council, Lobster Council, Municipal Shellfish Committees, Lobster Zone Councils and lobster harvesters. While the response was low the task force members believe it reignited the conversation with many resource users and will continue to collect and process results. DMR will facilitate continued conversations about green crabs and their effects with industry interest groups, communities and advisory boards. DMR will also work with the Coastal Zone Management program and DEP to provide materials to property owners about marsh bank erosion caused by green crabs.
- **Establish a website "clearing house" for all things related to green crabs**

  The task force members agreed that the DMR website should host a clearing house for all information related to green crabs. It will include permitting, rules, regulations, biological information, current and ongoing research, gear suppliers, buyers, composting facilities, how-tos and any other relevant information. This website will be kicked off with the release of the green crab task force report.

- **Streamline the permitting for trapping, fencing and netting activities (DMR, DEP, ACOE, NMFS)**

  DMR will work with the Department of Environmental Protection, Army Corps of Engineers (ACOE) and the National Marine Fisheries Service to continue streamlining the permitting process especially for municipal shellfish programs that want to control green crab populations. The ACOE presented the permitting process for installing fencing at the municipal green crab workshop hosted by DMR in March 2014. DMR has also issued several letters of support to researchers/communities applying for ACOE permits and committed response personnel in the event threatened or endangered species were caught. DMR will work to clarify the permitting required for predator netting through the ACOE Northeast General Permit.

- **Define municipal leasing process**

  DMR has recently hired a new aquaculture hearings officer who can assist with the development and approval of municipal lease applications. Municipal leasing is permitted by statute and the process can be clearly defined and provided to the communities with shellfish programs. A guide to municipal leasing will be posted on the DMR website.

- **A gear depot for municipalities interested in conducting predator control projects**

  Many municipal shellfish programs have insufficient funding to purchase green crab traps. DMR (or another entity like a local land trust) could purchase green crab traps and loan them, free of charge, to towns who are interested in conducting green crab trapping programs. By signed agreement, the gear would be returned at the end of the season and any damaged or lost gear would be replaced by the municipality. The Department could also convert and sell confiscated lobster gear to support municipal green crab trapping efforts. The estimated cost of conversion is $3.50 per trap.

b. Long-Term Recommendations (greater than one year)

- **Research that evaluates relative impact of green crabs on bivalve shellfish resources and other species compared to other threats (acidification, habitat loss, overfishing etc.)**

  Dr. Brian Beal has established an extensive research project in Freeport to test the relative impact of green crabs on bivalve shellfish compared to acidification. Research on the impacts of habitat loss and overfishing in relation to the impact of green crab predation should be investigated by researchers.

- **Research to characterize green crab movement patterns and spatial distribution to determine best time for trapping/remediation**

  Some research on this topic has been done in Maine (Freeport and Brunswick) and in Atlantic Canada; however it is still a high research priority. With limited resources, municipal shellfish programs intending to mitigate the impact of green crab predation should focus on the most effective time to trap and remove green crabs. Preliminary data indicate that trapping in the fall can be most effective in reducing the berried female population (Beal, pers. com.).

- **Research to optimize trapping, fencing, netting etc**

  Habitat considerations are important when identifying effective control methods. Researchers should examine methods to reduce the abundance of green crabs in salt marshes; exclusion fencing may be less effective in salt marshes as green crabs can climb *S. alterniflora* stems. If management of green crab populations in rocky habitats is desired for economic or ecological reasons, researchers should find control strategies that work in hard substrate environments. Several projects have shown that the effectiveness of fencing is related to the construction, durability, span and maintenance. ACOE permitting requires escape gaps in some fences (to prevent fish entrapment) and the impact of these on green crab movement should be evaluated. Trap configuration, soak times, bait type etc should be explored with the objective of maximizing green crab catches for a commercial fishery or mitigation project. Predator nets are proven effective in protecting seed clams, but the effective coverage area, maintenance schedule and ability to trap wild spat should be investigated.

- **Green crab monitoring (similar to historic DMR efforts in the 1950s)**

  Future commercial fisheries or market development and the ability to proactively respond to a green crab population surge will depend on consistent monitoring of abundance and impact of predation on other valuable resources and habitat. Researchers should determine if rocky habitats are a source for larvae/migrants for colonization into soft sediment habitats (seagrass, marshes, mud flats). Larval abundance and recruitment would aid with proactive responses to large green crab year classes.

- **Spatial component, variable differences in impacts of green crabs regionally (east/west, inshore/offshore, mainland/islands etc.)**

  Research should be conducted on the variability of green crab occurrence and abundance. Are there refuge areas such as deep channels and island habitat? What are the larval delivery patterns and what areas are at the highest risk of future green crab population explosions?

- **Bivalve shellfish resource monitoring**

  In order to gauge the impact of green crab predation, it is critical to monitor the larval delivery, post settlement survival and resource abundance. Recent studies have shown a large supply of wild seed clams in several regions, but a complete lack of surviving year classes in some areas (Heinig, 2013). Effective management of exploited resources requires monitoring so catches can be controlled if necessary, recruitment enhanced, survival increased, spawning stock preserved and harvest targeted to market product.

- **Monitoring of habitat/environmental parameters to identify drivers, or status of environmental degradation and capacity for recovery of bivalve shellfish, eelgrass beds and marsh banks**

  Researchers and managers should increase the frequency of mapping eelgrass to determine changes more regularly and map the coast comprehensively. Develop an increased understanding of the relationship between eelgrass decline, specific water quality parameters, and green crabs and the resiliency of eelgrass beds relative to abundance of green crabs and sediment type. Continue to examine the extent to which green crabs are responsible for marsh creek bank destabilization/collapse by expanding experimental enclosures and geographic scope. Determine the threshold densities over which high abundance of green crabs can destabilize creek banks.
- **Identifying adaptation strategies in the event of green crab abundance and habitat decline**

  Researchers and managers should increase modeling and predictive capacity, as well as, evaluate the shift in viability of commercially harvested species, impacts of poorer attenuation of nutrients (e.g. loss of eelgrass), increases in ocean acidification and water quality parameter changes. Scenarios regarding a complete shift in existing coastal ecosystems should be considered. Determine the characteristics of salt marshes that render them more or less susceptible to high densities of green crabs (e.g. sandy vs. peaty marshes, marsh age, restoration status, marsh fucoid algae abundance; Tyrrell et al. 2012).
- **Assess haplotypes of salt marsh dwelling green crabs versus eelgrass meadows vs rocky substrates**

  Is eelgrass destruction and salt marsh destruction due to the aggressive northern haplotype? Has survival of green crabs increased due to the intermixing of the northern haplotype and thus resulted in increased habitat destruction and predation?
- **Economic research into multi product processing opportunities**

  This was done as a major section of the green crab task force report by experts from industry, non-profit organizations and state government. This work could be expanded on and updated as necessary.
- **Development and housing of education materials for school groups**

  Many Maine schools have incorporated green crabs into their curriculum. A Yarmouth Middle School class entered a national video competition, a North Haven grade school class presented a poster at the Green Crab Summit and a special program in Stonington (Eastern Maine Skippers Program) is using green crabs as the focus for the 2014/15 school year. Coordinating all the information, study plans and materials from these efforts would help other schools and teachers incorporate this important issue into their teaching. This would also help keep awareness of the green crab problem in the minds of Maine youth from coastal communities and help with proactive responses to future green crab population explosions.

- **Re-implementation the regional "clam conferences" (1950s-1980s) to track bivalve shellfish issues (biology, management, predators etc.)**

  The Clam Conferences provided a venue for regional researchers and managers to get together and discuss relevant issues related to shellfish biology, propagation, resource management, disease and predation. These conferences were held from the early 1950s to the early 1980s and provide documentation on the "revelation" of the green crab predation problem in the 1950s. Reinstating these conferences would be a way to ensure the critical and historic knowledge of shellfish biology, propagation, resource management, disease and predation are passed on from one generation of professionals (research, management and industry members) to the next.

8. The Direct Economic Impacts of European Green Crab Predation on the Bivalve Shellfish Resources of Maine.

The impacts of green crab predation are well documented especially for bivalve shellfish species (see Competition and Predation section 4.b.). There have been no studies that the Task Force members were aware of directly evaluating green crab predation impacts to bivalve shellfish resources in Maine. There have however, been several studies on the economic impacts of shellfish closures such as those for red tide events. While these economic costs are temporary in nature in that they are a regulatory restriction of access to existing resources, they can illustrate the short-term economic impacts and be expanded to long-term impacts that would be more representative of green crab predation effects.

Most of the economic analyses of red tide closures are focused on the soft-shelled clam and blue mussel fisheries; however, green crabs also have an influence on survival of shellfish aquaculture seed. "We've done some lab experiments which demonstrate that green crabs are able to eat 30 small oysters per day" (University of Prince Edward Island researcher Luke Poirier as reported by CBC). Some shellfish aquaculturists in Maine have indicated that seed survival of bottom cultured oyster seed is only about 30% and green crabs are a significant contributor to the losses. Many aquaculturists actively trap green crabs on their lease sites.

Maine DMR received red tide federal disaster relief funds in 2009. Some of the funds were directed toward a socioeconomic study of the effects of red tide closures on the Maine shellfish industry. Porter Hoagland of Woods Hole Oceanographic Institute was selected as the contractor to conduct the study. He provided a report to DMR in 2012 titled: "A Framework for Estimating the Economic Impacts of Red Tide Closures on Yields of Molluscan (Bivalve) Shellfish in Coastal Maine" (Hoagland, 2012). While this work was related to red tide closures it can be informative on potential economic impacts of green crab predation. However, while red tide closures are limited in time, predation effects are permanent as the organisms are consumed and thus removed from the ecosystem.

As summarized in Hoagland (2012), widespread red tide closures during the months of April through August in 2005 led to estimates of $2-4 million in lost sales of soft-shell clams and blue mussels (Athearn 2008; Jin *et al*. 2008). Athearn (2008) also estimated the direct, indirect, and induced economic impacts of the 2005 red tide on both harvesters and downstream wholesaler dealers, resulting in a total impact estimate of about $7 million.   Using the county/"all shellfish combined" model, Hoagland (2012) estimated that lost sales during the same year were on the order of $0.4 million. Jin *et al*. (2008) found, however, that lost sales revenues in 2005, and therefore adverse economic impacts, were mitigated to a significant extent by increased prices in the relevant shellfish markets in the spring and early summer (April to June), resulting from supply reductions. This finding emphasizes that while economic impacts in specific areas are significant, if resource loss is inconsistent throughout the coast, areas where resource is still available can benefit from increased prices. Similarly to red tide events, severe green crab predation does not seem to occur evenly throughout the state and where desirable product remains available, harvesters have received high prices in 2014. The DMR Landings Program reports that the price for soft-shelled clams averaged $1.58/lb. in 2013, but preliminary data indicates that the average price was almost $2.00/lb. in 2014. Many dealer records show values occasionally approaching $3.00/lb in 2014.

While the overall value of the fishery may not decline precipitously with reduced catches due to the increased price, the municipal management structure in Maine means many harvesters are trapped in one or more towns and cannot necessarily move to areas with available resource. Therefore the economic impact disproportionally affects local residents both positively and negatively. Hoagland (2012) found through interviews of harvesters that diggers will relocate to underutilized areas when displaced from closed areas. Examples exist of relocation into shellfish areas that do not necessarily require licenses from non-residents. The net effect of these behaviors arguably could lead to increases in production and sales value when closures [or presumably predation effects] are implemented at small scales.

A case study of the recent impact of green crab predation on the soft-shelled clam resource is the Town of Yarmouth. In 2013, Yarmouth hired MER Assessment Corporation to conduct a comprehensive survey of the soft-shelled clam resource. The findings for the Cousins River were summarized by Heinig (2013):

> *Clam size distribution is heavily weighted by the larger size categories with many of the clams being "off scale" (>90mm or >3.5 inches); these large clams are buried deep in the sediment at up to 18 inches. In contrast, there are very few small or intermediate size clams found in any of the samples indicating that at least two year classes are missing from the population and an aging resident population.*

The presence of mostly very large clams buried deep in the sediment and the absence of two year classes strongly indicates a predation impact by green crabs.

> *The exact reason for the observed decline in soft-shell clam populations is not clear, but the recent explosion of the green crab, Carcinus maenas, appears a likely cause. The near absence of what appears to be two year classes across all flats covered by the 2013 survey is a matter of serious concern since all indications are, if the present population were to be fully harvested, no subsequent generations are present to replace the harvested crop, thus leading to a potential collapse of the soft-shell clam industry in the area for the foreseeable future, that is, until the populations recover. One glimmer of hope may be the number of small seed collected from the spat subsamples taken at each plot during sampling indicating that settlement is occurring.*

One of the primary reasons Yarmouth hired MER Assessment Corporation to do a resource survey was the reclassification of the Cousins River in 2013. This opened access to potentially 3,200+ bushels of soft-shelled clams worth over $300,000 (Heinig, 2013). The absence of two year classes in the Cousins River therefore represents a loss of more than $600,000 in revenues. Without successful recruitment of additional year classes the annual loss of more than $300,000 in just the Cousins River would presumably continue.

9. Costs Associated With Control Strategies

The most commonly utilized green crab control methods are fencing, trapping and netting. Costs for implementation of all of these strategies include materials, installation and tending/maintenance. Trapping also incurs the cost of bait and netting might involve the purchase of nursery seed. Anecdotal information and the conclusions of a few research reports indicate that consistent maintenance is critical to the success of predator control strategies.

Fencing: the cost of green crab fencing depends largely on design. Basic materials include netting, lumber and fasteners. Costs can vary significantly with selection of materials; however recent fencing efforts in Freeport have produced fencing for an average cost of $375 for a 30’x30’ plot. The price break down is as follows: a 30-ft x 30-ft fence was constructed of twelve, 10-ft sections that needed to be pounded into the mud then "tied together." The wood for a single fence cost $250 and the netting per fence was $103. The hardware for the fence (aluminum flashing @ $15/fence; screws, nails, etc.) was approximately $22. This fencing design emphasizes durable construction so the fencing maintains its integrity throughout the season especially during big tides when the fences are exposed to the highest tidal currents. Labor requirements include a significant investment in constructing the fencing panels, installing them in the field, maintaining the fence during its deployment and recovering the fence. It is difficult to estimate the total costs for building, installing, maintaining and recovering fencing. Labor is likely the most costly factor in a successful fencing effort and can be done with hired workers or with volunteer efforts. The Freeport project estimated an average of 5-6 hours for 2-3 laborers per fence for installation alone.

Trapping: the cost of purchasing traps for green crabs can vary from dedicated trap designs to modified lobster traps. A trap designed specifically for catching green crabs can cost between $50 and $80. Green crabs can also be trapped using conventional lobster traps which can be purchased for as little as $7-$10 used and outfitted with a modification that costs $2 and takes about 10 minutes to install per trap. Shrimp, eel and top entry crab traps can also be used. Trap tending can be done at low water in intertidal areas on foot or by boat at high tide or in subtidal areas. Running boats is an obvious added expense. Tending traps can vary from sets of only hours to days or even weeks. However, recent trapping efforts report that when crab densities are high traps should be hauled at least daily. Bait is often the limited factor and can be depleted rapidly therefore reducing trap efficiency. Overcrowding can also limit trapping success. Bait is also a significant expense with trapping. DMR green crab regulations require the use of approved bait meaning that things like road kill, slaughter waste and other potential free sources of bait are not permitted. Currently herring, the most common bait used for lobster fishing on the Maine coast sells for about $120/barrel. A barrel is roughly 400 pounds and can bait between 80-100 traps.

Netting: Using lightweight polypropylene product that is UV stabilized with an aperture of 1/6-inch x 1/6-inch to make 14-ft x 22-ft panels costs approximately $42.00. This figure includes 5, 4-inch Styrofoam floats installed under the netting. Clams are generally seeded on the flats within a 12-ft x 20-ft area. Seed can cost between $4 and $20 per 1,000 animals depending on the size (DEI website: http://www.downeastinstitute.org/ordering-soft-shell-clam-juveniles.htm). Then, the net is laid over the clams with the toggles down and the sediments either are soft enough to walk in the periphery into the mud, or, if it is sandy, then a furrow must be dug with a clam hoe all the way around the periphery, stick the edge of the net into the furrow, and then fill the furrow back with the sandy sediments. Installation of the net takes about 15-30 minutes for a team of 2-3 people. The softer the sediment the quicker installation can be allowing the nets to be “stepped in” versus dug in. Netting requires regular maintenance to ensure it doesn’t become fouled. Nets are generally removed in the fall to prevent damage by ice over the winter.

Green crab mitigation can be expensive in not only materials but also in labor. For any of the three methods to be effective, they have to be built, maintained and tended regularly. Several recent green crab projects showed that without regular maintenance fencing, trapping and netting are not effective. Mitigation efforts in the past two years have ranged from tens to hundreds of thousands of dollars largely depending on the scale of the project and volunteer versus paid labor.

10. Resources Section

a. Composting Facilities and Potential Buyers/Receivers

DEP Waste Management page: http://www.maine.gov/dep/waste/residuals

Maine DEP Compost Facilities List: http://maine.gov/dep/maps-data/documents/compostfacil.pdf

Maine DEP contact for Composting Information:
Michael Clark
Bureau of Remediation and Waste Management
Solid Waste Division
1-207-822-6341
michael.s.clark@maine.gov

Accepting Green Crabs (as of 03/28/14)
City of Portland at Riverside Recycling, Maine Waste Solutions Contact: Brett Richardson, 272-0896

Benson Compost, Gorham. Contact: Ed Benson, 892-6446 or 318-8567

Dubois Compost, Arundel. Contact: Marcel, Rick or Randy Dubois, 282-4445

Ecomovement d/b/a Mr. Fox Composting, Eliot. Contact: Rian Bedard, 603-828-4435

Knox Ridge Farm, Thorndike. Contact: Wes Kinney, 568-3683

Coast of Maine, Machias. Contact: Carlos Quihano, 879-1197

Phil Harrington Bait, Woolwich, ME. Contact Margaret Harrington, 443-3834
Phil@Phil-Harrington-Bait.comcastbiz.net

Squire Tarbox Farm, Westport Island, ME. 522-0840, Kyle
squiretarboxfarm@yahoo.com

Channel Fish Company, East Boston, MA. Contact: Adam Holbrook, 1-617-569-3200
info@channelfishco.com

Bay City Crab Company, Aurora, N.C. Contact: Christina Fulcher, 1-252-322-5291
christinafulcher98@gmail.com

b. New Chapter 25 Green Crab Regulations

DEPARTMENT OF MARINE RESOURCES
Chapter 25 – Lobster and Crab

25.02 Definitions

~~1.~~ A. "Rigged to Fish for Lobster" means to have on board a lobster fishing vessel a machine capable of hauling lobster traps. This device could be a pot hauler or other mechanical device capable of hauling lobster traps to the surface.

~~2.~~ B. "Alternative bait" means any bait that does not naturally originate from the ocean in accordance with 12 M.R.S.A. §6175. See Chapter 25.12 for regulations.

C. "Approved crab trap" means any top-entry trap with an opening on the top of the trap that has a minimum diameter of 3.66 inches.

25.40 Green Crabs

A. Definitions

(1) Green Crab. The green crab is defined as the species *Carcinus maenas*, also known as the common shore crab.

(2) Green Crab Trap. "Green crab trap" means a trap, pot or other stationary contrivance or device that may be set on the ocean bottom and used for taking green crabs in compliance with the regulations in Chapter 25.40(B)(1)(b).

B. Trap Design and Marking Requirements

(1) It shall be unlawful to fish for or take green crabs with a trap other than:

(a) A trap constructed with any opening greater than 1 ½ inch wide; any length is allowed; or
(b) An approved crab as defined in Chapter 25 02(C).

(2) Escape Panel. All green crab traps must be equipped with a biodegradable escape panel located in the bottom third of the trap that has a minimum size of 3 ¾ inches by 3 ¾ inches~~, which is designed to release green crabs from traps that are lost while fishing~~.

(3) Marking. It shall be unlawful to set, raise, lift or transfer any green crab trap unless it is clearly marked with a buoy that has the owner's green crab fishing license number written on it. ~~Trap buoys must be at least 12 inches long and n~~No floating or neutral line shall be allowed. ~~When fishing green crab traps a 12 inch~~ A green crab only license holder must display a buoy with the green crab license number, and the buoy must be mounted in a manner so that it is clearly visible on both sides of the boat.

C. Limitations

(1) Fishing Method. Green crabs may be taken as a by-catch by DMR licensed commercial lobster fishermen or by traps that meet the design and marking requirements in Chapter 25.40(B), by hand, ~~hand implement,~~ hook and line, or as by-catch in another licensed fishery~~, or any other method approved by DMR~~.

(2) Trawl Trap Limit. It shall be unlawful to have on a trawl more than 3 green crab traps on one warp and buoy.

(3) Fishing Area. Fishing for green crabs shall be limited to the territorial waters of the State of Maine defined as all waters of the State within the rise and fall of the tide seaward to the 3-nautical-mile line as shown on the most recently published Federal Government nautical chart, but does not include areas above any fishway or dam when that fishway or dam is the dividing line between tidewater and fresh water.

(4) Lobster By-catch Prohibited. The holder of a commercial green crab only license may not be in possession of any lobster or lobster parts in accordance with 12 M.R.S.~~A.~~ §6808(8) or other marine organism in accordance with laws and regulations pertaining to the taking or possession of that species. Otherwise, any marine organism caught by a green crab trap other than green crabs shall be immediately liberated at the location of capture.

(5) Exemptions.

(a) Personal Use. A license is not required to fish for, take, possess or transport green crabs for personal use pursuant to 12 M.R.S.~~A.~~ §6808(4) ~~regardless of method of take other than by trap~~.
~~(b) Lobster/crab license holder. A lobster/crab license holder may take green crabs from lobster traps to remove, for personal use such as for bait, fertilizer or to discard and is exempt from the design and marking requirements in Chapter 25.40(B). To sell green crabs a lobster/crab license holder must obtain a green crab only license pursuant to 12 M.R.S.A. §6808(2).~~

(6) Enforcement. Marine Patrol Officers may inspect, at any time, any trap or related equipment to ensure compliance with this regulation.

(7) Night prohibition. It shall be unlawful to fish for or take green crabs during the period ½ hour after sunset, as defined in 12 M.R.S. §6001(46), until ½ hour before sunrise, as defined in 12 M.R.S. §6001(45).

(8) Bait. Bait used in green crab traps shall comply with all applicable regulations pursuant to 12 M.R.S. §6175 and §6432-A and Chapter 25.11.

D. License and Reporting

(1) License Required. It is unlawful to take green crabs without a license pursuant to 12 M.R.S.A. §6808, or as a by-catch in another licensed fishery. ~~effective July 1, 2001~~. ~~A license may be obtained upon request from the Department of Marine Resources, State House Station 21, Augusta, Maine 04333-0021.~~

~~(2) Reporting: See Chapter 8.20(A) Landings Program~~

~~(a) Reporting Exemption. Individuals who fish for, take, possess or transfer green crabs for personal use pursuant to 12 M.R.S.A. §6808(4) are exempt from the reporting requirement under Chapter 8.20(A).~~

~~(3) Municipal Exemption. Municipalities are exempt from obtaining a license to harvest green crabs pursuant to 12 M.R.S.A. §6808(4). Municipalities harvesting green crabs pursuant to this exemption are not permitted to sell green crabs harvested, and shall comply with the reporting requirements above in Chapter 8.20(A).~~

25.50 Closed Season Regulation on Fishing for Crabs in Sheepscot River

It shall be unlawful to fish for or take crabs, except green crabs, from December l to April 30, both days inclusive, from the waters inside and upstream of the following lines:

A. From the extreme tip of Phipps Point, Woolwich, to the southern tip of Hubbard's Point in Westport;

B. From the tip of Kehail Point, Westport, to the most southerly end of Barter's Island in the town of Boothbay;

C. Along the length of the Barter's Island Bridge and Knickerbocker Bridge, in the town of Boothbay.

25.55 Closed Season on Fishing for Crabs in Damariscotta River

It shall be unlawful to fish for or take crabs, except green crabs, from December l to April 30, both days inclusive, in the Damariscotta River above a straight line drawn across the River from a point on the shore of Back Narrows on the west side of the River in the Town of Boothbay intersecting the southwestern point of Fort Island and the red nun navigational Buoy #10 to a point on the opposite shore in the Town of South Bristol.

25.60 Closed Season on Fishing for Crabs in Medomak River

It is unlawful to fish for or take crabs, except green crabs, from December 1 to April 30, both days inclusive, in the Medomak River, from the waters inside and upstream of a line drawn from the southernmost tip of Jones Neck in Waldoboro northwest to the southernmost tip of Hardy Island then true west to Keene Neck in Bremen, including all waters of Broad Cove, Eastern Branch and Western Branch.

Chapter 8 -- Landings Program

8.02 Compliance

Dealers and harvesters must comply with reporting requirements in this Chapter. Data collected pursuant to this Chapter is subject to the confidentiality provisions of 12 M.R.S §6173 and DMR regulations Chapter 5. ~~Failure to comply with these reporting requirements may result in the denial for renewal of a license or permit in accordance with 12 M.R.S §6173(2) or license suspension in accordance with 12 M.R.S §6412~~. Any misrepresentation of information in connection with the reporting requirements of this chapter shall be a violation of this rule. All data and reports shall be submitted to the Department of Marine Resource's Landing Program unless specifically noted otherwise. See contact information in Chapter 8.01(7) above unless specifically noted otherwise. All data and reports shall be submitted to the Department by the10th day of the following month unless otherwise noted; for example, reports for the month of January must be submitted by the dealer or harvester in time for the report to arrive at the Department by February 10th, unless otherwise noted. , unless otherwise noted. All data sent to DMR must be legible, coherent and in conformance with DMR specified standards.

8.20 Harvester Reporting

~~A. Green Crabs (previously Chapter 25.40(D)(2) and (D)(2)(a))~~

A. Green Crabs (repealed)

~~1. Any person holding a green crab license issued pursuant to 12 M.R.S §6808 or fishing for green crabs as a commercial by-catch in another licensed fishery must submit monthly reports to the Department, on forms provided by the Department, providing the total weight of green crabs harvested, along with such other information as the Commissioner deems necessary.~~

~~2. Reporting Exemption~~
~~Individuals who fish for, take, possess or transfer green crabs for personal use pursuant to 12 M.R.S §6808(4) are exempt from the reporting requirement under Chapter 8.20(A).~~

c. Army Corps. Regulations for Fencing and Leasing Efforts
GREEN CRAB PREDATOR FENCING OR OTHER STRUCTURES BELOW THE MEAN HIGHWATER LINE

Applicants for activities that are eligible for the Department of the Army Maine General Permit must:

1. Apply directly to the Corps using the Corps application form (ENG Form 4345). A copy of this form may be obtained by contacting the Corps of Engineers, Maine Project Office, 675 Western Avenue #3, Manchester, ME 04351, (207) 623-8367; or on our website at the following link: http:/ /www.usace.army.mil!Portals/2/ docs/ civil works/regulatory/engform4345 2013july.pdf

2. Submit the following information. Additional information may be requested by the Corps post submission.

    a. Narrative of the proposed project to include the project purpose and description;
    b. location map with the boundaries of the proposed project clearly defined; identify coordinates in GPS, LAT LON; and area to be occupied in square feet;
    c. tax map showing the location of the project in the vicinity to other structures, moorings, proximity to land;
    d. overhead view (plan view) of the structures to be installed inclusive of but not limited to number and dimensions of nets, traps, cages, fences, spacing of structures, mooring tackle, marking of the site;
    e. elevation view (plan view) of fencing (w/dimensions), mooring tackle, MHW, ML W;
    f. Monitoring plan inclusive of the following:
    1. Identify the individual(s) responsible for the active maintenance and survey of the project.
    2. Identify the frequency of intended site visits. (i.e. 1x per tide cycle, 1 x per 24/48 hours, etc.)
    3. Identify the individual(s) conducting the site visits.
    4. Maintenance protocol of the structures. (how often occurring, anticipated maintenance required, methodology utilized for anticipated maintenance)
    5. Submission of monitoring reports indicating date of occurrence, site conditions observed, any maintenance issues, identification of any species other than the intended trapped by the structures, timing of submission (i.e. weekly, bi-weekly)
    g. Is the site located in an area that drains completely at low tide?
    h. Identify the past, current, and future uses of the project location.
    i. What is the timeline of the project? Anticipated installation and removal dates.
    j. Identify the individuals that will install and remove the structures.

k. How long will it take to install/remove? For example, "all structures to be installed during low tide, when the tide is below the work area; approximately 3 days for completion".
l. Identify any installation methods that may result in disturbance of the substrate.
m. Identify point(s) of access to and from the site for installation of structures, monitoring efforts, and storage of structures and gear post removal.
n. If available, provide details of funding organizations, grants obtained to conduct the project.
o. Note the location environmental resources in the vicinity of the project such as eelgrass, mud flats, etc.

3. Recommended/required Outreach.
   In a blanket letter, request the review (in brief narrative form) of the project and comment from the Town Harbor Committee, Shellfish Wardens, Town Harbormaster, Marine Patrol, U.S. Coast Guard, and Maine Department of Marine Resources.

General Considerations:
*If pursuing a "fence" project, identify the locations and treatment of "gate" locations that will allow for the unimpeded access for safe navigation as well as passage for marine species. These are to be included on the project plans and description included within the project narrative.

*Time necessary to apply for and obtain a Corps permit.

*Responsiveness to agency coordination. Keep in mind, delays in responding to information requests will only delay permit issuance.

*Questions. Contact any of the staff at the Corps of Engineers Maine Project Office. (207) 623-8367.

LeeAnn Neal, U.S. Army Corps of Engineers, leeann.neal@usace.army.mil
Jay Clement, U.S. Army Corps of Engineers, jay.l.clement@usace.army.mil
Shawn Mahaney, U.S. Army Corps of Engineers, shawn.b.mahaney@usace.army.mil
Rodney Howe, U.S. Army Corps of Engineers, Rodney.A.Howe@usace.army.mil
Peter Tischbein, U.S. Army Corps of Engineers, Peter.Tischbein@usace.army.mil

Other Points of Contact:
Steven Pothier, US Coast Guard, Aids to Navigation, steven.r.pothier@uscg.mil
J. Kohl Kanwit, Director, Bureau of Public Health, ME DMR, kohl.kanwit@maine.gov

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12. Appendices

a. Historical data from DMR studies (1950s-80s)

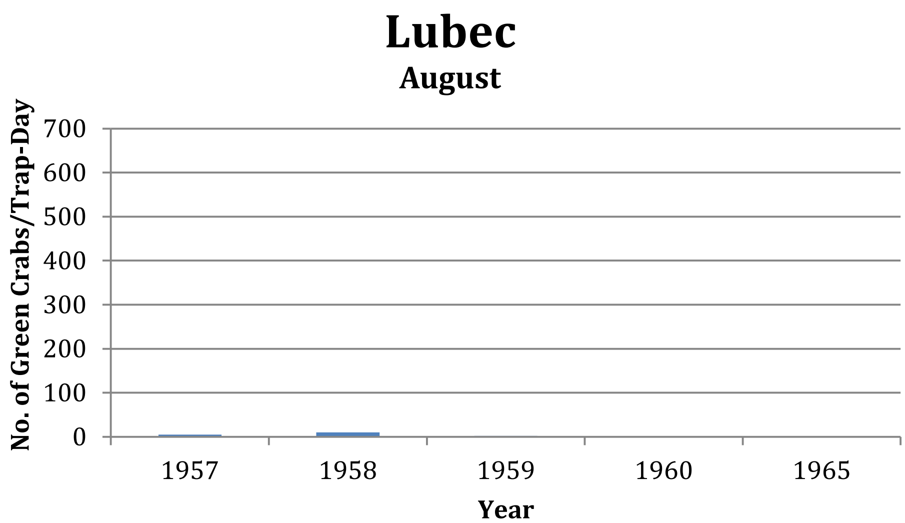
Initiated in 1953 the DMR (then called Department of Sea and Shore Fisheries), under the leadership of Walter Welch, conducted intertidal surveys and trapping for green crabs along the coast of Maine. Summarized by Welch (1969), the methods used for historical samples from the mid 1950's to the mid 1980's were the same standardized and used by National Marine Fisheries Service and DMR personnel. Littoral samples from the salt marsh areas were obtained by digging into the *Spartina* sod banks along the tidal streams where the crabs excavate burrows for cover. One man-hour was spent in obtaining each sample; in addition, the size of the area searched was estimated. Littoral samples along the rocky shore were obtained by spending one man-hour looking under rockweed, under loose rocks, and in the sediments below loose rocks. For shallow water, sub tidal samples, standardized traps designed to minimize escapement were utilized. Three traps were used for each area and were fished each month for two back to back twenty-four hour soak times. The traps were baited with ten pounds of fresh, frozen fish.

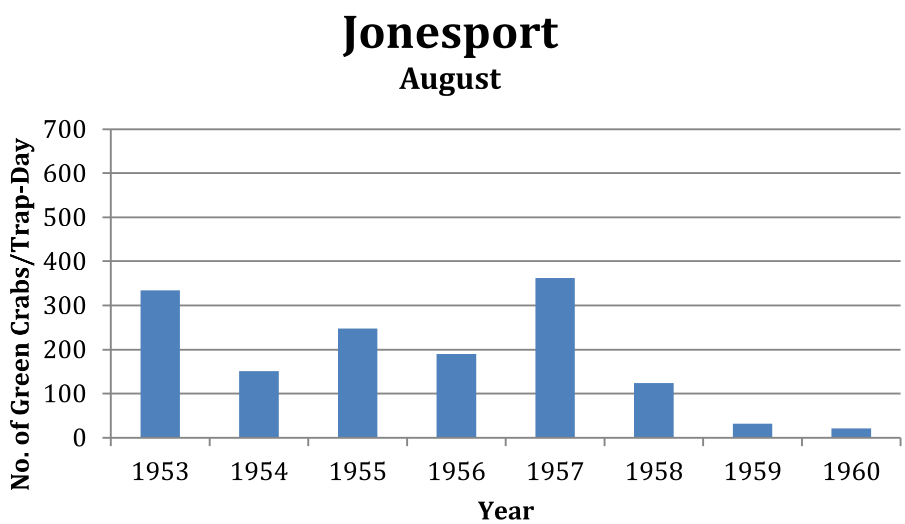
Fall was usually chosen as the time to conduct the surveys due to: 1) the young crabs of the current year are mostly large enough to be readily found if abundant; and 2) most of the mature females have hatched off their eggs and are not as likely to be in seclusion (buried in the mud).

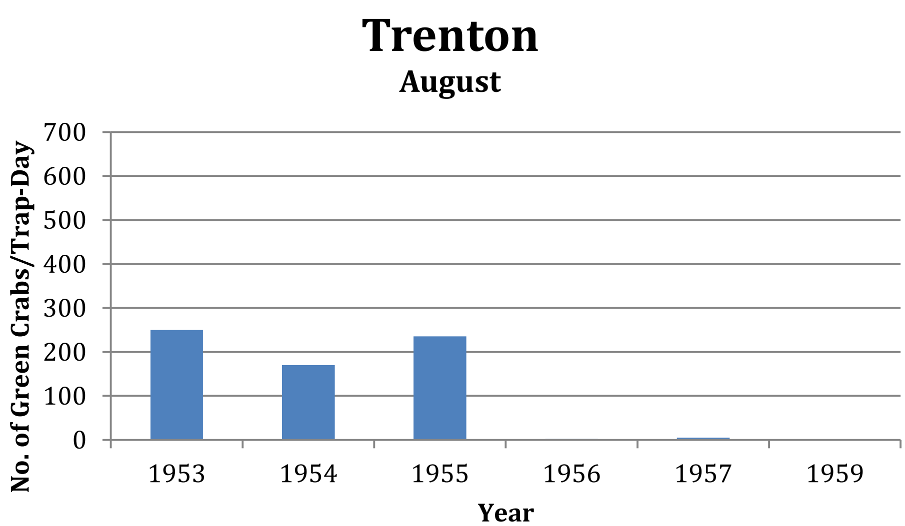
Results from this dataset show that green crab populations decreased from the mid 1950's until the late 1950's. From the late 1950's until the early to mid-1970's populations stayed low except for a spike in 1960 and a spike from 1964 to 1966. In the early 1970's the population started increasing again until the late 1970's when they decreased into the early 1980's. The highest numbers of crabs were seen in the southwest end of the state with lower numbers in the northeast part of the state. The highest number of green crabs trapped was in West Boothbay Harbor in August of 1965 when the average was 644 green crabs per trap per day. The highest number of green crabs seen in a littoral survey was during the fall of 1976 in Jones Creek in Scarborough where 961 green crabs were counted in a one hour survey.

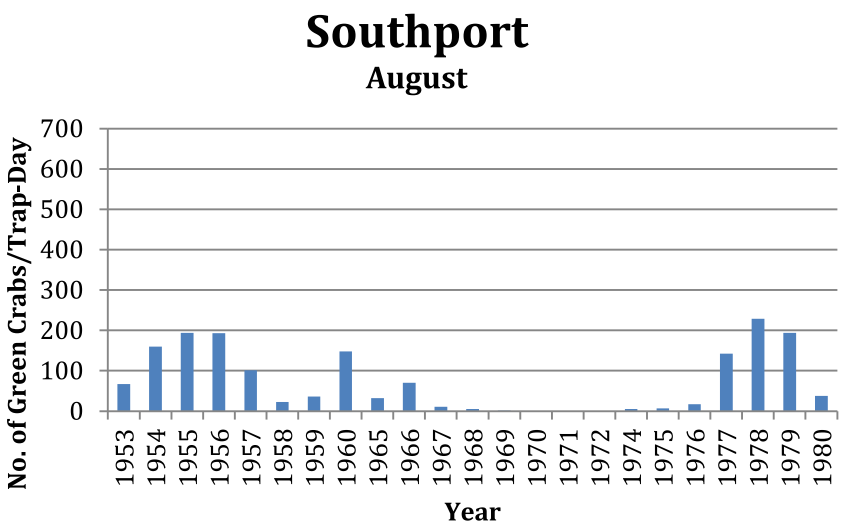
Welch (1969) noted the decline in green crab abundance in the 1960s was associated with lower temperatures. Abundance levels declined to a point where green crabs were scarce and soft shell clam abundance recovered.

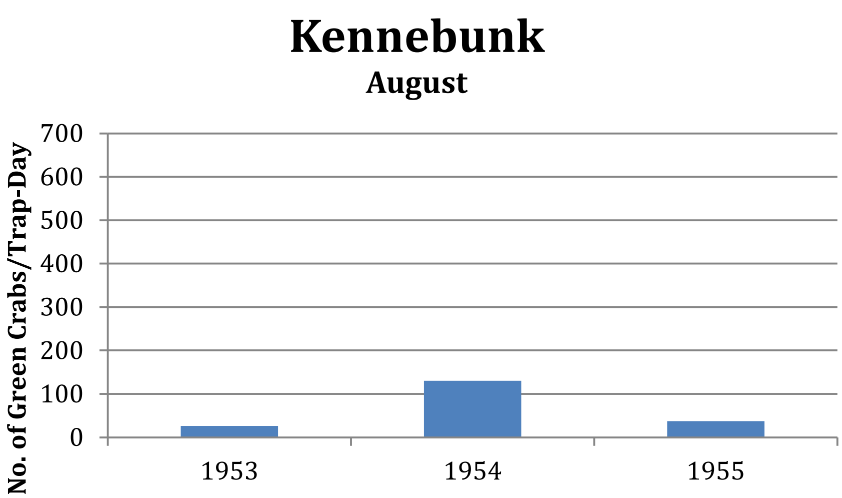
The following graphs depict green crab catches by trap from the 1950s to 1980s where data were available for various towns in Maine.

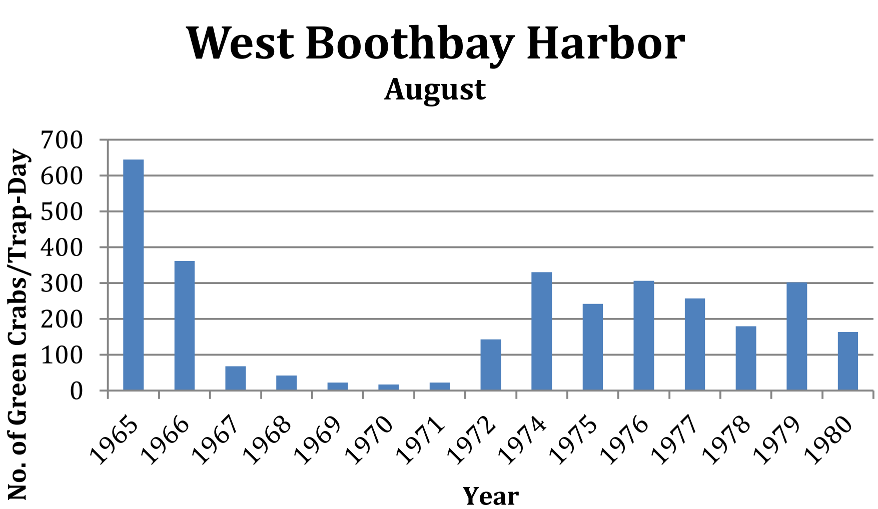

Lubec
August
No. of Green Crabs/Trap-Day
700
600
500
400
300
200
100
0
1957
1958
1959
1960
1965
Year


Jonesport
August
No. of Green Crabs/Trap-Day
700
600
500
400
300
200
100
0
1953
1954
1955
1956
1957
1958
1959
1960
Year


Trenton
August
No. of Green Crabs/Trap-Day
700
600
500
400
300
200
100
0
1953
1954
1955
1956
1957
1959
Year


Southport
August
No. of Green Crabs/Trap-Day
700
600
500
400
300
200
100
0
1953
1954
1955
1956
1957
1958
1959
1960
1965
1966
1967
1968
1969
1970
1971
1972
1974
1975
1976
1977
1978
1979
1980
Year


Kennebunk
August
No. of Green Crabs/Trap-Day
700
600
500
400
300
200
100
0
1953
1954
1955
Year


West Boothbay Harbor
August
No. of Green Crabs/Trap-Day
700
600
500
400
300
200
100
0
1965
1966
1967
1968
1969
1970
1971
1972
1974
1975
1976
1977
1978
1979
1980
Year

b. Current Research Summaries

i. DMR trap study (2014)

The purpose of a trap study initiated in 2014 is to determine the catch rates of each of the traps and the optimal soak times for each type of trap to maximize removal of green crabs. Recent attention to green crabs has increased the desire to use lobster traps for harvesting. Lobster traps have several requirements that limit the utility for green crab trapping, namely the requirement of 1 15/16” rectangular or 2 7/16” circular escape vents. Nonetheless, unused lobster traps represent a significant source of potential traps, and there is a need to evaluate common modifications. Recent regulatory changes require green crab traps to have a 1.5” maximum entrance with no requirement for escape vents (DMR Chapter 25).

We deployed five different traps in this study. (1) The first trap is a legal single bedroom 36”x24”x15” lobster trap. (2) The second trap is a slightly modified single bedroom 36”x24”x15” lobster trap so that it is green crab legal. Escape vents were disabled using a 6”x7.5”panel of 1.5x1.5”. Each entrance head was reduced by hog-ringing a 6”x7.5” panel, with a 1.5x4.5” opening, to the hoop. (3) The third trap type of trap is a heavily modified single bedroom 36”x24”x15” lobster trap. The first modification of this trap is that the bottom and sides are lined with 9mm oyster bags. Each entrance head was reduced by hog-ringing a 6”x7.5” panel, with a 1.5x4.5” opening, to the hoop. (4) The fourth trap type is an Acer Crab Trap. This trap is a cylindrical trap measuring 18” x 36” made out of 0.5”x0.5” wire. On each end is an inverted cone that comes to a 5.5” x 1.5” opening. (5) The fifth trap type is a standard shrimp trap, 48”x24X15”, with an 18” by 1.5” trough in the top with 1.0 x0.5” mesh wire.

To test the impacts of soak and trap design, three different sets of traps were deployed around Winter Point Oyster in West Bath. One set of traps was put in the channel where at low tide the traps are about 1 foot under water. The second set was deployed near the rocky coast where at low tide you could just see the tops of the traps. The third set of traps was deployed around the end of a point where three different coves drain out. These traps were about 1 foot under the water at low tide. The traps were hauled on soak times of 1, 2, 3, 4, 5, and 6 hours. Each month, for three months the traps were hauled once for each soak time. The catch was removed separated out by species and sex, then weighed and measure for each trap.

This study is ongoing, but preliminary results indicate the green crab catch was highest in the Acer Crab Trap and the unmodified lobster trap caught the least.

ii. One day trap survey results (2013)

Introduction

The one-day green crab trapping survey was coordinated by the Department of Marine Resources (DMR) and was conducted to provide a snap-shot of the relative abundance and distribution of green crab populations along the coast of Maine. It was also designed to increase awareness of municipal shellfish program officials and industry members to the presence of green crabs in their harvest areas. The data, collected primarily by volunteers, was used to evaluate if coastal areas have significant green crab populations and if these populations likely constitute a problem to the commercial viability of their shellfish resources.

Methods

The one-day green crab trapping survey was conducted along the Maine coast from August 27 to 28, 2013 by volunteers; some of whom were teamed up with scientific personnel. Participants were asked to set baited traps in locations where a current or recent (within 2 years) high abundance of soft-shelled clams was observed. The traps were set in shallow water (less than 20 feet deep at low tide) and DMR asked that two traps be set in each location to help with data replication. Any trap type was acceptable, but the presumption was most participants would have easiest access to lobster traps. If lobster traps were used, the vents were closed but the degradable links on the vents were not modified. The traps were left in the water for 24 hours, and when the traps were hauled the next day green crab collections were measured in terms of the volume of green crabs caught in each trap using a 5-gallon bucket measure. All of the crabs in one, 5-gallon bucket were counted if time allowed, and if the total catch was less than 1 bucket, all of the crabs were counted and their volume was estimated. Scientists from DMR and Maine SeaGrant were assigned to accompany a subset of volunteers throughout the coast. If a scientist was part of the survey crew, a random sample of 50 crabs was collected from each trap, measured to the nearest millimeter, sexed, and the reproductive status of females was noted (e.g. berried) and recorded on datasheets.

Results

DMR sent a request for volunteers to participate in the one-day green crab trapping survey on August 1st. The response was overwhelming with twenty-eight towns eventually participating in the survey, resulting in thirty-eight separate trips and 208 traps set (Figure 1). There were 193 collections of green crabs coast-wide. Four types of traps were used by the volunteers: crab and lobster primarily with a few shrimp and eel traps used by some participants. Most of the crab traps were used in the Midcoast and Southern parts of the state, and shrimp traps were used in Biddeford and Boothbay. Two eel traps were used in Georgetown. Data collection and recording was somewhat inconsistent among participants, therefore limiting the results and interpretation.
Catch rates per trap (catch per unit effort or CPUE) were determined for towns along the coast, with no consideration for the type of trap (Table 1). Harpswell caught the most crabs per trap (350), but this result must be tempered by the fact that the trap catch rates had to be estimated for eight out of the ten traps set, due to time restraints limiting data collection. Catch rates for the towns with the next highest CPUE values were as follows: Stockton Springs (191), Freeport (181), Scarborough (151), Waldoboro (146), Biddeford (144), Trenton (136), Brunswick (124) and Sorrento (102). Yarmouth's catch was estimated for four traps, because the actual data sheets were lost. Chebeague Island and Sullivan only estimated bucket amounts, and didn't count crabs, so they have no catch per unit effort results, although Chebeague's catch of 12 buckets from five traps is clearly very high.

Figure 1. Trap Set Locations (only set locations submitted with coordinates are shown)

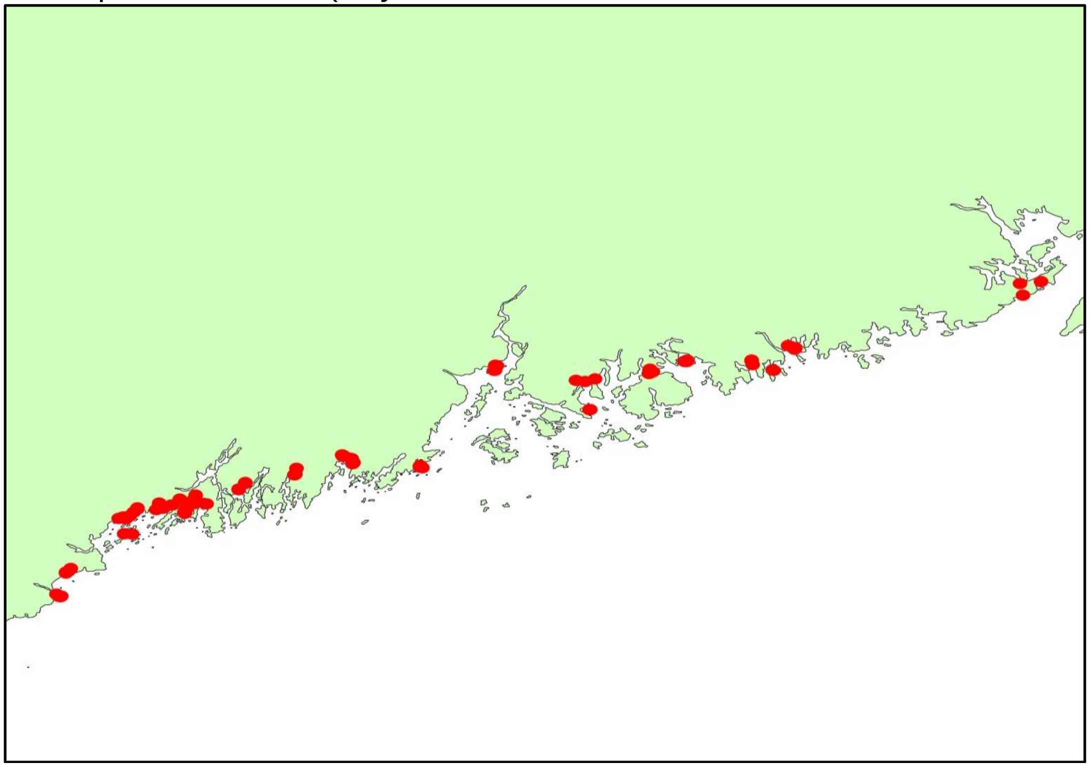


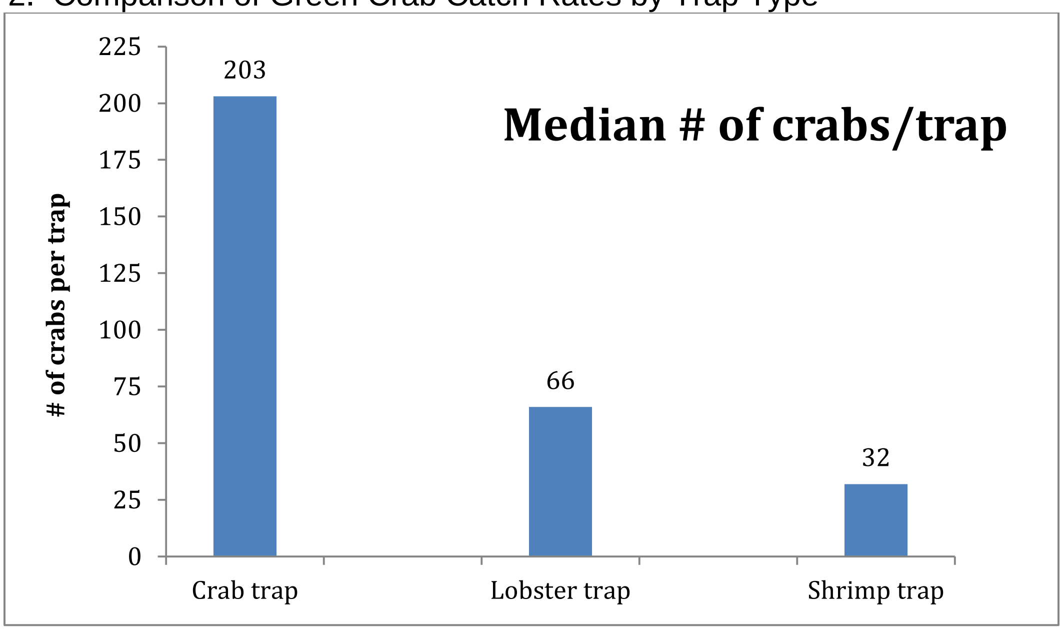
Table 1. Green Crab Catch Per Unit Effort by Participating Town
n=18,806 crabs

Town	Trap type(s)	N. of traps fished	Total green crab catch (N.)	CPUE crabs/trap
Bar Harbor	Lobster	6	316	53
Beals	Lobster	10	7	0.7
Biddeford	Crab/shrimp	10	1,447	144
Blue Hill	Lobster	3	227	76
Boothbay	Shrimp	10	471	47
Brunswick	Crab/eel/lobster	19	2,364	124
Chebeague Is.	Lobster	5	12 buckets	N/A
Damariscotta	Lobster	2	150	75
Freeport	Crab	5	903	181
Georgetown	Eel	2	33	17
Harpswell	Crab	10	3,502 (estimate)	350
Jonesport	Lobster	4	129	32
Lamoine	Crab/lobster	9	322	36
Lubec	Lobster	10	569	57
Milbridge	Lobster/bait trap	6	83	14
Scarborough	Crab/lobster	7	1,060	151
Searsport	Lobster	10	402	40
Sorrento	Lobster	10	1,020	102
South Bristol	Crab	5	284	57
Steuben	Crab/lobster	5	85	17

Stockton Springs	Lobster	10	1,912	191
Sullivan	Crab/lobster	4	1.75 buckets	N/A
Thomaston	Lobster	11	140	13
Trenton	Crab/lobster	5	682	136
Waldoboro	Crab/lobster	15	2,193	146
Westport Is.	Lobster	3	4	1.3
Wiscasset	Lobster	10	194	19
Yarmouth	Lobster	6	308 (estimate)	51

When the type of trap was taken into consideration, crab traps caught the highest median number of crabs per trap (203); followed by lobster traps (66), while the trips that fished shrimp traps caught 32 crabs per trap (Figure 2). Most of the trips that used crab traps were in the southern part of the state, so the catch data for crab traps is concentrated in that region. There were many observations reported of smaller green crabs escaping through the mesh of lobster traps as the traps were being hauled. As a result, the final statistics do not accurately reflect the size range of crabs that could have been collected in lobster traps had the smaller ones not been able to escape.

Figure 2. Comparison of Green Crab Catch Rates by Trap Type



Catch from Crab Traps

Using crab trap data, lengths of male and female crabs in millimeters were compared (Table 2). The largest percentage of both males and females were caught in the 46-60 mm range. However, the male catch was spread among a greater range of sizes than the female catch.

Table 2. Percentage of Green Crab Catch from Crab Traps by Size Range and Sex (Data from Biddeford, Waldoboro, Scarborough, Brunswick, Harpswell and Freeport)

	1-15 mm	16-30 mm	31-45 mm	46-60 mm	61-75 mm	76-90 mm
Females (n=636)	0%	5%	28%	58%	9%	0%
Males (n=713)	0%	2%	20%	42%	31%	5%

The catch for all towns was centered in the 31-75 mm size ranges, with most towns showing the highest percent catch in the 46-60 mm category (Table 3).
Table 3. Percentage of Green Crab Catch from Crab Traps by Size Range for Specific Towns

	1-15 mm	16-30 mm	31-45 mm	46-60 mm	61-75 mm	76-90 mm
Biddeford (303 crabs)	0%	7%	29%	58%	4%	1%
Brunswick (373 crabs)	0%	1%	21%	36%	35%	6%
Freeport (168 crabs)	0%	13%	35%	35%	15%	0%
Harpswell (202 crabs)	0%	0%	23%	59%	17%	0%
Scarborough (50 crabs)	0%	8%	36%	48%	8%	0%
Waldoboro (253 crabs)	0%	0%	12%	60%	26%	2%

Catch from Lobster Traps
The catch of crabs in lobster traps was more widespread over the Maine coast, because more volunteers used lobster traps for the survey. Using lobster trap data, lengths of male and female crabs in millimeters were compared over four regions of coastal Maine; the regions and the towns they include are listed as follows: Southern (Scarborough): Midcoast (Waldoboro, Wiscasset): Penobscot Area (Bar Harbor, Blue Hill, Lamoine, Stockton Springs): and Downeast (Beals, Jonesport, Lubec, Milbridge, Steuben; Table 4). Three regions caught more males than females (Midcoast, Penobscot Area and Downeast). The Southern region caught more females than males, but was only represented by Scarborough.

Table 4. Percentage of Green Crab Catch from Lobster Traps by Size Range and Sex

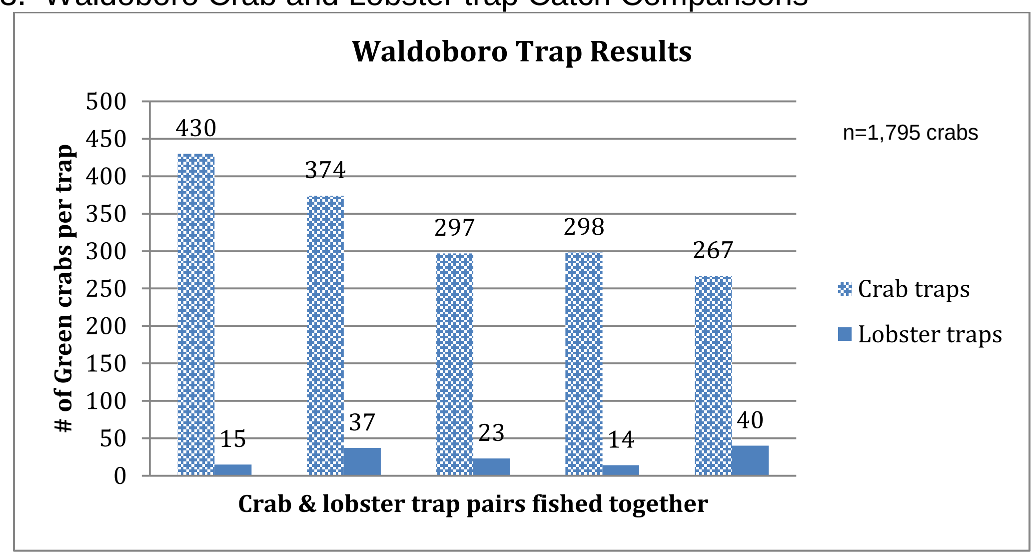
Region	Sex	1-15 mm	16-30 mm	31-45 mm	46-60 mm	61-75 mm	76-90 mm	>90 mm	Count	Percent F/M
Southern	F	0%	2%	20%	75%	3%	0%	0%	195	78
N. 250	M	0%	4%	24%	71%	1%	0%	0%	55	22
Midcoast	F	0%	2%	8%	51%	35%	2%	0%	179	33
N. 546	M	0%	0%	2%	19%	68%	11%	0%	367	67
Penobscot Area	F	0%	0%	17%	60%	23%	0%	0%	284	25
N. 1140	M	0%	0%	1%	18%	65%	16%	0%	856	75
Downeast	F	0%	2%	26%	48%	24%	0%	0%	123	20
N. 604	M	0%	2%	2%	11%	64%	21%	0%	481	80

A comparison of male and female sizes for crab trap and lobster trap catches was done using the 31-60 mm size range as a standard for comparison. Crab trap female catches resulted in 86% of females in this size range, while males in the same range comprised 61% of the male catch. When lobster trap catches were analyzed for males and females in this same size range, the females sized 31-60 mm composed 77% of the female catch, while males in this size range were 20% of the male catch. This would seem to indicate that the lobster traps caught fewer midsized green crabs than the crab traps. When crab and lobster traps were compared for male and females in the size range of 61-90 mm, female green crabs in the 61-90 mm size range were 9% of the total female catch, while male green crabs in this size range were 36% of the male catch. In contrast, lobster traps contained 21% of the female catch in the 61-90 mm size range, and caught 79% of the total male catch in this size range. The data indicates that larger (>61 mm) male and female green crabs were caught in lobster traps.

Side-by-side Trap Comparison

The town of Waldoboro did a side-by-side catch comparison of specially designed crab traps and lobster traps. They set five pairs of traps; one crab and one lobster each in the same location. The specially designed crab traps caught more green crabs than lobster traps in every case (Figure 3).

Figure 3. Waldoboro Crab and Lobster trap Catch Comparisons



Discussion

This project was designed and implemented in a very compressed timeframe with only a couple of simple goals; establish the relative abundance of green crabs coast-wide and increase local awareness of the problem. The limited goals were established based on reasonable expectations for a fully volunteer effort across the entire coast in one day. Standardized gear and bait could not be provided for the participants so variability was inevitable. There are presumably differences in crab catches due to the various types of bait used in the traps. Volunteers used bait that was easy to obtain, so there may be differences in how enticing green crabs found the offered bait. The amount and sizes of green crabs caught in lobster traps does not accurately reflect the total numbers of green crabs originally caught in these traps, because smaller crabs were observed escaping through the mesh as they were being hauled. DMR also provided options to towns in what data they collected from just the volume of catch to counting crabs and measuring subsamples. Because volunteers didn't all record the same data and only a subset of participants were assigned scientific observers, not all comparisons could be made between towns (e.g. CPUE).

Conclusions

Despite the limited nature of the data collected, this project was able to conclusively show that green crabs are present throughout the state and largely in numbers that represent a detrimental impact to bivalve shellfish. Crab traps captured more green crabs than lobster traps or shrimp traps and crab traps fished side-by-side with lobster traps caught more crabs than lobster traps. The data indicates that crab traps capture more mid-sized (31-60mm) male and female crabs than lobster traps; and lobster traps capture more large-sized (>61mm) male and female crabs than crab traps. This project confirmed what some harvesters observed for the last few years regarding the density of green crab populations while revealing to others the cause of high levels of predation and habitat destruction (erosion of marsh banks and destruction of eelgrass beds).

Recommendations

Future green crab work should focus on specific questions such as the effectiveness of trapping and fencing efforts in protecting valuable shellfish resources, size ranges of existing green crab populations, time of year effects on trapping gravid females v. juveniles etc, and refining trapping methods including trap design, bait type, soak time, night v. day hauling and other parameters. Some areas along the Maine coast might still benefit from basic survey work similar to what was conducted in this study, particularly in Downeast Maine where voluntary participation was more sparse.

Acknowledgements

The DMR wishes to thank the many volunteers who participated in the survey, especially Abden Simmons and Glen Melvin of Waldoboro who conducted the side-by-side trap comparisons and Chad Coffin who initiated the initial conversations about green crabs. DMR also acknowledges the Sea Grant staff, DMR staff and others who helped count and measure crabs in the field; the contributions of Dr. Brian Beal in the study design; Katherine Evans for data entry; Denis Nault, Peter Thayer and Hannah Annis for planning and executing the project and Jeff Nichols for promoting awareness of the project and the green crab issue in general.

iii. Other current studies

Northwest Atlantic population structure and gene flow in the Green Crab: current understanding of a dynamic invasion front, population admixture and continued anthropogenic expansion

April MH Blakeslee (Long Island University-Post, Brookville, NY) and Joe Roman (University of Vermont, Burlington, VT)

Goals:

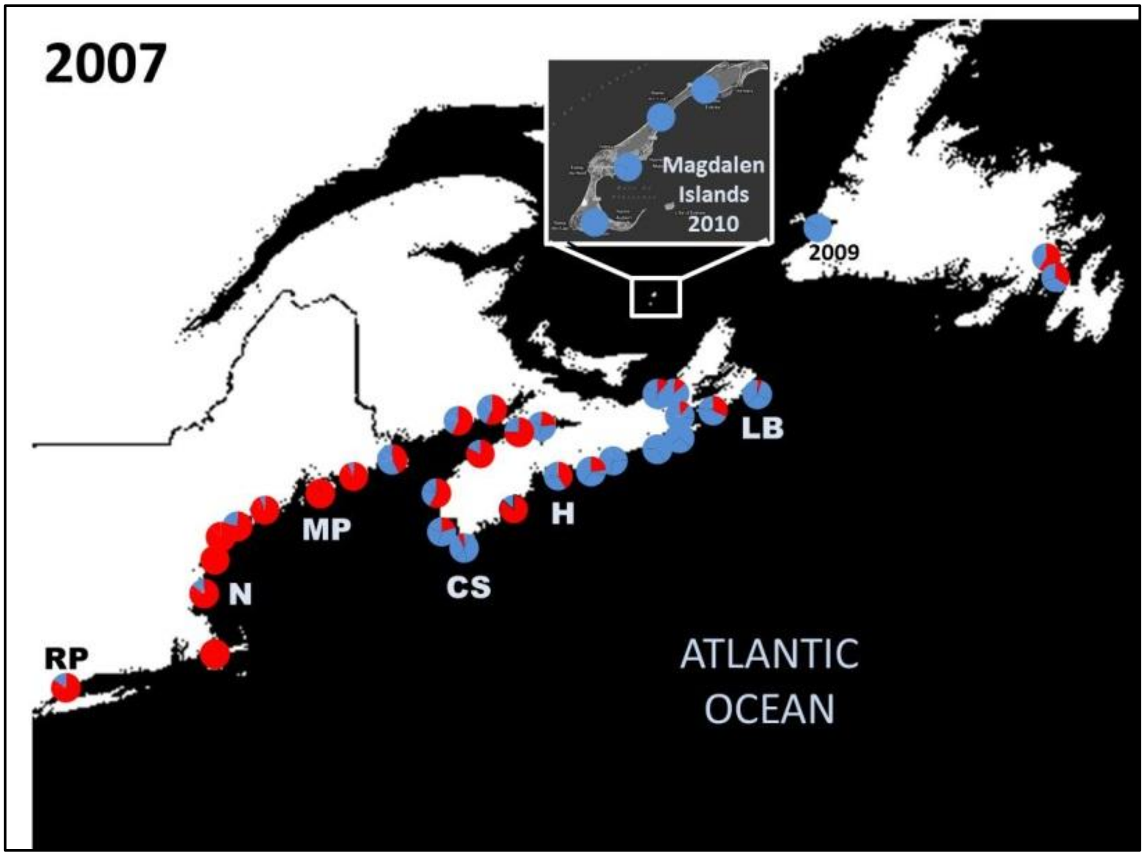
- To explore the population genetics of the green crab throughout the western Atlantic, including Atlantic Canada and northeastern USA.
- To determine the current extent of the admixture zone between the historical 1800s introduction and the newer 1990s introduction to eastern Nova Scotia (Roman 2006), which is now spreading southwestwards into the US. The last exploration occurred in 2007 and the admixture zone was primarily in western Nova Scotia and New Brunswick (Pringle et al. 2011; Darling et al. in review).
- To determine the geographic range of the new genotypes, and whether these have spread into Maine and further south.
- To compare recent population genetics data (2013-2014) to past data (2000, 2002 and 2007) found in Roman (2006), Blakeslee et al. (2010), Pringle et al. (2011), and Darling et al. (in review).
- To work with colleagues in Nova Scotia (Claudio DiBaccio and Ian Bradbury) to explore population genetics throughout the western Atlantic with multiple molecular markers.
- To explore possible correlations of the recent genotype spread and recent invasion impacts, as well as possible evolutionary aspects, like local adaptation (with a colleague, Carolyn Tepolt).

Methods:

- Collect ~15-20 young-of-the-year (typically <10 mm CW) green crabs by hand from the intertidal zone per population. In the past, we have sampled ~30 populations ranging from eastern Nova Scotia to Long Island.
- Crabs are preserved in ethanol or frozen until they can be processed for DNA sequencing. We use standard methods for DNA extraction, PCR amplification, and sequencing (see methods in papers listed above).
- Sequence and microsatellite data are analyzed for population differentiation, gene flow, admixture, and phylogeography.

Preliminary Results:

- Past data for comparison are found in the papers listed above. For example, the figure below demonstrates a haplotype frequency map of the historical (red) haplotypes and the recent (blue) haplotypes and their distributions when they were last explored in 2007 (figure adapted from Pringle et al. 2007).
- Preliminary analysis of some midcoast and northeast Maine haplotype data show some incursion by the newer haplotypes. Analysis of these data are currently in progress.


2007
Magdalen
Islands
2010
2009
LB
MP
H
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RP
ATLANTIC
OCEAN

Range retraction of novel northern lineages of the invasive green crab, *Carcinus maenus*, along the Northwestern Atlantic Coast

Authors: Larissa M. Williams[1,2,*], Camilla L. Nivison[1], William G. Ambrose, Jr. [1], Rebecca Dobbin[1], William L. Locke[1].
Affiliations: [1]Biology Department, Bates College, Lewiston, ME, 04240, USA [2]The Mount Desert Island Biological Laboratory, Salisbury Cove, ME, 04609, USA
*Corresponding author: lwillia2@bates.edu

One of the most successful marine invaders, *Carcinus maenas*, has established populations along many global temperate coasts. Introduced over 200 years ago to the East Coast of North America, it now ranges from New York to Canada. In the 1980s, a secondary invasion of several novel European lineages occurred in Nova Scotia. The most recent genetic study, analyzing samples from 2007, showed that the more recently introduced northern haplotypes of the mitochondrial *cytochrome c oxidase I* (COI) gene were present in low frequency along several coastal sites in northern New England. Our study sought to determine whether there has been an expansion of northern COI haplotypes. Six haplotypes, encompassing three previously identified northern haplotypes, one previously identified southern haplotype, and two novel southern haplotypes, were identified in 165 crabs sampled at 11 sites from Nova Scotia to New York. Northern haplotypes were only found in Nova Scotia, Beal's Island, ME and Mount Desert Island, ME at a frequency of 86%, 6%, and 33%, respectively; the remaining eight sites were predominantly composed of haplotype 1, at a frequency ranging from 93-100%. Thus, broadening of novel northern haplotypes and a subsequent shift of the genetic cline may not occur as rapidly and permanently as previously thought. The loss of the northern haplotypes south of Mount Desert Island in the intervening years since 2007 could indicate that the southern haplotype is still favored in the upstream edge of the range.

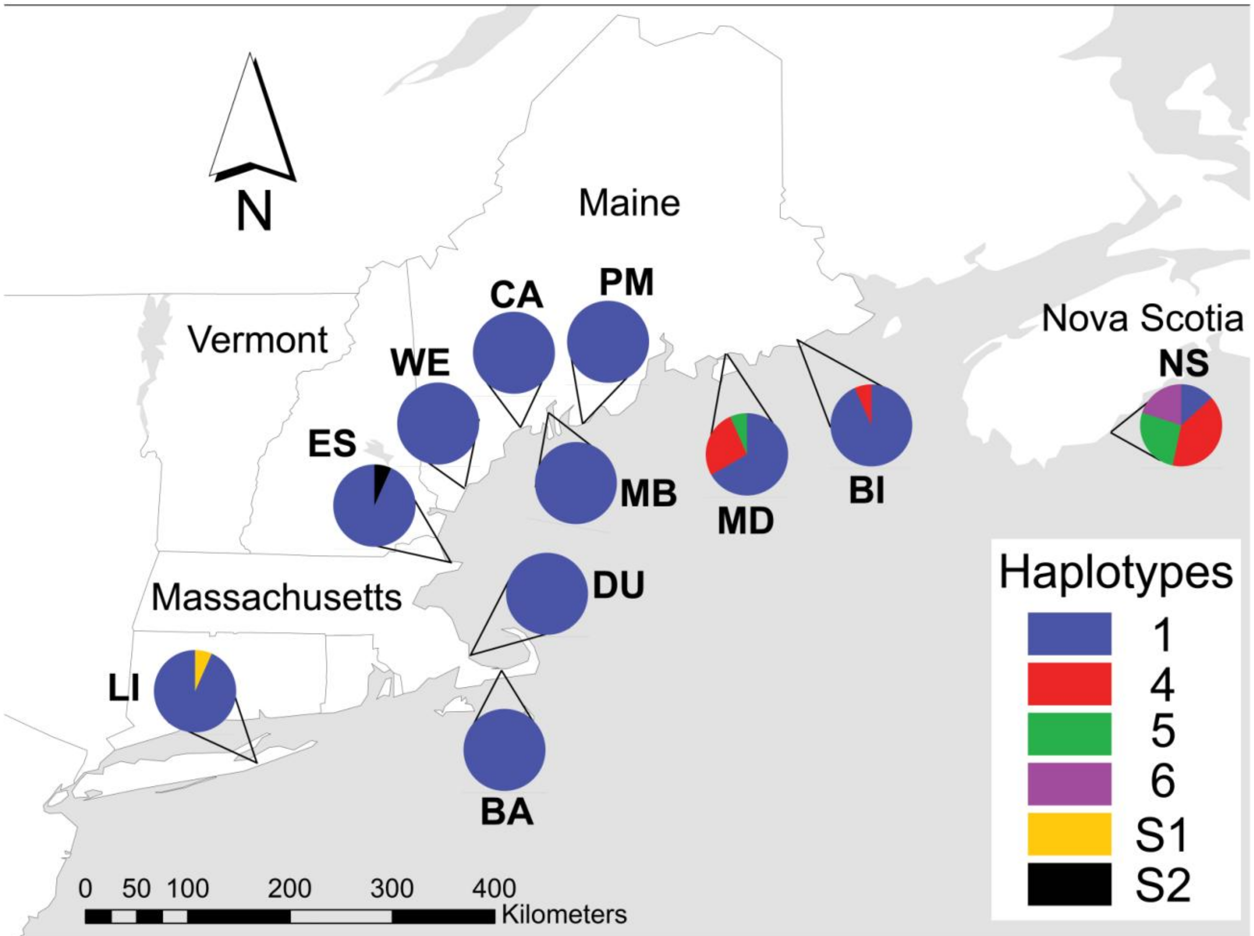


Fig 1. *C. maenas* haplotype frequencies of a 400 bp region of the cytochrome oxidase I gene (n=15 per site). Pie charts indicate proportion of haplotypes found from each population.

Population Genetics of the Invasive European Green Crab, *Carcinus maenas* and its role in eelgrass loss around Mount Desert Island

Authors: Mary Badger[1,4], Alden Dirks[2,4], Larissa Williams[3,4], Jane Disney[4]
Affiliations: 1.Smith College, Northampton, MA. 2. Swarthmore College, Swarthmore, PA. 3. Bates College, Lewiston, ME. 4. Mount Desert Biological Island Laboratory, Bar Harbor, ME

In 2013, there was a devastating loss of eelgrass (*Zoestra marina*) in upper Frenchman Bay, Mount Dessert Island, Maine. This study examined the relationship between the most recent invasion of novel haplotypes of the European Green Crab (*Carnicus maneas*) and the decline of eelgrass in upper Frenchman Bay. While *C. maneas* is an invasive species that has been present in the Gulf of Maine for over 100 years, a second invasion of *C. maneas* in Nova Scotia occurred during the 1980s and 1990s, bringing novel haplotypes of the species that have been cited to be more cold tolerant voracious as compared to other haplotypes. The presence of these new haplotypes has been hypothesized to be a contributing factor of increasing disruptive effects along the Maine coast. In 2013, northern haplotypes of green crab were documented in upper Frenchman Bay where the eelgrass had disappeared. In order to assess this relationship, the cytochrome oxidase I (COI) haplotype of the crabs at sites around Mount Desert Island was determined as well as the abundance of the eelgrass at corresponding study sites. The study did not find a significant correlation between the presence of northern green crab haplotypes and eelgrass abundance at the study sites. This indicates that the status of eelgrass health is not dependent on the genetic composition of green crabs that are present. It is more likely that factors such as green crab abundance or water quality are contributing to the declining health of eelgrass beds along the Maine coast.

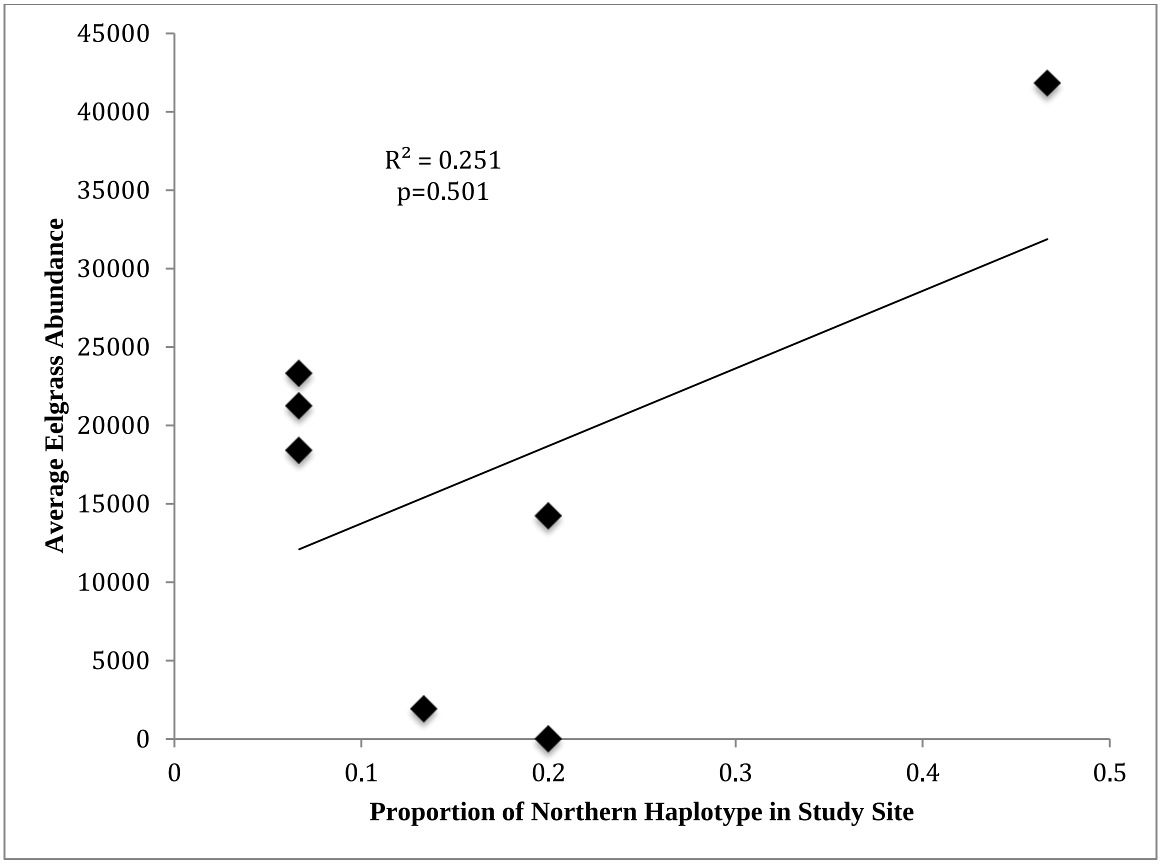


Figure 1. Average eelgrass abundance at study sites (average number of vegetative and flowering shoots per meters squared * average maximum flowering plant height (cm)) as a function of the proportion of crabs with northern haplotypes at each study site. The weak negative relationship between average eelgrass abundance and fraction of northern haplotypes is not significant ($p=0.501$).

Status of Green Crabs in the Damariscotta River

Dr. Bob Steneck and Jeff Dubois; University of Maine, School of Marine Sciences

Green crabs have frequented the shores of the Damariscotta River for decades. Historically, green crabs populations have increased suddenly in conjunction with periods of warm sea temperatures. Green crab population spikes occurred between 1925 and 1935 and again between 1947 and 1960 (Welch 1968). Both of those population explosions reversed during periods of colder than average temperatures (Boothbay Harbor sea surface record by Maine's Department of Marine Resources). Both times softshell clam revenue declined presumably due to green crab predation.

Recently, Maine experienced both another population spike in green crabs coincident with a spike in sea surface temperatures. Notably, 2012 was the was the warmest on record in Maine with average annual temperature more than half a degree warmer than the average for the year 2000. Once again, the softshell clam industry was particularly concerned about this increase.

To determine if population spike is comparable to those of the past, we deployed two types of traps for catching green crabs. We used the Acer crab and standard shrimp traps. Both were baited with either softshell clams or herring. Our prime objective was to determine if population densities of green crabs now are comparable with those recorded in the early 1960 by Welch (1969). Welch used a crab trap with an opening at the top that crabs would fall into but not be able to escape. We used a commonly used crab trap called the "Acer Trap" and a shrimp trap of about the dimensions of Welch's crab trap. By using two different traps we can determine the variation in catch rate that is entirely the result of trap design. All of our crabs were deployed around Wentworth Point on the Damariscotta River.

Our study is being done in conjunction with a broader state-wide study organized by Dr. Brian Beal (U. Maine Machias). The protocol for Beal's design is to use Acer Traps baited with softshell clams. The Welch (1969) study used herring bait on traps checked daily, we included the Welch baiting and monitoring protocol along with the Acer traps baited with clams so we can be commensurable with past and present green crab monitoring, respectively.

We baited and checked traps from May through June of 2014. During that time we saw a decline of catch rate (crabs caught per trap haul per day), from a high of about 140 crabs caught per day (May 23rd) to an average of about 40 crabs caught per day (June 17th) (Fig. 1).

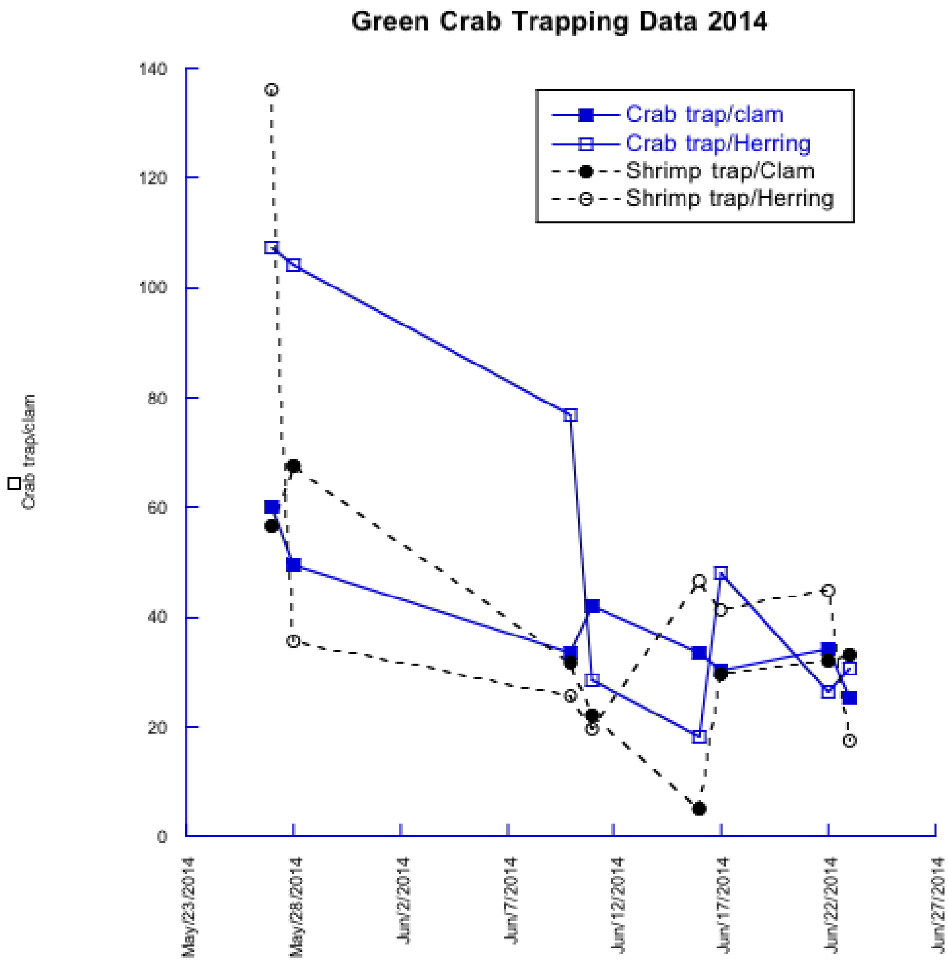


Fig. 1. Catch rate of green crabs using crab and shrimp traps baited with either clams or herring.

The decline in catch rate may result from green crabs moving into the intertidal zone or very shallow subtidal zone during the summer. The patterns of abundance and decline did not vary significantly between trap designs or bait used.

Making historical comparisons with Welch's study, we found that the catch rates from a comparable area (Southport, Maine) in 1953 to 1966 were about four times higher than those recorded in the Damariscotta River in 2014 (Fig. 2).

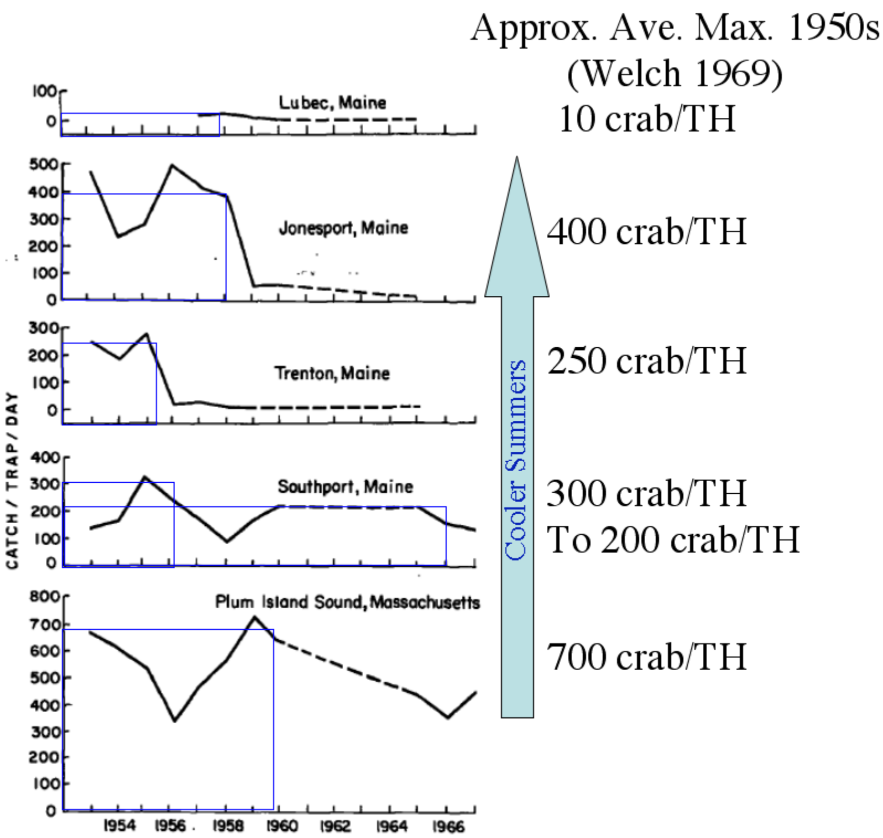


Fig. 2. Catch rate of green crabs (Welch 1969) from cold summers (top) to warm summers (bottom)

The size-frequency distribution of the green crabs caught in 2014 had a mean and median size of 62 mm carapace width. Crab sizes ranged from just under 40 to 90 mm CW (Fig. 2).

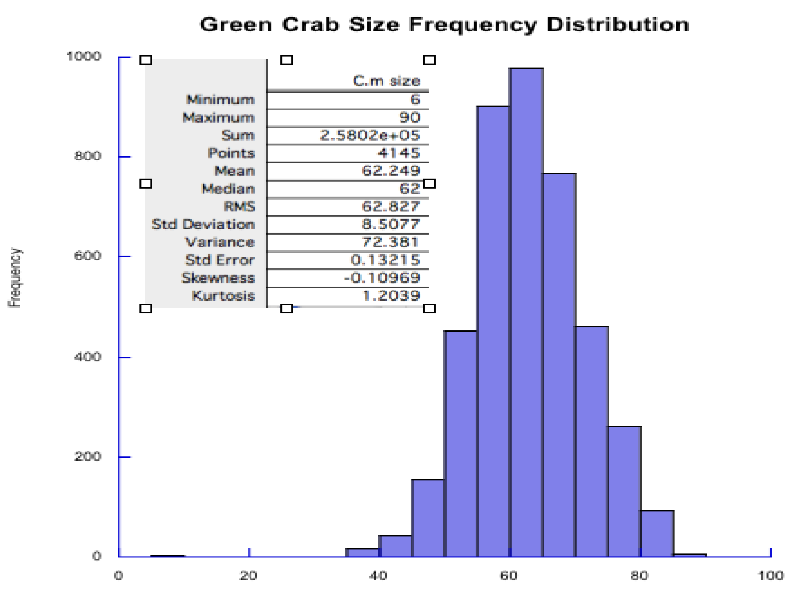


Fig. 3. Size-frequency distribution of green crabs from all trap and all bait treatments.

The shallow subtidal zone is also home for the rock crab *Cancer irroratus*. They were the only other megafauna found in traps during our study. On occasions we recorded over 150 rock crabs in a single trap-haul. However, the highest density of rock crabs was found during times of low catch rates of green crabs (and the reverse). The resulting weak inverse relationship between rock and green crabs (Fig. 3) suggests the two crab species compete.

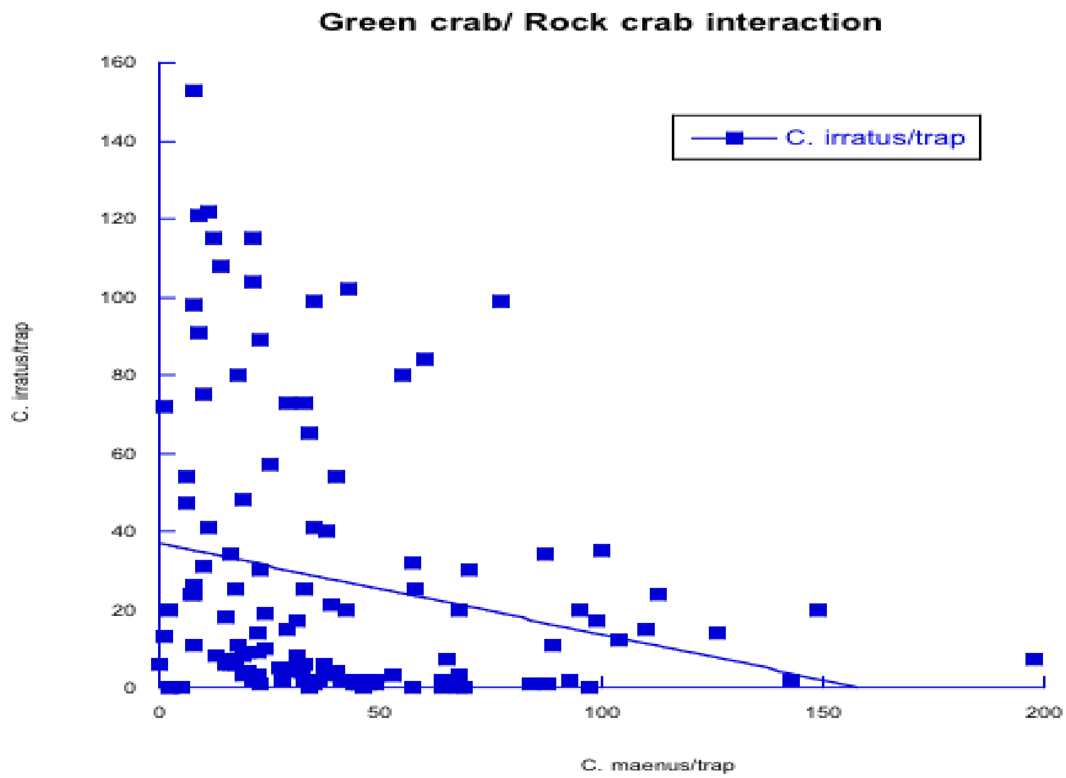


Fig. 4. Catch rate of rock crabs (C. irroratus) green crabs (C. maenus). Note the absence of either species when one species catch rate becomes too high.

We suggest similar efforts to quantify green crabs in ways commensurate with past studies be taken on by other researchers to determine the magnitude of the green crab population explosion in recent years.

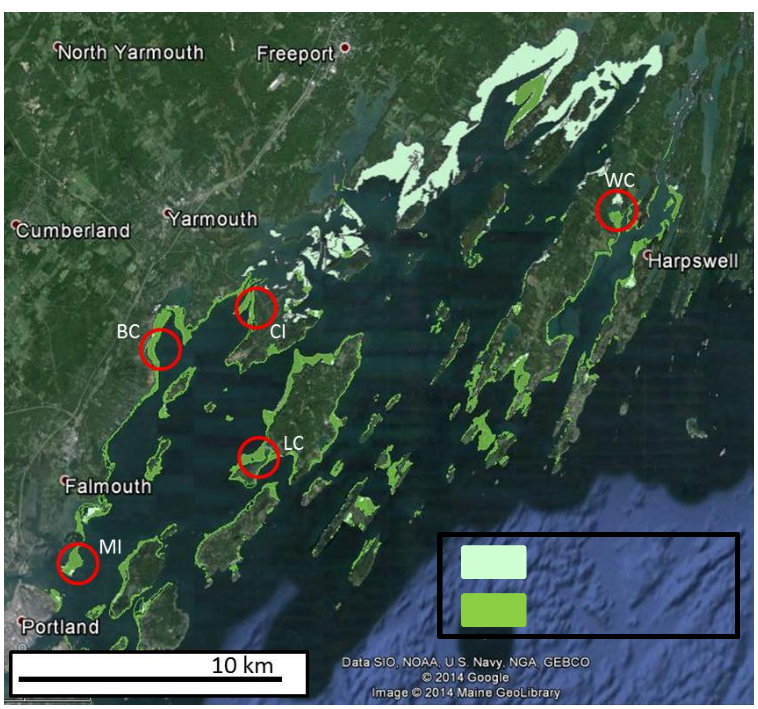
Literature Cited

Welch, W. R. (1969). *Changes in abundance of the green crab, Carcinus maenas (L.), in relation to recent temperature changes*. Maine Department of Marine Resources. Bureau of Commercial Fisheries Biological Laboratory.

Investigation of Green Crab – Eelgrass Relations in Casco Bay

Project Partners: USGS Patuxent Wildlife Research Ctr., Hilary A. Neckles; ME Department of Environmental Protection, Angela D. Brewer; Friends of Casco Bay, Mike Doan; Casco Bay Estuary Partnership, Curtis C. Bohlen, Matt Craig; USFWS Gulf of Maine Coastal Program, Sandra J. Lary; Bowdoin College, John Lichter, Sabine Berzins; Seagrass-mapping contractors, John W. Sowles, Seth Barker

Evidence from a short-term exclosure experiment conducted in September, 2013, points to green crabs as a primary cause of loss of eelgrass (*Zostera marina*) from upper Casco Bay (H.A. Neckles, pers. obs.). Because of the importance of this habitat to the region's ecology and economy, a broad partnership has come together to investigate whether eelgrass loss is continuing in Casco Bay and to better understand factors that may exacerbate or mitigate damage by green crabs. We are focusing efforts on five locations that span the range of eelgrass condition throughout the bay, from areas of transition between formerly and currently vegetated zones in the upper bay to areas of persistent eelgrass cover in the lower bay (see map below). At each target location we are (1) mapping eelgrass from low-altitude aerial photographs to quantify large-scale changes in coverage since eelgrass was last mapped in August, 2013; and (2) measuring eelgrass population characteristics along fixed transects to quantify small-scale changes during the period of maximum eelgrass growth (June – September). At locations where eelgrass is growing in a range of sediment types, eelgrass transects have been established in both fine and coarse sediments. To determine if eelgrass change is correlated with patterns in green crab densities, we are monitoring green crab abundance in the vicinity of each eelgrass transect as biweekly catch-per-unit-effort; details of the green crab monitoring are described separately. Finally, we are measuring the following eelgrass stressors to assess their influence on eelgrass response to green crab disturbance: water-column light attenuation (biweekly), sediment organic content, presence of eelgrass wasting disease, and accumulation of epiphytic algae and/or tunicates on leaves. We expect information on trends in eelgrass abundance and the factors contributing to eelgrass resilience to help guide protection and ultimate restoration of eelgrass habitats in Casco Bay.



2014 Eelgrass and Green Crab Study Sites in Casco Bay (left):
WC=Widgeon Cove, Harpswell
CI=Cousins Island, Yarmouth
BC=Broad Cove, Cumberland
LC=Little Chebeague Island, Long Island
MI=Mackworth Island, Falmouth

Summary submitted by:
Hilary A. Neckles

Effects of predation and ocean acidification on the dynamics of wild clam populations – Town of Freeport and the Downeast Institute, 2013 and 2014

Dr. Brian Beal, University of Maine Machias, bbeal@maine.edu

2013

In 2013, using only local municipal funds, the town of Freeport initiated an historic pilot-scale shellfish management program to examine the interactive effects of predation and ocean acidification on the dynamics of wild clam populations. In April 2013, Freeport's Town Council approved $65,000 for its Shellfish Commission to undertake a three-pronged study to quantify population numbers of green crabs at selected intertidal and subtidal sites, to examine effects of green crab fencing on soft-shell clam recruitment, and to sample sediment and overlying water column pH to quantify potential threats of an increasingly acidic environment on settling clam post-larvae.

2014

Study #1: Green Crab Predator Exclusion Fencing

Beginning in early February 2014, we applied for an Army Corps of Engineers permit to undertake a fencing project at Staples Cove (lower Harraseeket River). The objectives were to determine the efficacy of fencing and netting (as intended at Little River Flat in 2013) and whether cultured soft-shell clam seed would grow and survive better in fenced plots, under netting, or in plots that were completely accessible by predators. The experimental design includes a total of twenty-eight 30-ft x 30-ft plots. Fourteen plots are surrounded by wooden fencing (see photos below), and fourteen plots have no fencing.

Study #2: Green Crab Trapping

Green crab trapping studies began the first week of May 2014. Traps similar to those used in 2013 are being used in 2014. Traps are being fished in ten locations within the Harraseeket River. At each location, five traps are set approximately 100-feet apart from each other. Five locations are in the Upper portion of the river (above the town dock), and five locations are in the Lower portion of the river.

Study #3: Adult Clams Used to Enhance Wild Clam Recruitment

Many marine invertebrates settle gregariously near their own kind, especially adults. This has been shown in barnacles, ascidians (sea squirts), tubeworms, oysters and other bivalves, but has not been shown definitively in soft-shell clams. In early May 2014, we set out a manipulative experiment at two intertidal locations in Freeport: immediately outside the trestles across Staples Cove, and at Recompence Flat. At both sites, five replicates of each of six treatments were distributed randomly in 10-ft x 10-ft plots within a 6 x 5 matrix (20-ft between rows and columns). The six treatments were as follows: 1) Plots with no clams; 2) Plots with no clams plus netting (flexible, 4.2 mm aperture) to discourage predators; 3) Plots with 1 bushel of live, commercial size clams that were hand-planted throughout the 100-square foot plot; 4) Plots with 1 bushel of commercial size clams plus netting; 5) Plots with 2 bushels of commercial size clams; and 6) Plots with 2 bushels of commercial size clams plus netting.

Study #4: Sediment Buffering for Coastal Acidification

In May 2014, we worked with Mike Doan from the Friends of Casco Bay who took sediment pH samples at five intertidal mudflats around Freeport. These included Winslow Park, Staples Cove, Cove Road, Sandy Beach/Cushing Briggs, and Recompence Flat. Ten samples were taken at each flat, and the averages ranged from 7.10 at Staples Cove to 7.8 at Recompence Flat. To determine whether sediment buffering with crushed clam shells would result in an enhancement of wild soft-shell clam spat, we chose the flat with the lowest sediment pH - Staples Cove. Of the ten samples taken at that location, pH values ranged from 6.78 to 7.47. Beginning on 18 May, we established 30 plots (6.6 ft x 6.6 ft, or 2 m x 2 m). Six treatments (5 replicates/treatment) were used: 1) 13 lbs of crushed soft-shell clam shells per plot; 2) 26 lbs of crushed soft-shell clam shells per plot; 3) No shells were added to plots -- controls; 4) 13 lbs of crushed soft-shell clam shells plus plastic, flexible netting (4.2 mm aperture); 5) 26 lbs of crushed soft-shell clam shells plus netting; and 6) Control plots with netting.

Study #5: Clam Enhancement Using Cultured Seed

In late April 2014, we established an experiment at two intertidal locations in the Upper Harraseeket River (Collins Cove, and directly across the river from Collins Cove along the Wolfe Neck shore) to determine the effects of planting density on growth and survival of cultured soft-shell clam seed under protected netting. Clams were seeded at one of two densities: 20 or 40 individuals per square foot. At each location, 40 nets (14-ft x 22-ft) were deployed and arranged in 10 groups of four nets each. A green crab trap was deployed alongside five of the groups and is being fished twice a week.

Study #6: Growing Cultured Clams to Transplantable Sizes Using an Upweller

Cultured clams are expensive, especially if a community purchases transplantable size clams (> 8 mm in shell length). However, it is possible for a community or individual to purchase small clams from a hatchery (1-2 mm in length), and to grow those clams in an upweller nursery. Because cultured soft-shell clam seed have never been grown in a nursery setting in Freeport, we wanted to see if it was possible. We began by having pieces of the upweller system built locally in Freeport.

The Town of Brunswick green crab projects – 2014
Dan Devereaux MRO/HM, Town of Brunswick

The Town of Brunswick has a few different projects going on this summer. We have an intense trapping effort in two of Brunswick's growing areas along the New Meadows River, Woodward Cove and Buttermilk Cove. This study is being funded by the Maine Coastal Program, New Meadows River Watershed Partnership, and Casco Bay Estuary Partnership. We are in hopes of identifying the best removal practices.

On a local funding front, staff at the Town of Brunswick is conducting an ongoing shoreline green crab survey. We are visiting areas along the Brunswick Coast that were identified last year as "HEAVILY populated green crab burrows" to help us better understand the population as they exist now and throughout the summer. We are also conducting soft-shell clam surveys and quahog surveys to help us better understand the impacts from the 2013 crab inundation.

What we have noticed so far this year is that there are a lot fewer green crabs present along our intertidal areas. SIGNIFICANTLY LESS. Currently our trapping numbers are meeting our targeted CPU, and based on the current conditions should be manageable if the numbers remain the constant throughout the summer. In the early spring, there were several reports of dead green crabs both in the rack and on the ocean bottom. This can most likely be related to severe winter conditions and the frigid water temperatures throughout the long winter and spring. Knowing this we are having some DNA samples taken to determine the typing of the crab we are currently catching i.e. Northern V' Southern. This will help us determine if the colder tolerant crabs from Atlantic Canada are the survivors of the 2013/14 harsh winter conditions.

We are also hoping to develop a standardized monitoring method for the future, i.e. traps per acre of intertidal, manageable catch amounts etc… If we can determine this we can begin to deploy these methods each year going forward. This will help us avoid being blindsided by explosion in the green crab populations.

The Towns of Brunswick, Harpswell and Freeport green crab projects – 2013 and 2014

Darcie A. Couture, Lead Scientist, Resource Access International

We are working with Dan Devereaux on the Brunswick sites, and we are also running trapping projects in Harpswell. We have a small predator control project at Strawberry Creek, and we have been collecting the crabs fished out of Quahog Bay as well. We are seeing fairly low green crab numbers at the intertidal sites, but we have been seeing fairly large numbers of crabs coming out of Quahog Bay - we have been collecting nearly 700 pounds each week out of that area, and the population is definitely different from what we see in the intertidal (larger crabs, different sex ratios, etc.). I have also had anecdotal reports from a recreational diver out of Bailey Island that he observed a pack of large green crabs in deeper water eating several juvenile lobsters (we all wish he has been armed with a video camera). I am concerned that we may be seeing a much smaller visible impact in the intertidal, while there is still a fairly healthy and robust population in the deeper waters, which may be having a different impact on our coastal environment than what we have all geared up to watch after last year (eelgrass damage and predation on bivalves). I would hate for everyone to get a false sense of security after this season and call off the alert on green crabs in the intertidal zone, while we are missing a different kind of threat/impact going on subtidally.

As part of another MTI cluster grant we're working on, we have collected and sequestered gravid green crab females, and captured images of newly hatched zoea on a FloCAM in the lab, so we have an image library to use with the instrument that will be able to detect them in local samples if we run any through the system.

Summary of the Maine Coastal Program's engagement regarding invasive green crabs

The primary role of the Maine Coastal Program (MCP) regarding green crab activities is to work collaboratively with networked partners and provide funding for conducting outreach, research, and monitoring. In conjunction with other organizations, the MCP helped Maine Sea Grant plan and sponsor the Maine Green Crab Summit, which was held on December 16, 2013, at the University of Maine at Orono. This one-day meeting focused on discussing the problems caused by green crabs and brainstorming potential management strategies and commercial solutions. More than 280 people registered for the meeting and many more participated remotely. The attendees represented various sectors from all over New England and Atlantic Canada, including the clamming industry and other commercial fisheries; aquaculture; academia; local, state, and federal government agencies; elementary school to graduate level students; and non-profit organizations.

In 2013, the MCP awarded the Town of Freeport a Shore and Harbor Planning Grant (PI: Darcie Couture, Resource Access International LLC) to conduct experiments on mitigating local ocean acidification and decreasing green crab abundance on clam flats. To understand natural and artificial sediment buffering capacities, treatment sites included locations with abundant natural shell hash and added pulverized shell. At both control and treatment sites, sediment pH was measured, as well as total alkalinity and dissolved inorganic carbon in the sediment and the overlying water column in order to calculate saturation state. After two months, an increase in pH was observed at the site where pulverized shell hash had been added, as compared to the control site. Additionally, the researchers attempted to decrease the local green crab abundance by installing exclusionary fencing across Recompense Cove, predator pens in Little River Cove, and crab traps. Initially they found that crabs inside the pens were generally smaller and less abundant. However, pens and exclusionary fencing were damaged by weather and tidal events, so they did not maintain their integrity over the course of the field season. It was concluded that revised fencing design and implementation would be necessary in future crab exclusion projects. Catch per unit effort (CPUE) also did not decrease over the course of the experiment, but due to inconsistent methods, it is unclear how beneficial these methods were at decreasing local crab abundance.

In February 2014, the MCP funded the Town of Brunswick, through the Coastal Community Competitive Grant program, to implement a management scheme for green crabs in two coves in Brunswick. After observing declines in productivity of commercially harvested soft shell clam flats, Dan Devereaux, Brunswick's Marine Resource Officer, and Darcie Couture, founder of Resource Access International, designed a project to deploy crab traps and predator fencing to decrease the abundance of green crabs on historically productive clam flats. This project is currently in progress and is expected to conclude in May 2015. However, in stark contrast to summer 2013, initial reports of green crab abundance have been very low, so it has been impossible to estimate population size through mark-recapture methods and difficult to assess the efficacy of the traps and predator fencing.

Island Institute Green Crab Monitoring and Education-
Susie Arnold, Marine Scientist at the Island Institute, sarnold@islandinstitute.org or
Ruth Kermish-Allen, Education Director, rallen@islandinstitute.org

In the fall of 2013, the Island Institute engaged in a green crab monitoring and education project with five island schools in Maine through its National Science Foundation funded WeatherBlur Project. The WeatherBlur (WB) Project is a cutting-edge online citizen science platform, co-created by the Island Institute with an active participant advisory board. WB successfully engaged K – 8 students, teachers, fishermen, and scientists in a non-hierarchical learning community to explore the local impacts of weather and climate in coastal communities in Maine and Alaska. WB was implemented in classrooms in two ways: through submission of daily weather *observations* through a data entry app and through collaborative *investigations*. The fall investigation with the Maine island schools (North Haven, Cliff, Chebeague, Long, and Peaks islands) involved working with island lobstermen to deploy ventless lobster traps (DMR special license #201-94-00). The original objective of the project was to study what other marine life lives with lobsters on the sea floor and how this has changed over the life times of the participating fishermen. Each school deployed one trap off of their island ferry pier at approximately 10-15 ft depth, and the participating island lobsterman deployed another trap in deeper water (6-12 fathoms on hard bottom). Each trap was baited with four average size herring and hauled twice per week from October 1 to December. Traps were equipped with temperature loggers (VEMCO Minilog-II-T as recommended by Jim Manning from the NOAA Emolt project).

After the first couple hauls, the investigation quickly turned into a “green crab investigation”. The students were surprised and fascinated that the majority of their catch, by far, consisted of green crabs (except for Cliff Island). They recorded data on abundance, size, and sex in google docs and posted figures and discussed their findings on the WeatherBlur online platform at www.weatherblur.com. To find results on this investigation on the site, click on Investigations- Bycatch Investigation or go straight there by clicking here: www.weatherblur.com/#/investigation/1634. Throughout the project, participating WB scientists, including Darcie Couture and her staff at Resource Access International helped to answer students’ questions about sex ratios, habitat preferences, predator/prey relationships, etc.

In culmination of their fall project, the schools put together a poster for presentation at the December Green Crab Summit in Orono. The North Haven Community School teachers and students attended the Summit and displayed their results from North Haven with a poster, a video of their methodology, as well as artwork they created related to the green crab invasion.

To share results amongst the schools, the Island Institute hosted a virtual poster session during which each school presented their results during an online video conference. You can watch the student presentations here:
http://islandinstitute.adobeconnect.com/p8gj1ntu3th/. I recommend checking out the

following highlights: Chebeague Island School at minute 5:45 and North Haven's presentation at 31:30.

Several YouTube videos and pictures are available that document this project, as well as the raw data recorded by the students. Check out this underwater footage off of Chebeague www.youtube.com/watch?v=SXjH8AJ6xiM&feature=youtube; North Haven www.vimeo.com/77813637; and Long Island www.youtube.com/watch?v=Q9sRtrttfdE. For photos from all of Chebeague's hauls, see: http://www.chebeague.org/school/2013/weatherblur/

The Eastern Maine Skippers Program - 2014
Christina Fifield - EMSP Coordinator

The Eastern Maine Skippers Program which consists of 45 students throughout 8 high schools will be studying the green crab issue in their cumulative project this academic year. The EMSP is coordinated by Penobscot East and offers student fishermen an authentic learning opportunity. The project “The Green Crab Invasion” will have our students asking “How can (the impact of) the green crab population be controlled in a way that conserves (sustains) our marine ecosystem and encourages new industry(s) from the green crab products.” Our project seeks to find a use for the crabs that could become a new emerging industry and to serve as a population control mechanism. The students will be taking on such assignments as:

- Communicate with local and state agencies in regards to regulations/licensing
- Testing control methods (traps vs. fences)
- Exploring uses (chicken feed, compost, etc.)
- Biological impact analysis of control methods
- Economic viability of developed/explored uses

The student’s final project has yet to be determined, but could include a food product, compost, animal feed, or some other creative solution. They will explore marketing options and develop business plans for these potential uses and present their work to an authentic audience.

Green Crab Mitigation Competition (draft summary provided in August 2014)
Goldfarb Center for Public Affairs and Civic Engagement - Colby College

Executive Summary
Green crabs are an invasive species that threaten the soft-shell crab industry and have the potential to greatly damage the lobster fishing industry along the coast of Maine. The Green Crab Mitigation Competition, sponsored by the Goldfarb Center of Public Affairs and Civic Engagement, and CEI, is designed to showcase student plans to ease or eradicate the green crab problem. It will be held at Colby College in February 2015, and will be open to undergraduate students from throughout Maine. These students may work individually or in teams, with the latter likely more effective given that complexity of the problem and difficulty of finding solutions.

Each individual or team will develop a detailed plan at their college or university, and pitch the proposals to a panel during the completion day at Colby. The event at Colby will conclude with a plenary dinner, a keynote address, and the presentation of awards.

The winning team will receive $1,000, followed by a second place prize of $500, and two honorable mentions of $250.

How the Competition Will Work
Notices will be sent in early September, 2014 to universities and colleges throughout the state inviting undergraduates to participate in the competition. Additional recruiting efforts will take place up until the October 4 registration deadline.

This will give each team of participants roughly 4 months to do research, develop their proposal, and hone their presentation. The proposals can be an entrepreneurial plan, an environment government policy, or a combination of both.

Each mitigation team will be advised to consider the following:

- short and long term goals of the plan;
- techniques, products or mechanism;
- any potential markets, including an estimated price, delivery system, and so forth;
- element a business plan, including initial capital, expenses, product line, partnerships, etc.;
- economic, cultural and environmental implications;
- long term ramifications.
- potential role of state and local governments

Each team is required to submit a two-page summary of their plan before the competition. The judges will use these summaries to prepare questions for the on-campus competition.

On the day of the competition, each team will be given the morning to prepare their presentation and the afternoon to present them to the judges. Each team is free to decide the best way to pitch their proposal.

Competition Timeline (draft)
Students will have approximately 4 months to prepare for the competition. The following is the proposed timeline for the event:

Early September 2014 – Invitations are sent to Maine universities and colleges inviting their undergraduates to the Green Crab Mitigation Competition at Colby College. Follow-up about the competition by emails and phone calls from the Goldfarb Center at Colby College

October 4 – RSVPs are due. Teams register on the website (TBD)

January 23 – Each team is required to submit their two-page summary.

February 8 – Competition at Colby College

Judging
Entries will be judged by volunteer judges from agencies working on the problem and a member of the Colby faculty. Judges will use the following criteria: scientific/technical accuracy; feasibility; quality of research/methods/procedures; creativity/originality; and quality of conclusions and presentation.

The entry should clearly illustrate how the proposal intends to confront the increasing green crab population and mitigate the effects of this explosion on Maine's lobster and clamming industries.

Judging Rubric
Scientific/Technical Accuracy
- The problem is stated clearly and unambiguously
- The solutions presented are grounded in scientific principals
- Scientific and/or technical facts and principles are correct and stated accurately throughout the proposal

Feasibility
- The solution addresses practical application/ potential impacts both negative and positive
- The solution is cost effective
- The solution will not harm other species
- The solution does not require unusual skills or experience

Quality Of Research/Methods/Procedures
- Adequate data were collected to support conclusions

Quality of Written Proposal and Presentation

- The proposal is well-written and engaging
- References are provided for all sources
- Graphics, images, charts/tables, are all clearly labeled
- Consistent style is used throughout
- The presentation is engaging, creative and professional
- Has natural delivery and is articulate; projects enthusiasm, interest, and confidence; uses body language effectively
- Uses slides effortlessly to enhance presentation; presentation is effective even without media

Quality Of Conclusions

- Data and results are clearly stated
- Conclusions are insightful and flow logically from the data
- Clearly communicates, organizes and synthesizes source information in a manner that supports project purposes

iv. Canada

Green Crab Monitoring, Mitigation and Research in Newfoundland
Cynthia McKenzie, Ph.D., Research Scientist- Science Branch, Fisheries and Oceans Canada, Northwest Atlantic Fisheries Centre

Monitoring – Green crab were first discovered in North Harbour, Placentia Bay in August 2007. Genetic analysis indicated that these populations probably originated from near Halifax (Blakeslee et at 2010). We conducted a rapid assessment survey in September throughout the Bay to determine the abundance and distribution. See attached 2007 map. Since that time they have spread throughout Placentia Bay, along the west coast of Newfoundland and more recently along the south coast in Fortune Bay. Refer to 2013 map. We are currently working on a project to determine the genetic populations from the different areas in Newfoundland. In short the spread has been quite spectacular over the six years and the numbers in some areas are very high. We use Fukui traps -this is standard for Fisheries and Oceans Canada and all green crab monitoring programs – Pacific, Gulf, Maritimes, Quebec and Newfoundland. Our standardized protocol is a 24 hour soak and we use herring for bait. Typically the traps are set along the coastline in shallow (<3 m water, particularly near eel grass beds). In Newfoundland the preferred habitat seems to be areas around eel grass beds with what is called here “puck mud” basically muddy bottom. Also we have found them in areas that are protected, mud flats, with a stream nearby. In some cases we have the traps saturated in 30 minutes or ca. 200 crabs per trap.

Mitigation – Following the discovery in 2007 and the survey we held a Green crab mitigation workshop in early 2008 with stakeholders including the fish harvesters, researchers, federal and provincial representatives. At that time we discussed several option but decided on mitigation through trapping. The fish harvesters put together a proposal and that summer in 2008, 2 fish harvesters working for 20 days each with 20 traps harvested 25,000 pounds of green crab (est. 350,000 crabs). The catch per unit effort did go down 0.9 to 0.46 lbs/trap/hr in 2008 and 0.41 to 0.12 lbs/trap /hr in 2009. Also the native rock crab numbers increased in areas where focussed trapping took place. Funding did not allow for the continued mitigation effort.

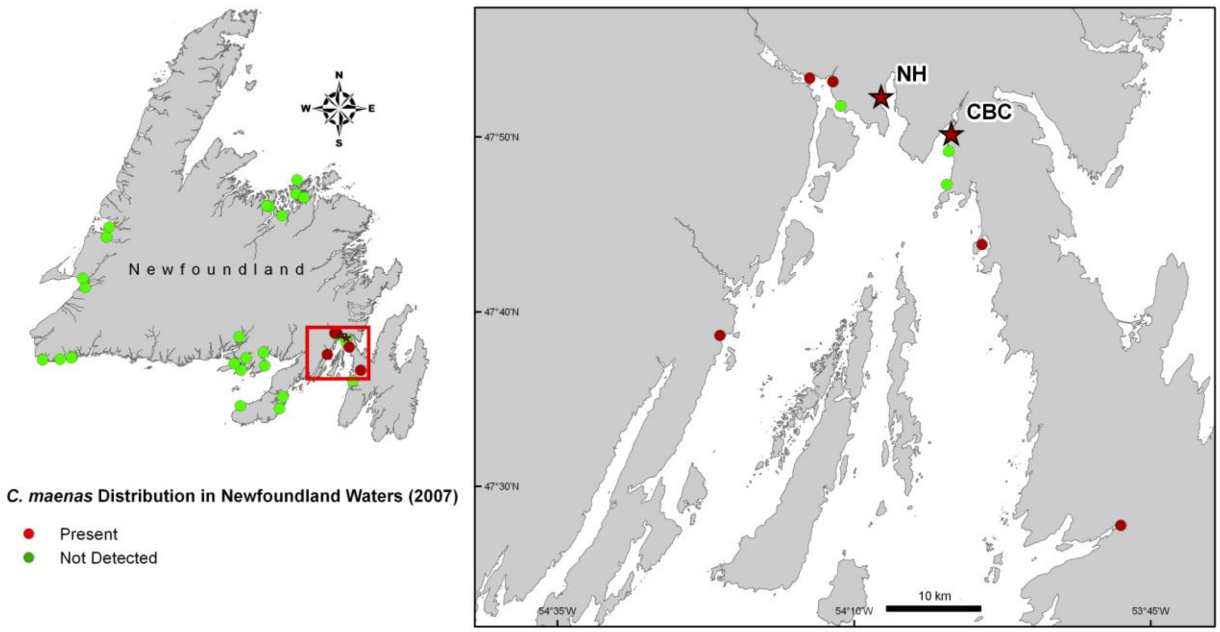
In March 2010 the Government of Canada held a regional Canadian Sciences Advisory Assessment for green crab entitled “Ecological assessment of the invasive European green crab (Carcinus maenas) in Newfoundland 2007 to 2009”. The assessment included what we knew to date on ecological impacts and concerns (eel grass and lobster) and what we knew regarding mitigation. We also included information from other areas of Canada, Basin Head and Keji (early stages of their program) and results from California mitigations in Bodega Bay.

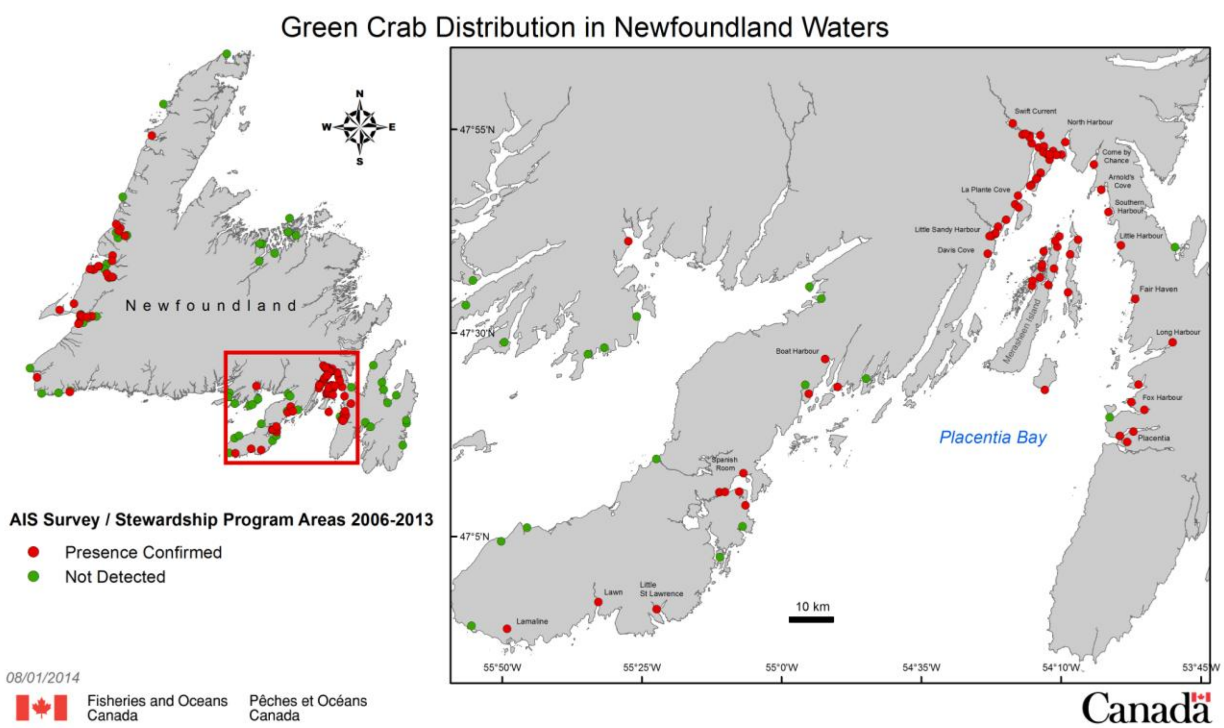
We have recently received funding from Vale Inco (through a marine stewardship program) and the Federal and Provincial governments. In late August and September, DFO science and the fish harvesters will conduct a targeted mitigation in Placentia Bay to remove green crab. We currently plan on the equivalent of 300 trapping days (ten harvesters for 30 days X 30 traps). The green crab will be composted (a company here is working on organic compost as a product) and also potentially for chitin processing. We do not allow green crab to be used as bait as we do not want to spread the crab to other areas. Current experimental licences require that no live green crab be transported from the bay where it was collected. They must be destroyed on site. We will be studying the CPUE, size and bi-catch.

Research - We have focussed our research on impact of green crab on shellfish (Matheson & McKenzie 2014, J. Shellfish Research in press "PREDATION OF SEA SCALLOPS AND OTHER INDIGENOUS BIVALVES BY INVASIVE GREEN CRAB, CARCINUS MAENAS, FROM NEWFOUNDLAND, CANADA"), eel grass (Matheson et al in prep. "Linking eelgrass decline and cascading impacts on associated fish communities to European green crab invasion") reproduction (Best, K., McKenzie, C.H. and Couturier, C. 2009 Early life stage biology of a new population of Green crab Carcinus maenas in Placentia Bay: Implications for mussel culture in Newfoundland. AAC Spec. Publ. No. 15:48-50) and aggression (2011. Rossong, M.A., Barrett, T.J., P.A. Quijon, P.A., Snelgrove, P.V.R., McKenzie, C.H. and Locke, A. Regional differences in foraging behavior and morphology of invasive green crab (Carcinus maenas) populations in Atlantic Canada. Biological Invasions DOI 10.1007/s10530-011-0107-7).

We have also conducted mark recapture experiments however the numbers have been so high and the system so open it has been difficult to estimate the population. We have also tracked them using acoustic tags to determine movement (overwintering) and interactions with other species, eg. rock crab and lobster.

One of our colleagues at the University of New Brunswick (Myrian Barbeau) is leading an Atlantic wide project on green crab where we propose to investigate many aspects of green crab including impact, usages and modelling of populations and spread. (This project has been submitted to NSERC – Canadian funding agency for funding). My area of interest in the project is green crab – lobster interactions. Our fish harvesters are very concerned about the effect green crab will have on lobster catch, juvenile lobster and eelgrass as habitat.


N
W
E
S
Newfoundland
C. maenas Distribution in Newfoundland Waters (2007)
Present
Not Detected
NH
CBC
47°50'N
47°40'N
47°30'N
54°35'W
54°10'W
53°45'W
10 km


Green Crab Distribution in Newfoundland Waters
N
W
E
S
Newfoundland
AIS Survey / Stewardship Program Areas 2006-2013
Presence Confirmed
Not Detected
08/01/2014
Fisheries and Oceans Canada
Pêches et Océans Canada
Swift Current
North Harbour
Come by Chance
Arnold's Cove
Southern Harbour
La Plante Cove
Little Sandy Harbour
Davis Cove
Little Harbour
Fair Haven
Long Harbour
Boat Harbour
Fox Harbour
Placentia
Placentia Bay
Spanish Room
Lawn
Little St Lawrence
Lamaline
10 km
47°55'N
47°30'N
47°5'N
55°50'W
55°25'W
55°0'W
54°35'W
54°10'W
53°45'W
Canada

Green Crab Invasion at Kejimkujik National Park Seaside – Nova Scotia
Chris McCarthy, Resource Conservation Manager, Mainland Nova Scotia Field Unit, Parks Canada,

Problems at Kejimkujik National Park Seaside have resulted from a recent invasion of a new strain of invasive European green crab from northern waters off Iceland. This is a very aggressive and cold tolerant species that has been causing major problems for Kejimkujik's estuaries. This crab is known as an ecosystem engineer and can cause major, cascading effects in ecosystems. In our case this has resulted in the mass destruction of our eelgrass beds and other native biodiversity including soft-shell clams. They rip up eelgrass which is the primary seagrass and an important nursery habitat for marine species. It also is important for buffering erosion effects of storm surges on our shoreline. Soft shell clam are the favorite food of green crabs in our area and the most prolific bivalve in our estuaries. By 2010, the total eelgrass in our estuaries was reduced to 2% of its original distribution and most of the smaller soft shell clams up to 45mm were missing.

Parks Canada has a mandate to maintain and restore ecosystems so in 2010; Kejimkujik began a coastal restoration program to control green crab numbers in collaboration with its partners and volunteers. DFO, local organizations and local fisherman. We have fished green crabs to below thresholds for ecosystem recovery (less than 15 crabs CPUE -now being maintained at about 8 and these are significantly smaller in size) and have transplanted eelgrass successfully to enhance restoration of the estuary. Native species (such as lobster, rock crabs, and the pipe fish are returning in high numbers (by-catch and monitoring results) as detected through our ecological integrity monitoring program. The effects of the invasive crab have been mitigated due to Parks Canada's efforts and we continue to contribute crabs for developing uses such as lobster bait, food product development and special uses. This work has been accomplished in one of the two principal estuaries at Kejimkujik Seaside, the other left as a control. Next year we plan to expand operations to the control estuary at St. Catherine's River to get the green crab under control there as well.

Last year we incidentally caught 14 blue crab in our green crab traps late in the year. So far this year we have caught over 300 and population estimates from swim surveys indicate there could be as many as 12,000 in Little Port Joli estuary. The only publication we are aware of on blue crabs in Nova Scotia indicates there were 6 specimens obtained at Cow Bay near Halifax in 1903. They likely arrived here in warmer ocean temperatures of 2012 as larvae and have taken up residence in our estuaries at Kejimkujik National Park Seaside. So far they appear to have few negative effects on native park resources. They are establishing in both estuaries. They occur mostly in fine mud bottoms near freshwater inputs and have been observed eating green crab and chasing them. They do not appear to be having any major effects on eelgrass and are not spending much time near the white sand flats where our larger clam populations reside, This is considered a range expansion of a native species and these crabs will be protected along with other native species.

v. Massachusetts and New Hampshire

Great Marsh Green Crab Depletion Program
Kelly A. Whitmore, Marine Fisheries Biologist, Invertebrate Fisheries Project
Massachusetts Division of Marine Fisheries

The Massachusetts Division of Marine Fisheries (MADMF) will administer and oversee the Great Marsh Green Crab Depletion Program to remove European green crabs (*Carcinus maenas*), with the goal of improving shellfish, eelgrass, and fishery resources along Massachusetts' upper North Shore. Several fishermen will be contracted to trap and remove green crabs from locations such as Plum Island Sound, Essex Bay, and Annisquam River estuaries. The contracted fishermen will be supplied with standardized fishing gear (approx. 200 traps total) and their landings will be tracked so that CPUE may be monitored. The program includes a pilot effort to develop the green crab bait market to prospectively enhance in-state utilization of product in the conch and tautog fisheries. Developing the bait market should encourage more sustainable removal of green crabs. Other research being conducted under the program includes identification of factors important for improving success of Great Marsh eelgrass transplant efforts in the presence of green crabs, as well as examination of trapping efficiency, trap use by sex and reproductive condition, and catch by depth to improve trapping efficacy. The Green Crab Depletion Program was funded at $133,000 for the 2015 fiscal year by the Massachusetts state legislature, with chief goal of removing green crabs from the Great Marsh. The bulk of funds will go toward purchase of trap gear, trapping contracts, and market development. Research institutions receiving funds from this program include the Merrimack Valley Planning Commission/MassBays National Estuary Program and Salem State University. Trapping is planned to commence in fall 2014 and continue through spring 2015.

Survey of Green Crabs in Salem Sound, Massachusetts

Alan M. Young, Salem State University

I have been conducting a survey of the green crab population in part of Salem Sound since last summer. I use box traps manufactured and sold by Ketcham Supply, New Bedford, MA that are constructed of 1" x ½" (23 mm x 10 mm) vinyl coated mesh and measure 18" x 24" x 9"H (46 cm x 61 cm x 23 cm) with a round 3" (76 mm) diameter PVC pipe entrance in the top. Traps are baited with whatever fish carcasses I can obtain from local fish markets, mostly swordfish and salmon but occasionally halibut or flounder. A single trap is deployed off docks at 5 locations in Salem and Beverly Harbors and the Danvers and Bass River estuaries once per month; water depth varies from less than 2 meters to nearly 4 meters at low tide. After a soak of 48 hours crabs are retrieved and frozen for later data collection; depending upon the number of crabs caught, the trap is either removed or allowed to soak for an additional 48 hours.

A crab bait preference study I conducted this week indicates that herring is by far the preferred bait. The bait ranks with crab catches for a 17-hour soak in parentheses were as follows: herring (258), salmon (70), swordfish (58), halibut (42), crushed clams & mussels (40), flounder (13). Apparently the oils in herring attract more crabs than do non-oily fish.

Crabs collected are later sexed and measured (maximum carapace width from tip to tip of the 5th spines) and ventral surface color is determined using a 12-point color index template constructed from Walmart paint color swatches ranging from green to yellow to orange to red.

To date we have collected a total of 3600 crabs from July 2013 through August 2014. Approximately 25% were males and 75% were females. This sex ratio was maintained throughout sites and months except in March, May and June when the proportion of males increased to 64, 41, and 45% respectively. The greatest female percentages occurred in October (82%), November (80%) and April (85%). Only 11 out of 2700 females (0.4%) were gravid. Catch per unit effort (CPUE) for a 48-hour period varied among months, with no crabs caught in February and very few in January & March and the most crabs caught in September, October, and November (mean 48-hour CPUE for all 5 sites during those 3 months of 51-56 with a high of 120 at one site in October). These catch numbers are much less than those reported from areas north of here and especially from New Hampshire and Maine, indicating that the population of green crabs in this area of Salem Sound is much less dense than in those regions. It is meaningless to report a mean carapace width since crabs smaller than 25 mm can escape easily (we do catch some if we are quick enough to grab them when they exit the trap but before they make it to the edge of the dock). The greatest number of crabs fall in the 45-60 mm size category, with the 30-45 mm category being the next most numerous. We have caught only 36 crabs that exceeded 70 mm (2 ¾") carapace width and 5 that exceeded 75 mm (3") with the largest caught being a 77 mm male in August 2013 and a 77 mm female in November.

A crab's ventral surface coloration progresses after molting from green to yellow to orange to red due to pigment photo-degradation. When a crab molts the color reverts back to a green or light yellow and begins the progression again. Crabs in their terminal molt get progressively darker red and often have fouling organisms such as barnacles and slipper shells attached, as well as pronounced shell necrosis. We have caught roughly equal numbers of crabs in each of our broad color categories (green, green-yellow, yellow, orange, red) with green and yellow crabs more common in the spring and early summer months and orange and red crabs more common in late summer and fall moths. No crabs smaller than 30 mm were red and very few were orange or yellow; almost all were green or green-yellow while very few crabs larger than 60 mm fell into the green category.

In summary, the population density of green crabs in the area of Salem Sound that I am surveying is much less than that reported for regions north of here. The greatest numbers of crabs are caught in September, October, and November. Approximately 75% of all crabs caught are females. Very few gravid females are caught. The largest crabs caught in this area are considerably smaller than the largest crabs caught in regions north of here, with very few crabs exceeding 70 mm and none exceeding 77 mm carapace width. The ventral surface of newly molted crabs is green if small and green to yellow if larger and then progresses from yellow to orange to red unless the crab molts again; crabs in their terminal molt get progressively darker red and often have fouling organisms attached to the carapace.

Note - - We will be conducting a comparison of different trap efficiencies over the next couple of months.

New Hampshire Green Crab Monitoring and Research

Elizabeth A Fairchild, PhD, Assistant Research Professor, Dept. of Biological Sciences
School of Marine Science and Ocean Engineering, University of New Hampshire

Green crabs have been a concern for us in NH too. We have noticed via other university research projects, primarily lobster trap-based studies and fisheries enhancement experiments that green crab prevalence and abundance have been on the rise over the past decades. In fact, we discovered that green crabs were to blame for high post stocking fish mortality and repeated efforts to mitigate or provide alternate fish release strategies to avoid high concentrations of green crabs proved near impossible (see Fairchild et al. papers). This has led to a concerted effort to understand and document green crab populations in NH waters, and how they affect other economically and ecologically important species such as lobster, oysters, clams, eelgrass, and juvenile estuarine fishes. In 2009-2010 a dedicated green crab trapping study was conducted in the two NH estuaries, Great Bay and Hampton-Seabrook to document temporal and spatial crab distribution as well as to understand the timing of the molt cycles. The Fulton et al. papers report those results. Although dedicated green crab studies are not active at the moment, crab populations have been and continue to be monitored as bycatch in active lobster studies; green crab density has been increasing. Future studies we plan to do include looking at the behavioral and size-hierarchy predator-prey interactions between green crabs and lobsters, blue crabs (now in NH estuaries more frequently and perhaps as residents), and oysters (growing aquaculture sector in NH estuaries), as well as the role eelgrass plays in green crab populations. No green crab mitigation occurs in NH waters as of now but many parties are interested in green crab removal and uses. Green crabs increasingly are being used as bait in other fisheries (i.e. lobster in Canada, conch in MA), and there is an interest in exploring their use in other industries (feed in aquaculture and poultry sectors; see Fulton & Fairchild 2013).

FAIRCHILD, E. A., N. RENNELS, and W. H. HOWELL, 2008. Predators Are Attracted to Acclimation Cages Used for Winter Flounder Stock Enhancement, Reviews in Fisheries Science, 16(1–3):262–268

Fairchild E.A., J. A. Sulikowski, N. Rennels,WH. Howell, P. C. W. Tsang, 2009. Effects of moving acclimation cages before release of cultured fish: alternate release strategies for a juvenile winter flounder Pseudopleuronectes americanus stock enhancement effort, Aquaculture Research,1-5

Fulton B.A., E. A. Fairchild, 2013. Nutritional Analysis of Whole Green Crab, *Carcinus maenas*, for Application as a Forage Fish Replacement in Agrifeeds, Sustainable Agriculture Research; Vol. 2, No. 3

Fulton B.A., E. A. Fairchild and R. Warner, 2013. THE GREEN CRAB *CARCINUS MAENAS* IN TWO NEW HAMPSHIRE ESTUARIES. PART 1: SPATIAL AND TEMPORAL DISTRIBUTION, SEX RATIO, AVERAGE SIZE, AND MASS, JOURNAL OF CRUSTACEAN BIOLOGY, 33(1), 25-35

Fulton B.A., E. A. Fairchild and R. Warner, 2013. *CARCINUS MAENAS* (LINNAEUS, 1758) IN TWO NEW HAMPSHIRE ESTUARIES. PART 2: ASSESSMENT OF AVERAGE INTERMOLT PERIOD, JOURNAL OF CRUSTACEAN BIOLOGY, 33(3), 339-347

c. Summary of Results from Harvester Survey (2014)

Introduction

European green crabs have long inhabited the Gulf of Maine (*Carcinus maenas*) (Rathbun 1905, Telport and Somero 2014). However, in recent years green crab populations have increased dramatically in some parts of the Maine coast, resulting in impacts to coastal habitats and resources (particularly shellfish species). First, in the 1950s and again in the mid-2000s, green crabs surged in numbers coinciding with periods of abnormally warm ocean temperatures (Welch 1969). Although this trend reversed in the 1960s and may have started to reverse after the cold winter of 2013, the future trajectory and long-term impacts of green crabs are largely unclear.

Formed in early 2014, the Maine Green Crab Task Force designed and carried out a survey of Maine harvesters and growers to acquire feedback and to gain insight into the recent occurrence and impacts of green crabs in Maine. The survey goals were to 1) determine whether harvesters and growers currently encounter green crabs, 2) characterize whether harvesters and growers have observed changes or impacts from local populations over the last several years, and 3) determine whether Maine harvesters and growers are engaged in successful control measures that could be implemented at a larger scale. Methods and preliminary results are summarized below to inform the Green Crab Task Force Report and future policy-management decisions.

Methods

The survey was distributed to the Lobster Zone Councils, the Maine Aquaculture Association, the Municipal Shellfish Committees, and the DMR advisory councils (shellfish, lobster, urchin and scallop). In early August, the questionnaire was mailed via state email lists to roughly 2000 potential respondents and responses were analyzed to quantify the knowledge and perception of coastal lobstermen, shellfish harvesters/growers, draggers/divers, and marine worm harvesters.

Results

Demographic Information

Out of roughly 2000 requests sent, we received 52 respondents (a 2.6% response rate). Of those respondents, the majority held a commercial lobster license, a recreational lobster license or municipal shellfish permit (32.8%, 39.1% and 18.7%, respectively; Figure 1). A few marine worm harvesters and commercial dive/drag license holders did respond, but accounted for a comparatively low percentage of respondents (4.7% and 3.1%, respectively). Nearly all respondents harvest in Maine State waters with less than 4% fishing outside the 3nm limit (Figure 2).

Are harvesters currently encountering green crabs?

Of respondents, 84.6% encounter green crabs while harvesting (Figure 3). Collectively, respondents observe green crabs during all four seasons, and in many coastal environments. However, green crabs seem to be most frequently observed from summer to fall, in soft mud habitats and in waters less than 60ft (Figure 4-7). Compared to previous years, harvesters seem to be encountering green crabs more frequently in recently years. Responses suggest that lobstermen and municipal shellfish harvesters, in particular, have seen drastic increases in green crab populations in the years since 2012 (e.g. from 40% to 60%; Figure 8).

Are harvesters observing impacts from green crabs?
Of respondents who do encounter green crabs, many reported or suspected seeing negative effects of green crab populations to their target species (36.5%), including evidence of predation on shellfish, eelgrass degradation and spatial displacement of lobsters at certain times of the year (Figure 9). However, most respondents were either unsure (17.3%) or had not seen negative impacts to date (38.6%). Most respondents have not seen positive impacts from green crab (59.6%), although one respondent did report seeing seabirds consume green crabs (Figure 9).

Are harvesters engaged in successful control measures?
Most respondents have not altered their harvesting behaviors either to control or avoid potential impacts (51.9%), however some respondents have begun to change their target areas, shift their target depth, shift bottom type or even pursue other fisheries in response to growing populations (Figure 11). Although many have not seen impacts from green crabs, 69.2% of respondents were concerned about the effect of invasive green crabs and the majority of respondents were in favor of Maine agencies or industries developing solutions either to reduce or control populations (Figure 12-14).

Discussion and Conclusions
This mail survey of Maine harvesters and growers is a good preliminary snapshot of the perception and attitudes of coastal harvesters toward European green crabs. Although the response was lower than expected, 52 is a reasonable sample size, bearing in mind the short response timeframe (30 days) and the season (summer, when harvesters are most active). We may not be able to draw conclusions representative of all harvester groups, particularly for marine worm harvesters and drag/dive license holders whose response was low. However we can make some definitive statements about the recent occurrence and recent impacts of green crabs in Maine from the perspective of shellfish harvesters and Maine lobstermen.

First, given that 86% of respondents encounter green crabs it is apparent that they are indeed abundant in places along the Maine coast. From 2012 onward, many commercial lobstermen and shellfish harvesters have observed large population increases in green crabs which corroborates recent trapping studies and anecdotal accounts. Second, many respondents have observed negative impacts from green crabs, suggesting that some form of action to reduce, exclude or capitalize populations is necessary. Third, the majority of survey respondents are concerned for the long-term trajectory and have already taken steps to protect the stability of their resource. An overwhelming majority are also in favor of Maine agencies, businesses and fishermen working together to find an agreeable solution.

Acknowledgements

The Maine Green Crab Task Force wishes to thank the many respondents who participated in the survey. The Task Force also acknowledges the Department of Marine Resource staff, Lobster Zone Councils, the Maine Aquaculture Association, the Municipal Shellfish Committees, and the DMR advisory councils, and others who helped distribute this survey.

Figure 1: Percent response by license type out of 52 respondents.

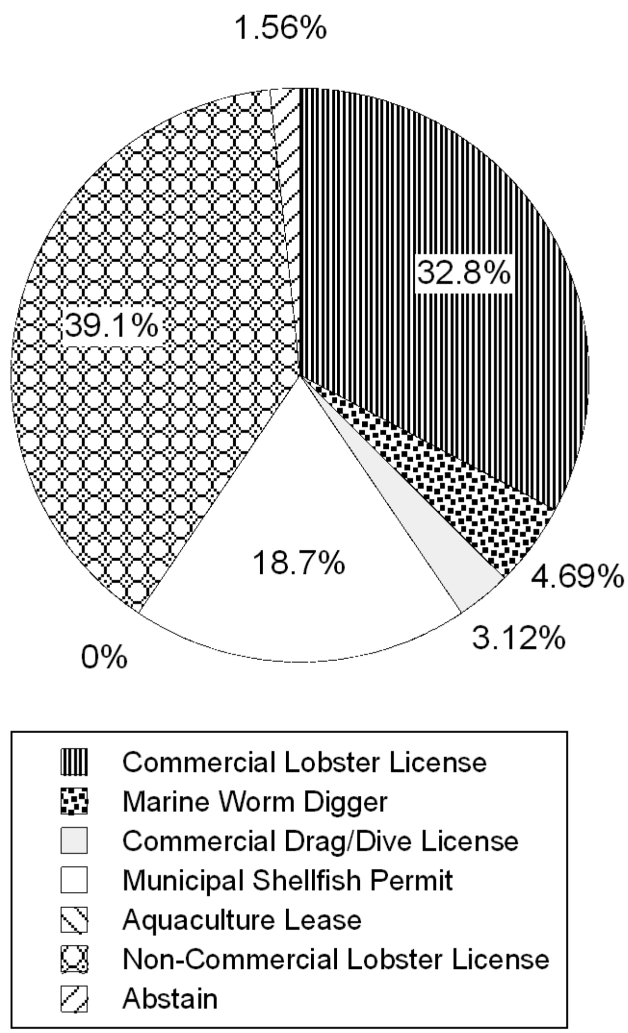


Figure 2: Harvest area of respondents overall (A) and by harvester license type (B).

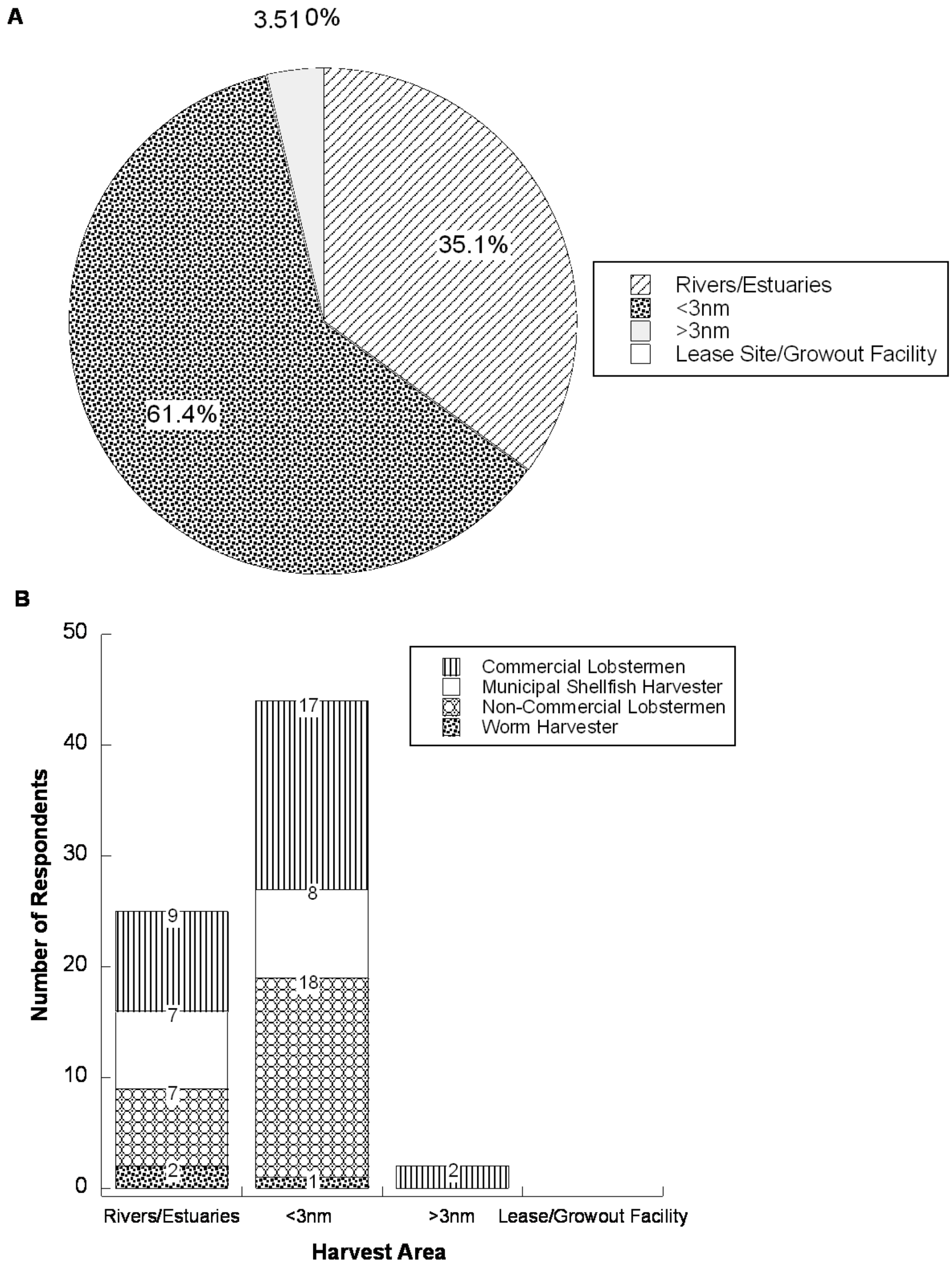


Figure 3: Do you encounter invasive green crabs while harvesting? Responses reported as a percentage.

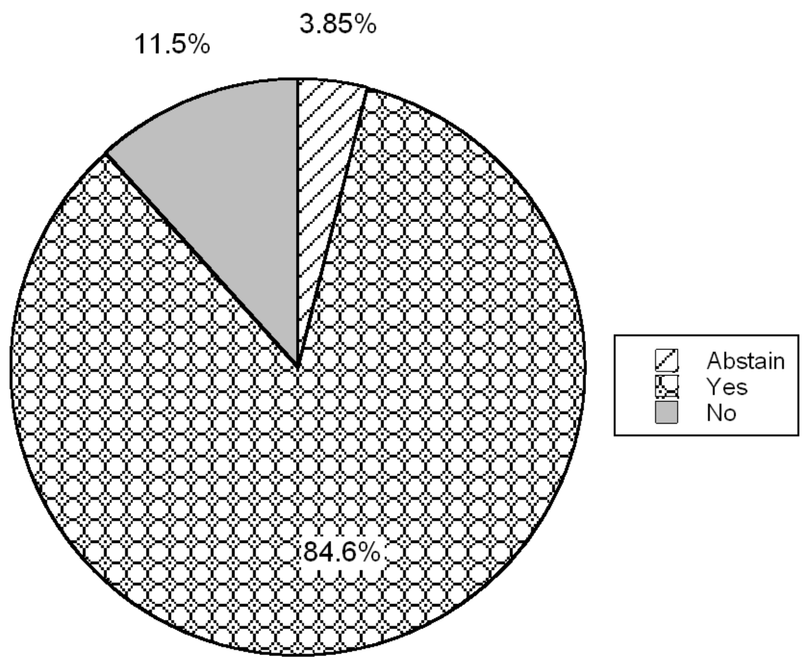


Figure 4: During which seasons do you observe invasive green crabs while harvesting? Responses reported as a frequency distribution.

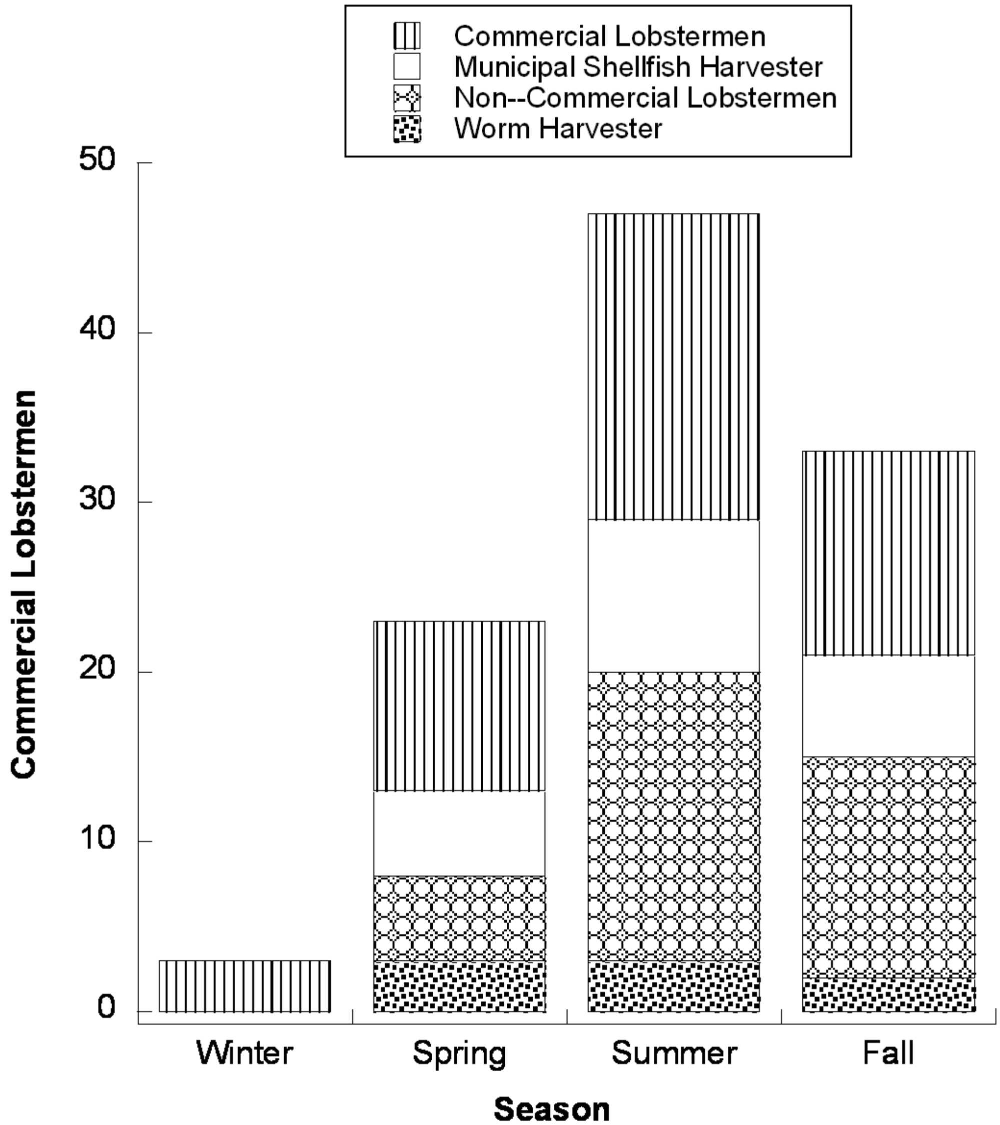


Figure 5: On which bottom type(s) do you observe invasive green crabs while harvesting? Responses reported as a frequency distribution.

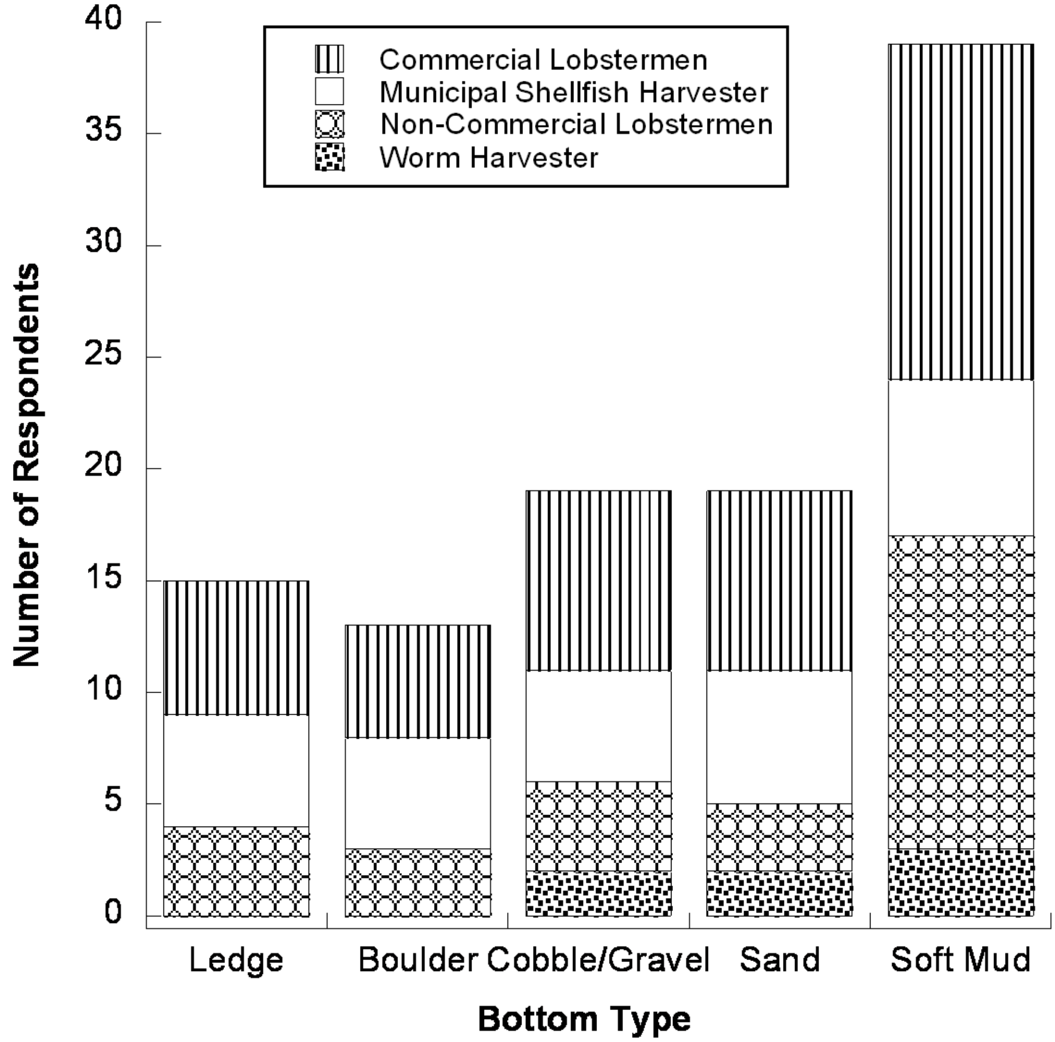


Figure 6: At which depth(s) do you encounter invasive green crabs? Responses reported as a frequency distribution.

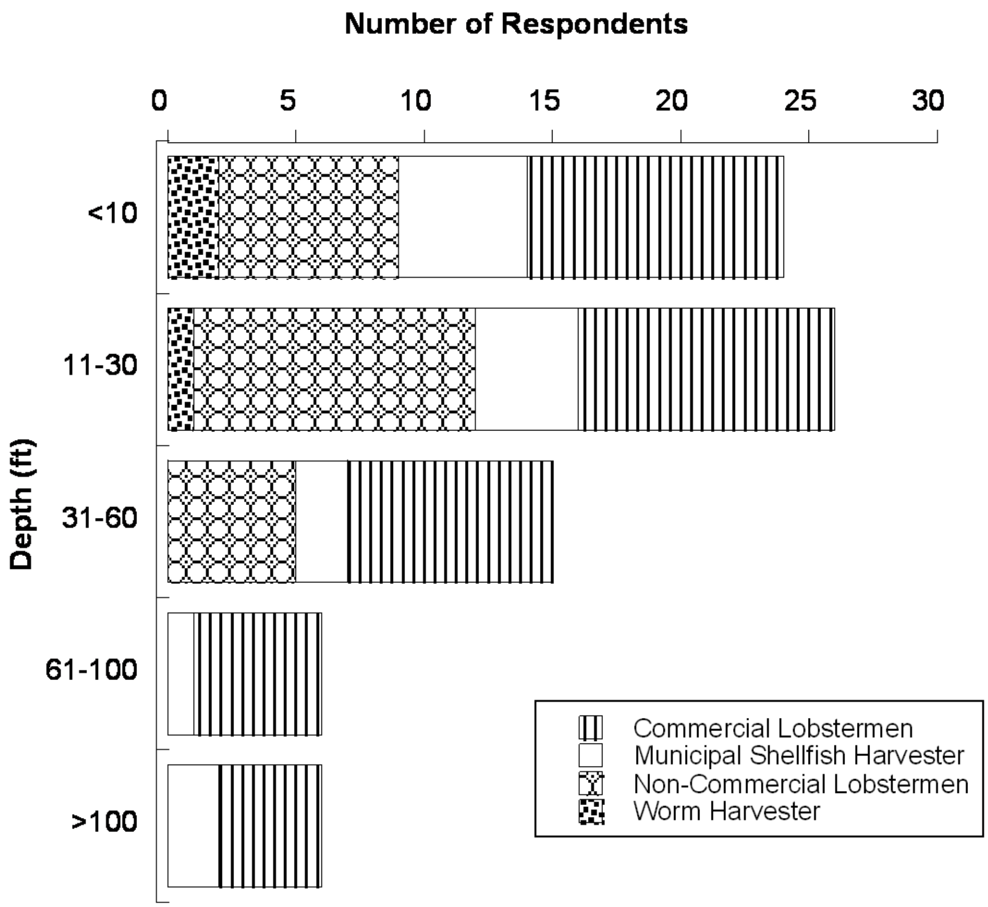


Figure 7: In which intertidal habitat(s) do you encounter invasive green crabs? Responses reported as a frequency distribution.

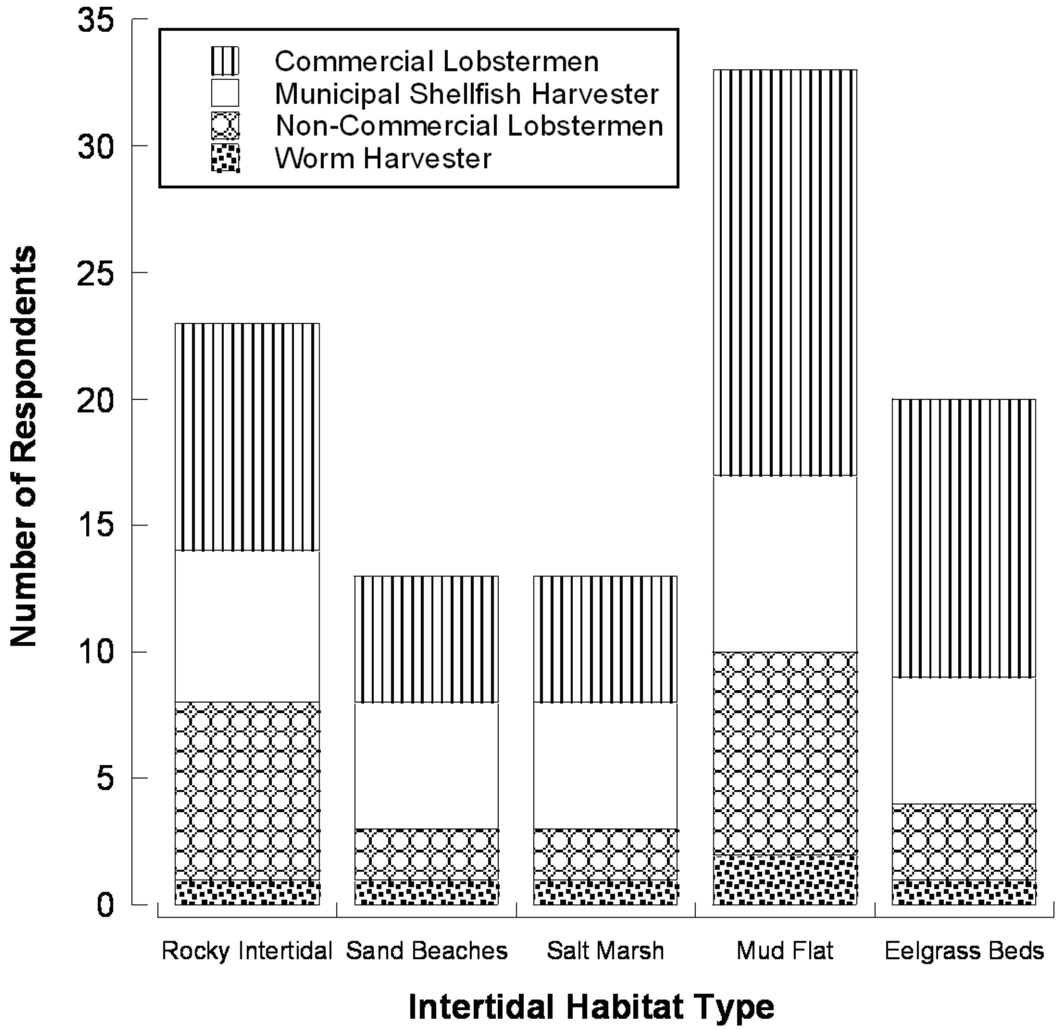


Figure 8: Over the last few years, how frequently have you encountered invasive European green crabs during your harvesting activities? Reponses reported as a percent of respondents by year and by harvester license type. The scale for response statements: 1, never; 2, at least once per month; 3, at least once per week; 4, at least once per week; and 5, multiple times per day.

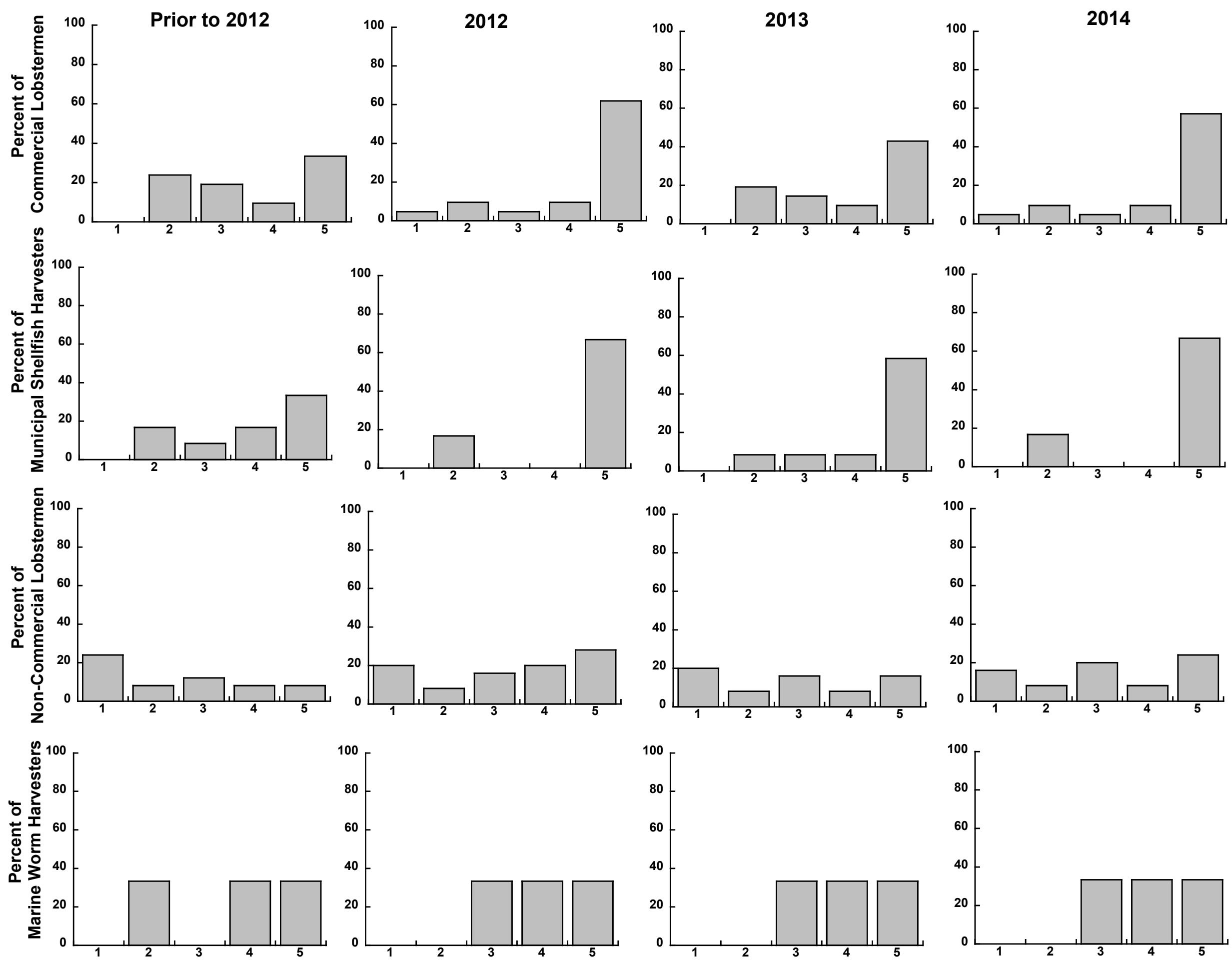
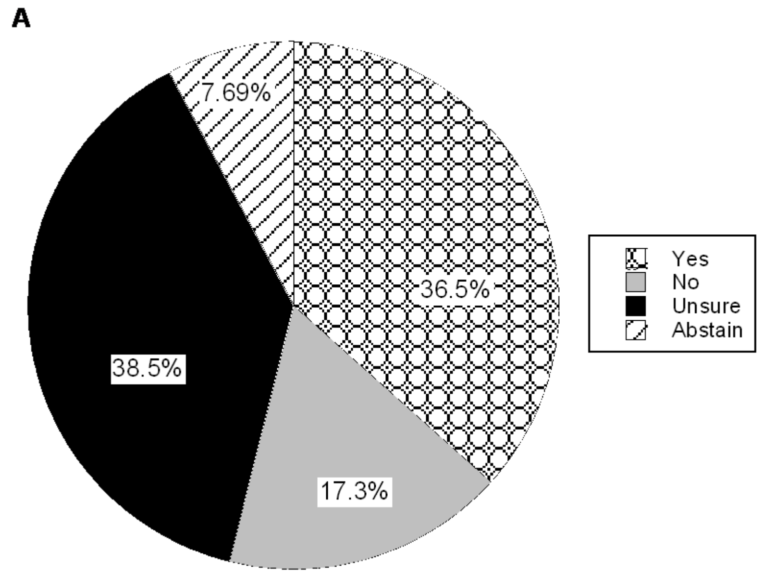
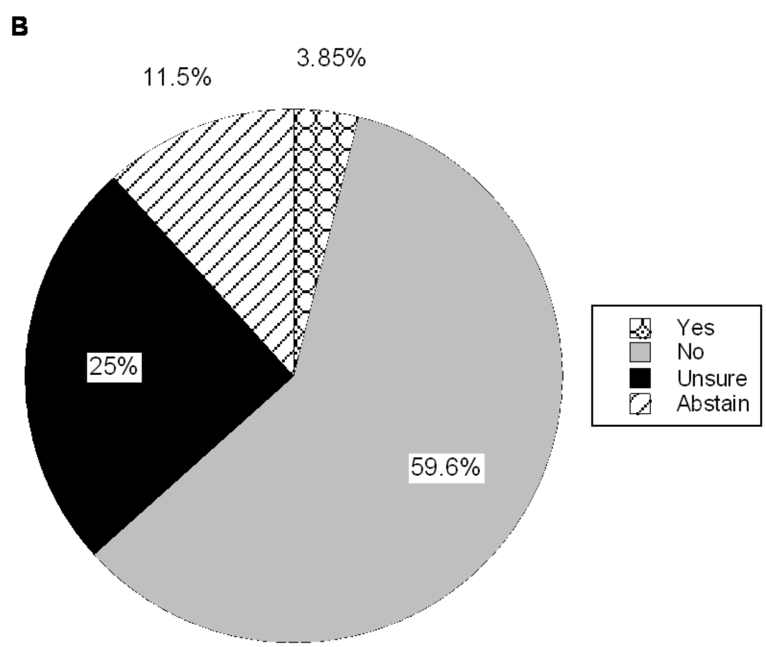


Figure 9: Have you observed negative (A) or positive (B) impacts to your target species or habitat from green crab populations? Responses reported as a percentage of respondents.



Reported "Negative" Impacts:
Predation on adult and juvenile shellfish
Competitive effects to lobster and other native crab species
Destrution of eelgrass
Consumption of lobster bait
Bank erosion



Reported "Positive" Impacts:
Food source for Eider ducks

Figure 10: Do you think European green crabs pose a significant risk to your target species or marine resource in coastal Maine? Responses reported as a percentage of respondents.

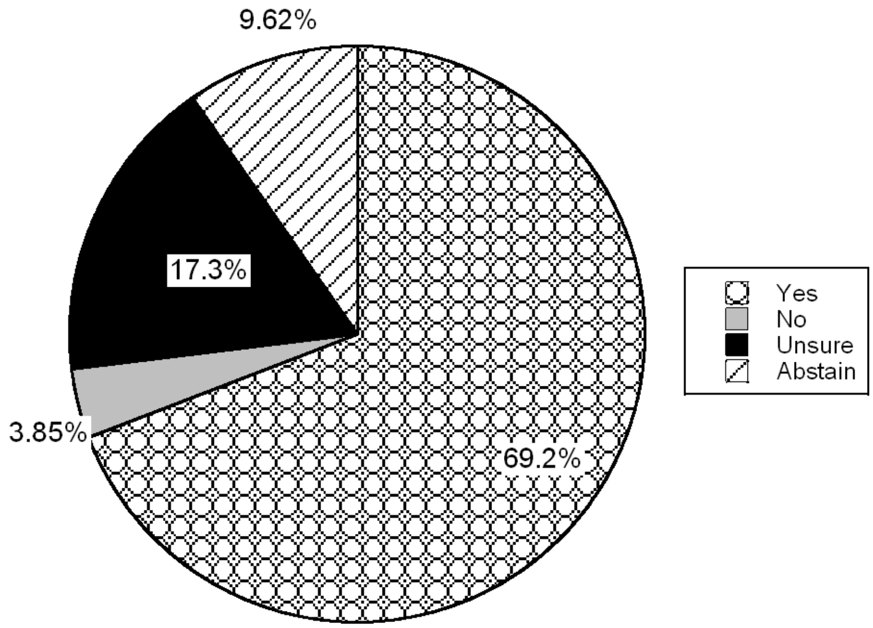
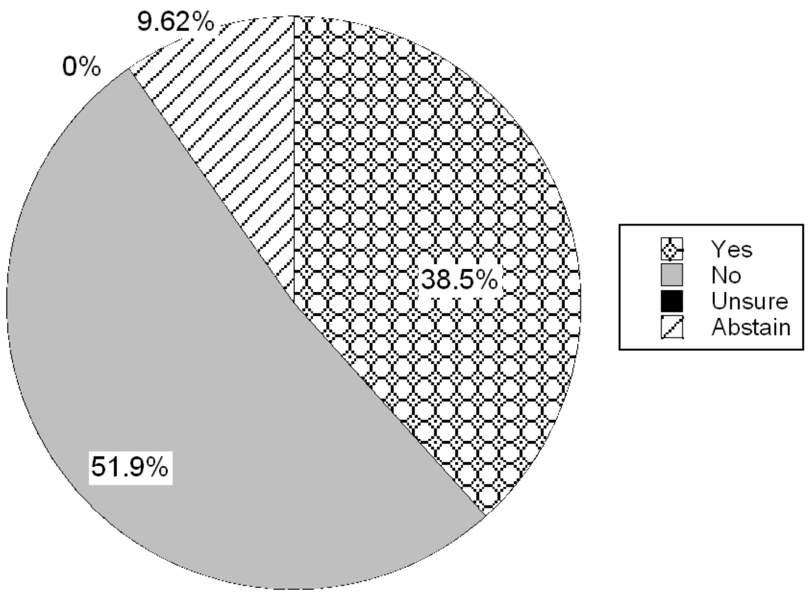


Figure 11: Have you altered your harvesting or growing practices in response to changes in green crab populations? Responses reported as a percentage of respondents.



Reported Altered Behavior(s)
Changed target area (28.85%)
Diversified activities (1.92%)
Shifted inshore (1.92%)
Shifted shallower (3.85%)
Shifted deeper (17.30%)
Shifted bottom type (12.46%)
Increased control measures (7.59%)

Figure 12: Are you in favor of Maine agencies and/or industries taking steps to address impact(s) from green crabs? Responses reported as a percentage of respondents.

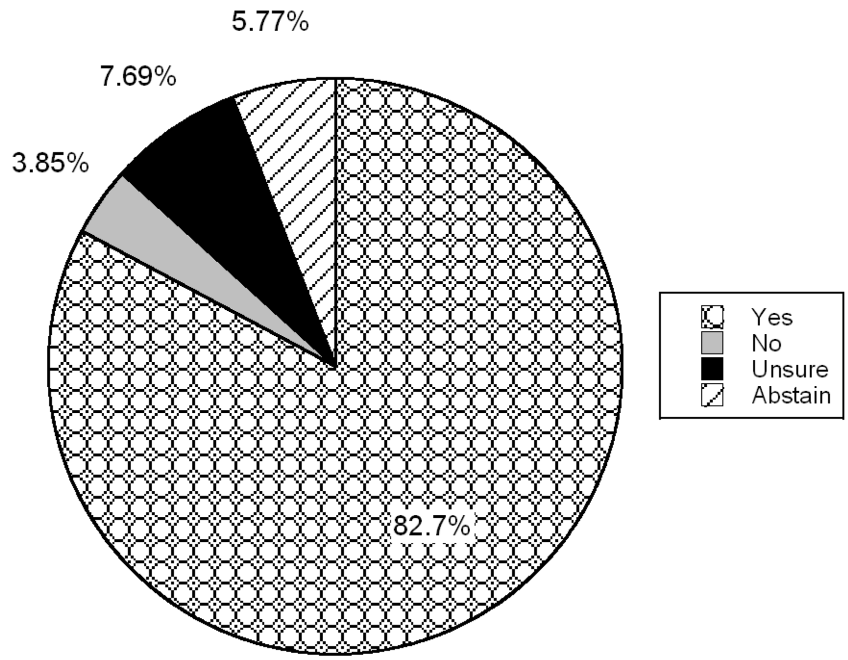


Figure 13: Do you think population control and/or impact mitigation efforts could be successful? Responses reported as a percentage of respondents.

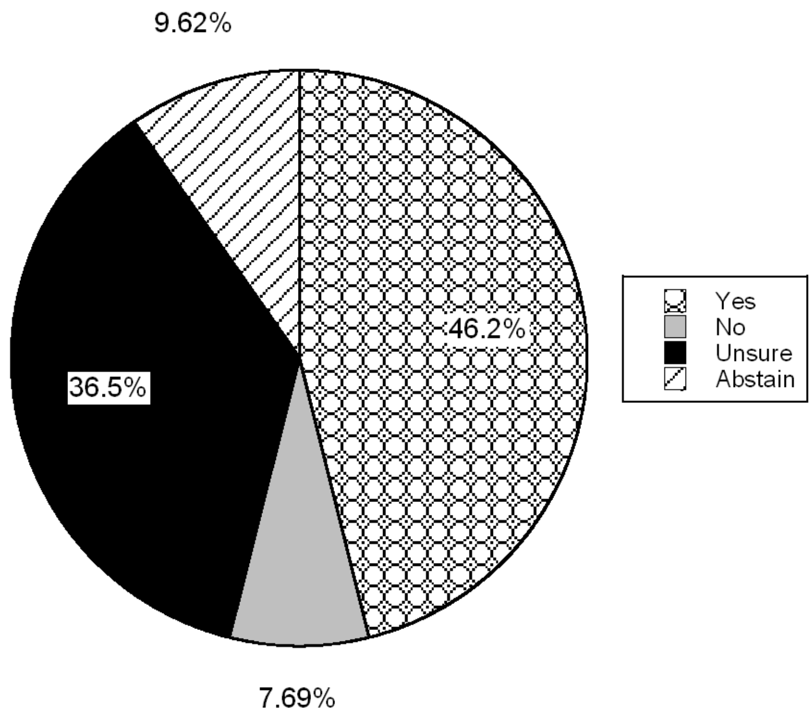
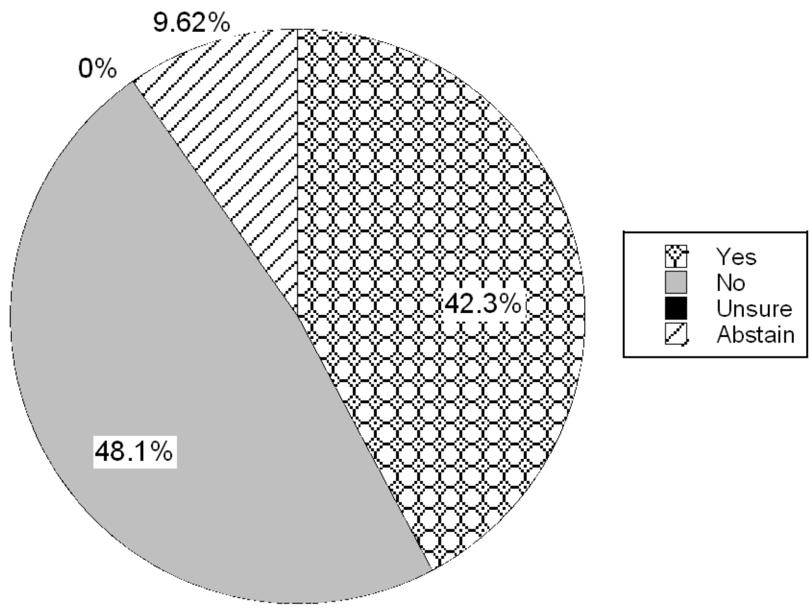


Figure 14: Are you actively engaged in trying to harvest or control green crabs populations in your area or zone? Responses reported as a percentage of respondents.



Suggested Control/Mitigation Measures:
Trap and kill
Develop new green crab markets
Trap for composting and fertilizer
Trap for commercial/recreational bait
Subsidize trapping/control measures
Bounty program
Protective nets over sensitive shellfish

References:

Rathbun (1905). Fauna of New England. Crustacea. Occ. Papers Boston Soc. Nat. Hist. (7), 1-117.

Telport and Somero (2014). Master of all trades: thermal acclimation and adaption of cardiac function in broadly distributed marine invasive species, the European green crab, *Carcinus maenas.* The Journal of Experimental Biology. Vol (217), 1129-1138.

Welch (1969). Changes in abundance of the green crab, *Carcinus maenas* (L.), in relation to recent temperature changes. Fisheries Bulletin. Vol (67), 337-345.

d. Maine Crab Products and Supplies

Crab Products and Suppliers (and Processing Facilities) in Maine

	Location				
Raw Products	County	Town	Facility Name	Phone	Website
Crab					
Crab	Washington	Jonesport	Alley's Seafood	207.497.2691	https://www.facebook.com/AlleysSeafood/info
Crab	Hancock	Stonington	Oceanville Seafood	207-367-5871	http://oceanvilleseafood.wix.com/maine#!
Crab	Waldo	Belfast	Young's Lobster Pound	207-338-1160	http://youngslobsterpound.webs.com/
Crab	Waldo	Ellsworth	Maine Shellfish	207-667-5336	http://www.ipswichshellfish.com/
Crab (Jonah)	Cumberland	Portland	Portland Shellfish	(207) 799-9290	http://portlandshellfish.com/
Crab Meat (Fresh)	Cumberland	Brunswick	Long Reach Shellfish, Inc.	207-729-0227	http://longreachshellfish.com/
Crab Meat Frozen	Cumberland	Brunswick	Long Reach Shellfish, Inc.	207-729-0228	http://longreachshellfish.com/
Crabs (Fresh, Jonah)	Cumberland	Brunswick	Long Reach Shellfish, Inc.	207-729-0226	http://longreachshellfish.com/
Crab (Jonah)	Cumberland	Portland	Maine Seafood Ventures, LLC	888-9-LOBSTER	http://www.maineseafoodventures.com/
Crab (Live)	Cumberland	Portland	ISF Trading, Inc.	(207)879-1575	http://www.seaurchinmaine.com/index.html
Crabs (Live)	Cumberland	Portland	Harbor Fish Market	207-775-0274	http://www.harborfish.com/index.php
Crab (Value Added)					
Crab Bisque	Washington	Whiting	Bar Harbor Seafood	800-962-6258	http://www.barharborfoods.com/index.php
Crab Cakes	Washington	Milbridge	Dorr Lobster Co.	(207) 546-7488	https://dorrlobster.com/
Crab Claws	Cumberland	Portland	Browne Trading Co.	207-766-2402	http://www.brownetrading.com/
Crab Claws (Cocktail, Jonah)	Cumberland	Portland	Harbor Fish Market	207-775-0272	http://www.harborfish.com/index.php
Crab Claws (Fresh)	Knox	Port Clyde	Port Clyde Fresh Catch	(207) 372-1055	http://www.portclydefreshcatch.com/
Crab Claws (Frozen, Cocktail)	Knox	Rockland	Linda Bean's Perfect Maine	(866) 989-9164	http://lindabeansperfectmaine.com/
Crab Claws (Frozen, Scored)	Knox	Rockland	Linda Bean's Perfect Maine	(866) 989-9164	http://lindabeansperfectmaine.com/
Crab Meat	Cumberland	Portland	Browne Trading Co.	207-766-2402	http://www.brownetrading.com/
Crab Meat	Cumberland	Portland	Harbor Fish Market	207-775-0273	http://www.harborfish.com/index.php
Crab Meat	Cumberland	Scarborough	Bayley's Lobster Pound	(207) 883-4571	http://www.bayleys.com
Crab Meat (Frozen)	Hancock	Trenton	Trenton Bridge Lobster Pound	207-667-2980	http://www.trentonbridgelobster.com/
Crab Meat	Hancock	Stonington	Stonington Sea Products, LLC	207-367-6377	http://www.stoningtonseaproducts.com/home/
Crab Meat	Knox	Rockland	Jess's Market	207) 596-6087	http://www.jessmarket.com/index.htm
Crab Meat	Lincoln	Boothbay	Pinkham's Seafood	(207) 633-6238	https://www.facebook.com/pages/Pinkhams-Seafood/140625735973368?sk=info
Crab Meat	Lincoln	Nobleboro	PB Enterprises Fresh Maine Seafood	(207) 841-7321	https://www.facebook.com/pages/PB-Enterprises-Fresh-Maine-Seafood/152930621418512
Crab Meat	Penobscot	Brewer	Cap Morrill's Seafood	(207) 989-2277	http://capmorrillswholesale.com/?area=home
Crab Meat	Waldo	Belfast	Maine Maritime Products	207-338-5046	http://www.memaritime.com/
Crab Meat	Waldo	Belfast	Young's Lobster Pound	207-338-1160	http://youngslobsterpound.webs.com/
Crab Meat	Washington	Addison	Maine Mahogany Shellfish	207/483-2865	http://www.downeastindepth.com/mahogany.html
Crab Meat	Washington	Milbridge	Dorr Lobster Co.	(207) 546-7488	https://dorrlobster.com/
Crab Meat	York	Kittery	Taylor Lobster Company	207-439-1357	http://www.taylorlobster.com/index.html
Crab Meat (Fresh)	Knox	Port Clyde	Port Clyde Fresh Catch	(207) 372-1055	http://www.portclydefreshcatch.com/
Crab Meat (Fresh)	Knox	Rockland	Linda Bean's Perfect Maine	(866) 989-9164	http://lindabeansperfectmaine.com/
Crab Meat (Legs Only, Jonah)	Cumberland	Portland	Harbor Fish Market	207-775-0296	http://www.harborfish.com/index.php
Crab Meat (Rock, Frozen)	Cumberland	Portland	Harbor Fish Market	207-775-0256	http://www.harborfish.com/index.php
Crab Pie	Washington	Whiting	Cobscook Bay Company	207-733-2222	http://www.maine-fresh.com/

Information assembled by CEI.

e. China & Taiwan Fish Processing Equipment Producers

Chinese and Taiwanese Producers of Fish Drying and Processing Equipment

I. Summary

This report contains a list 22 Chinese and Taiwanese producers and venders of fish processing and drying machinery and fishmeal production equipment.

II. Chinese Producers and Distributors of Processing Equipment and Systems

Hopeland Bio-Tech Co., Ltd.
Notes: *Produces fish meal production equipment*
Address: No.9, XiShan Road,
Changzhou city, China
Tel: +86 519-8510-2276 / +8 1357 190-0119
Email: trade@85xianji.com
Web: http://www.aac-machine.com/

Shining Fish
Notes: *Products include shrimp processing equipment and systems*
Address: No.362, Yecheng Road.,
Jiading District, Shanghai,
China 201200
Tel: +86-21-6052-5218
Email: info@shiningfish-tech.com / enquiry@shiningfish-tech.com / Online Form
Web: http://shiningfish-tech.com/

Henan Siyuan Machinery
Notes: *Produces various food and agricultural processing machinery*
Address: No.126 East Street, Zhengzhou
Henan, China 450000
Tel: 86-15890-0672-64
Email: Contact Form
Web: http://siyuanjixie.en.ecplaza.net/

Beihai Xinhong Fishmeal Equipment Co., Ltd.

Notes: *Produces fishmeal processing equipment.*
Address: Hepu Industry, Beihai City,
Guangxi Province, 536005, China
Tel: 86-779-223-2000 / 86-152-7896-5886
Email: Contact Form
Web: http://xhyfsb.en.alibaba.com/ / xhfishmealplant.en.china.cn/

Jinan Saibainuo Technology Development Co., Ltd.

Notes: *Products include fishmeal processing machinery*
Address: No.2-1Lanxiang Road,
Tiangqiao Industry Zone,
Jinan, China
Tel: 86-136-0641-8121
Email: if@cnsbn.com / chinamachine@cnsbn.com
Web: http://saibainuo.en.china.cn/ / http://www.cnsbn.com/en/

Zhousan Xinzhou Fishmeal Equipment Factory

Notes: *Produces fish meal equipment and related systems.*
Address: 263, Xingzhou Avenue,
Zhoushan City 316041,
Zhejiang Province, China
Tel: +86 580-880-3521 / 880-3508
Email: xzfeed@163.net
Web: http://en.zhejiang-fishmeal.com/index.php#

Jinan Arrow Machinery Co., Ltd

Notes: *Produces food manufacturing equipment.*
Address: Jiangjiagou Industrial Area,
Jinan, Shandong, China
Tel: 0531-8827-5995
Email: info@znmachinery.com
Web: www.jnarrow.com

Shanghai Zhanwang Mechanical & Electric Equipment

Notes: *Produces fish feed processing equipment.*
Address: Zhangyan Town
201514, China
Tel: 86-021-5731-9098
Web: www.shzwjd.com / http://shzhanwang.en.alibaba.com/

Qingdao Xiao Dao Food Machinery Co., Ltd.

Notes: *Produces various food processing machinery and equipment*
Address: W Lingsan Rd. and N Jinhai Rd.,
266400, Shandong,

Quindao Jiaonan, China
Tel: 86-0532-8199-1888
Email: Contact Form
Web: http://www.qdxiaodao.cn

Henan Shenyu Equipment Co., Ltd
Notes: *Products include food processing machinery.*
Address: Jinger Road,
Xihuan Industry Gathering Zone,
Weibin District, Xinxiang, Henan, China
Tel: 86-373-585-0238
Web: www.insulator.net.cn/

Zhengzhou Allance Trading
Notes: *Products include various food processing machines.*
Address: A507, Suoke Yufa building.,
No.26 Jingliu Road
Zhengzhou, China
Tel: 86-371-6595-0319 / 13733816811
Web: http://zzallance.en.china.cn/ / http://zzallance.en.alibaba.com/
Email: Contact Form

Zhengzhou Whirlston Trade Co., Ltd
Notes: *Products include various food processing and drying equipment.*
Address: Jinshui, Zhengzhou, 450000
Henan, China
Tel: 0086-371-6595-6636
Email: whirlstonmachinery@gmail.com / Contact Form
Web: http://www.whirlstonmachinery.com/ / http://whirlston.en.alibaba.com/

Henan Modest Machinery Equipment Co., Ltd.
Notes: *Produces food processing and drying machinery.*
Address: No.1 Suoling Road,
Jinshui District, 450000,
Henan China
Tel: 86-0371-8602-6810s
Email: Contact Form
Web: http://modest.en.alibaba.com/

Zhengzhou Maike trading Co., Ltd.
Notes: *Products include food processing machinery.*
Address: Room 407, Building No.4, Huabanli Community,
Huayuan Road and Sanquan Road crossings,
Zhengzhou, 450045, China

Tel: 86-371-8601-7295
Email: Contact Form
Web: http://zzmk.en.alibaba.com/

Changzhou Yixin Drying Equipment Co., Ltd
Notes: *Products include various drying and processing machinery for food.*
Address: Sanhekou Zone, Changzhou,
Jiangsu, 213115, China
Tel: 86-0519-8890-8898
Email: Contact Form
Web: http://yixindrying.en.alibaba.com/company_profile.html

Jinan Xucheng Import & Export Co., Ltd / Zhangqui Yulong Machine Co., Ltd
Notes: *Products include various food processing and drying machines, and feed pellet machines*
Address: Xiuhui Town, Zhangqiu, Jinan,
Shandong Province,
China 250201
Tel: 0086-531-8348-3995
Email: Yulongmachine@163.com / admin@jnxucheng.com
Web: http://www.yulongjixie.org/

Jinan Americhi Machinery & Equipemtn Co., Ltd
Note: *Products include fish feed processing machinery*
Address: No.27 Xingfu Street, Huaiyin District
Jinan City, Shandong, China, 250023
Tel: 0086-531-8596-9757
Email: americhi@live.com
Web: http://www.americhi.cc/

Zhejiang Longyuan Sifang Machinery Manufacture Co., Ltd.
Note: *Products include fishmeal machinery*
Address: No.1 Lanhua Road, Dinghai District
Zhoushan, Zhejian, China
Tel: 86-580-205-4750
Email: info@zjlysf.com
Web: http://www.zjlysf.com/ / http://lysfprime.en.alibaba.com/

Xingxiang Longxing Trading Co., Ltd
Note: *Produces feed and pellet processing machines*
Address: Building 7, Century Village
Hongqi district, Xinxiang City,
Henan Province, China
Tel: 0086-373-387-8388

Email: Zack130@live.cn / andyzaoo@gmail.com
Web: http://www.xxlxsm.com/ http://xxlxsm.en.alibaba.com/contactinfo.html

III. Taiwanese Producers and Distributors of Processing Equipment and Systems

Shang Jer Industries Co., Ltd.

Notes: *Products include fish meal drying equipment.*
Address: No. 19-53, Xingang Township
Chiayi County 616, Taiwan
Tel: 886-5-374894~5
Email: shang@shang-jer.com.tw
Web: www.shanq-jer.com.tw/

Hsin Lih Machinery Co., LTD.

Notes: *Provides aquaculture and livestock feed crushing, drying, milling, and classifying equipment for plants.*
Address: No.2 Dershing 4th Rd.,
Dongshan Hsiang,
I-lan, Taiwan
Tel: 886-3-990-1221
Email: hsin.lih@msa.hinet.net
Web: http://www.hsinlih.com.tw/

Kinn Shang Hoo Iron Works

Notes: *Manufactures food processing equipment including fish drying equipment.*
Address: No.11 85, Chin Yun St.,
Ku San Dist., Kaohsiung City,
Taiwan
Tel: 886-7-551-5397
Email: ksh6671@ms27.hinet.nets / Online Form
Web: www.ksh.com.tw/e-catalog/index.html

f. Icelandic Fish Processing Equipment Producers

MAINE INTERNATIONAL TRADE CENTER
Global Resources. Local Expertise.

Icelandic Producers of Fish Processing and Drying Equipment

IV. Summary

This document contains a list of 13 Icelandic businesses that sell or produce fish processing and drying equipment or provide consulting and systems for establishing processing facilities. Also included are 11 Icelandic companies that process fish, but do not sell machinery or systems.

V. Icelandic Producers and Distributors of Processing Equipment and Systems

Samey

Notes: *Provides automated systems and equipment for fish processing and drying.*
Address: Samey ehf
Lyngasi 13
210 Gardabaer
Iceland
Tel: +354 510-5200
Email: Sala@samey.is / info@samey.is
Web: www.samey.is/

Marel

Notes: *Provides fish processing systems and equipment.*
Address: Marel
Austurhraun 9
Gardabaer
IS-210 Iceland
Tel: +354-563-8000
Email: Online form
Web: marel.com/

Traust

Notes: *Provides equipment and solutions for fish and shellfish processing.*
Location: Borgarnes, Iceland
Tel: +354 516-3000
Email: Traust@traust.is
Web: www.traust.is

IceBits ehf

Notes: *Provides concepts and designs for plants & packages; applies equipment to conditions at the construction sites and issues drawings and specifications for local do-it-yourself fabrication, assembly, and installation of equipment and plants; represents suppliers of new and used machinery; and assists clients in the acquisition of equipment and accessories for their projects (Fish meal processing, waste incineration and refrigerating techniques).*
Address: Glosalir 7, Suite 704
IS-201 Kopavogur, Iceland
Tel: +354 562-2524 / +354 896-1892
Email: ingvar@ingvar.is
Webs: www.ingvar.is

Samhentir

Notes: *Sells and manufactures packaging, operating supplies and packing machines for the fishing industry, food processors, and manufacturers.*
Address: Samhentir-Kassagerð ehf
Suðurhrauni 4a
210 Garðabæ, Iceland
Tel: +354 575-8000
Email: sale@samhentir.is
Web: www.samhentir.is/en

Matís

Notes: *Government owned research company that provides research, consulting, and analysis for food processing, production and biotech industries.*
Address: Vinlandsleid 12,
113 Reykjavik, Iceland
Tel: +354 422-5000
Email: Matis@matis.is
Web: www.matis.is

Valka

Notes: *Provides equipment and software for fish processers, from single machines to complete systems.*
Address: Vikurhvarf 8
203 Kópavogur
Iceland
Tel: +354 519-2300

Email: sales@valka.is
Web: valka.is/

3X Technology
Notes: *Builds processing equipment and provides systems/solutions for the seafood processing industry.*
Sales and Service Office
Address: Fiskislóð 73
101 Reykjavik
Tel: +354 450-5050
Headquarters and Production
Address: Sindragata 5
400 Ísafjörður
Tel: +354 450-5000
Email: Sales@3xtechnology.com
Web: www.3x.is/

A.M Sigurdsson Ehf
Notes: *Supplier of seafood processing equipment. Has made at least one sale to Bristol Seafood in Portland.*
Address: Hvaleyrarbraut 2
220 Hafnarfirði, Iceland
Tel: 354 565-2546
Email: Mesa@mesa.is
Web: www.mesa.is

Kaelismidjan Frost Ehf
Notes: *Design and contracting company working with primarily refrigeration for seafood processers.*
Address: Fjolnisgata 4b
603 Akureyri
Iceland
Tel: +354 464-9400
Contact: Gudmundur Hannesson
Email: gummi@frost.is
Web: www.frost.is

Loft Og Reftaeki
Notes: *Processing Machinery*
Address: Hjallabrekka 1
200 Kopavogur, Iceland
Tel: 00354-564-300
Contact: Bjarni Halldorsson
Email: Bjarni@loft.is

Mannvit

Notes: *Activities include engineering, procurement, and project and construction management for the seafood processing industry.*
Iceland Office
CEO: Eyjólfur Á. Rafnsson
Address: Urðarhvarf 6
203 Kópavogur
Iceland
Tel: +354 422-3000
Email: Online Form
US Office
Director: Runólfur Maack
Address: 4305 Gesner Street, Suite 214
San Diego, CA 92117
Tel: +1 619 550-2953
Email: Contact Form
Web: www.mannvit.com/

BASIS International

Notes: *Supplier of fish processing machinery and equipment*
Address: Snæland 8
108 Reykjavik
Iceland
Tel: +354-899-2166
Email: Basis@simnet.is
Web: www.isholf.is/basis/

VI. Icelandic Fish Processers

Isfelag Vestmannaeyja HF

Notes: *Catches and processes* fish*; produces fish meal.*
Address: Ísfélag Vestmannaeyja
Strandvegi 26
900 Vestmannaeyjar
Tel: +354 488-1100
Email: isfelag@isfelag.is
Web: www.isfelag.is/en

Esjka

Notes: *Catches and processes fish.*
Address: Strandgata 39
735 Eskifjörður
+354 470-6000
Email: eskja@eskja.is

Web: eskja.is/

Sildarvinnslan hf

Notes: *Catches and processes fish; operates three fishmeal and oil factories as well.*
Address: Hafnarbraut 6
740 Fjarðabyggð
Tel: +354 470-7000
Email: svn@svn.is
Web: www.svn.is/english

Rammi

Notes: *Runs 5 fishing trawlers, and a processing facility for lobster, shrimp, and fish. Holds a stake in the chitin and chitosan producer Primex.*
Address: Main Office
Granugata 1-3
580 Fjallabyggo, Iceland
Tel: +354 460-5500
Email: Listed by area of work here
Web: www.rammi.is

Salka-Norfish Ltd.

Notes: *Exports dried fish.*
Address: Ráðhúsi Dalvíkur
620 Dalvík, Iceland
Tel: +354 466-1875
Web: www.norfish.is

HB Grandi

Notes: *Catches and processes fishes.*
Address: Nordurgardur 1
101 Reykjavik
Tel: +354 550-1000
Contact: David Davidsson (Sales manager)
Email: David@hbgrandi.is
Web: www.hbgrandi.com/Home

Samherji HF

Notes: *Involved in all stages of the value chain from fishing, farming and processing to export and sales.*
Address: Samherji Hf.
Glerargotu 30
600 Akureyri, Iceland
Tel: +354 560-9000
Email: samherji@samheri.us

Web: www.samherji.is/en/home

Brim Hf.

Notes: *Owns and operates fishing vessels and drying/processing facilities.*
Address: Brim Hf.
Bræðraborgarstígur 16, 101
Reykjavik
Tel: +354 580-4201
Email: Brimseafood@brimseafood.is
Web: www.brimhf.is

Iceland Seafood International

Notes: *Large, global seafood exporter.*
Address: Kollunarklettsvegur 2
104 Reykjavik
Iceland
Tel: +354 550-8000
Email: is@is.is
Web: is.is/

Ice-Group Ltd.

Notes: *Export company, specializing in exporting fish products from Iceland, Norway, UK, and Morocco to Africa, Asia, and Europe.*
Address: Ice Group
Idavellir 7a
IS-230 Reykjanesbaer
Tel: +354 421-7041
Email: icegroup@icegroup.is
Web: www.icegroup.is

Haustak

Notes: *Specializes in drying fish.*
Address: Know Runway 3
230 Ports Reykjanes
Iceland
Tel: +354 421-6914
Email: Haustak@haustak.is
Web: www.haustak.is/

g. Chitin Producers and Market Report

Global Chitin Producers and Market Report

VII. Summary

This report contains a listing of 35 chitin and chitosan producers and an analysis of the global chitin market.

The majority of the chitin producers are located in Asia, particularly in China and India, while many are also located in Europe and North America. In Canada, several businesses are investing in new production capability.

The global chitin and chitosan market is projected to grow rapidly over the next few years, driven by new processing technologies and applications for the versatile material. The Asia-Pacific region is the largest regional market and has the greatest projected growth potential, followed by the United States.

VIII. Chitin & Chitosan Market Analysis

Overview:

Chitin, generally derived from crustacean and shrimp shells, but also common in other organisms such as squid and fungi, is an abundant naturally occurring polymer. Along with chitosan, a deacetylated form of chitin, it is used in a wide range of applications.

The global market for chitin, chitosan, and their derivatives is expected to grow rapidly over the next few years. New technologies and processes for extracting chitin from a variety of raw materials and increasingly diverse applications for the versatile product are key drivers of this growth.

As one of the most abundant biodegradable materials in the world, chitin is used in a wide variety of fields including biomedicine, nutrition, food processing, pharmacology, microbiology, agriculture, cosmetics, and clothing, among others.[6] Newly developed

[6] http://www.prweb.com/releases/chitin_chitosan/derivatives_glucosamine/prweb4603394.htm

applications include turning chitin into "active" packaging for food, aimed at reducing plastics made from petro-chemicals.[7]

These natural compounds are poised to make waves, especially in the fields of biomedicine, nutrition and food. Increasing health consciousness among individuals coupled with growing cholesterol-related problems has resulted in an increased consumer demand for chitin and chitosan, especially due to the properties of fat-absorption and lowering of cholesterol-level.[8]

Market Growth Projections

Despite the fact that the functionality of chitin derivatives spans across various applications, these biopolymers remain an underutilized resource. Given the lack of awareness with respect to prospective applications of chitin and chitosan and absence of aggressive commercialization initiatives by industry participants, opportunities remain significant in the long term. In the coming years new applications are likely to emerge, further diversifying the existing uses.[9] Consequently, future market growth projections are high.

According to 2010 estimates, the global market for chitin derivatives will reach $63 billion, while the global chitosan market will reach $21.4 billion by 2015.[10] One estimate puts the global market growth at 15% annually.[11] The global market for chitosan was estimated at 13.7 thousand metric tons in 2010, with 21.4 thousand metric tons expected by 2015.[12] For chitin and chitosan combined, the global market is expected to exceed 118 thousand metric tons by 2018.[13] In the largest market, the Asia-Pacific, the chitosan market is expected to grow by 4.2 thousand metric tons from 2010 to 2015. [14]

Regional Analysis

As of 2010 the Asia-Pacific region was the leading chitosan market with an estimated 7.8 metric tons traded. Japan was the single largest market worldwide for chitin and chitosan. The country represents an established market, with biomedical applications of chitin

[7] http://www.alaskafishradio.com/chitin-from-crab-shrimp-shells-used-for-bio-plastics-smooths-car-scratches-and-more/
[8] http://www.prweb.com/releases/chitin_chitosan/derivatives_glucosamine/prweb4603394.htm
[9] http://www.companiesandmarkets.com/Market/Chemicals/Market-Research/Chitin-and-Chitosan-A-Global-Strategic-Business-Report/RPT1124927
[10] http://www.prweb.com/releases/chitin_chitosan/derivatives_glucosamine/prweb4603394.htm
[11] http://www.savingseafood.org/science/three-year-project-to-produce-high-value-medical-grade-chitosan-from-northern-shrimp-completed-in-newfoundland-c-3.html
[12] http://www.nutraceuticalsworld.com/contents/view_online-exclusives/2010-12-02/the-global-chitosan-market-/
[13] http://www.companiesandmarkets.com/Market/Chemicals/Market-Research/Chitin-and-Chitosan-A-Global-Strategic-Business-Report/RPT1124927
[14] http://www.nutraceuticalsworld.com/contents/view_online-exclusives/2010-12-02/the-global-chitosan-market-/

widespread in the region. Wound dressing materials and artificial sutures within biomedical applications account for the largest end use of the products within Japan.

Growth-wise, the Asia-Pacific region is projected to be the fastest growing regional market for chitin derivatives, with a compound annual growth rate (CAGR) of more than 12.0% over the analysis period. The Asia-Pacific region, having access to large source of raw materials, is a promising market for locating manufacturing units for chitin and chitosan and India and China both already host a sizable number.

The United States trails Japan in terms of sales, but represented the second biggest market for chitin and chitosan in 2010, with an estimated market size of 3.6 thousand metric tons.[15] With over 200 patented applications in the United States driving growth in advanced medical fields, the North American Market for high grade chitosan is projected to grow 17% per year.[16]

Product Analysis

In terms of chitin derivatives, glucosamine represents the largest segment globally. Cornering an estimated market share of more than 60% of the total chitin derivatives market in 2010, Glucosamine is projected to continue its dominance over the coming years. Chitosan represents the other prominent segment within the chitin derivatives market globally. Among the end-use applications of chitosan, water treatment represents the largest end-use application. However, the agrochemicals industry represents the fastest growing end-use application, with consumption of chitosan surging at more than 12% over the analysis period.

Chitin applications in food additives, drug capsules, cosmetics, bandages (used by the US and UK military), and burn dressings are increasing at a rapid pace. Potential growth areas include paper production, biomedical applications, textile finishes, cements, heavy metal chelating agents, photographic products, and waste removal. Chitin continues to arouse interest in view of its potential industrial and biomedical applications. Compared to chitin, chitosan is more useful for biomedical applications and dehydrations of aqueous solutions, since it has both hydroxyl and amino groups that can be modified with ease.[17]

Market Challenges

Major issues impacting the chitin and chitosan market include high production costs, a lack of quality chitosan available in the market, production shortages, and heavy pollution during the production process.[18]

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[15] *Ibid*. http://www.prweb.com/releases/chitin_chitosan/derivatives_glucosamine/prweb4603394.htm

[16] http://www.savingseafood.org/science/three-year-project-to-produce-high-value-medical-grade-chitosan-from-northern-shrimp-completed-in-newfoundland-c-3.html

[17] http://www.prweb.com/releases/chitin_chitosan/derivatives_glucosamine/prweb4603394.htm

[18] *Ibid.*

Crab Sourcing Prospects

Along with shrimp, crab shells are one of the most abundant and commonly used sources of chitin. Dried crab shells contain about 15-20% chitin, compared to 25-40% of shrimp shells. More than 25 billion tons of chitin from seafood products are dumped each year rather than used.[19]

Note: Most information presented above is drawn from excerpts and summaries of a market report on chitin and chitosan from Global Industry Analysts, Inc. The full report is available here for a fee.

IX. Global Chitin & Chitosan Producers and Processors

Listed below are 35 chitin and chitosan companies. The majority are producers that process chitin from shellfish shells. However, some are secondary, value-added producers or related industry groups.

X. Asian Chitin & Chitosan Producers

China & Taiwan

Qingdao BZ Oligo Biotech Co., LTD.
Produces chitosan from Alaska deep-sea snow crab shells.
Address: Room 1705 D&D Fortune Center, No. 182-6 Haier Road, Quingdao 266061, China
Tel: +86-532-8192-6227
Email: ann@marine-oligo.com
Web: http://www.marine-oligo.com/

Qingdao Yunzhou Biochemistry Co., LTD
Produces 320-400 tons of chitosan annually.
Address: Economic Development Zone, Jimo, Quingdao, Shandong, China
Contact: Wang Feifei
Tel: +86-532-8387-2926
Email: qdyunzhou@hotmail.com / qdyunzhou@gmail.com
Web: http://www.qdyunzhou.com/eindex.asp
http://qdyunzhou.en.alibaba.com/

G.T.C. Bio Corporation

[19] http://www.fftc.agnet.org/files/lib_articles/20140401150447/bc007.pdf

Produces various chitin and chitosan products from primarily shrimp and crab shells, particularly Alaska snow crab, as well as some lobster shells. Annual production capacity has reached over 300 tons.
Address: No. 52 Hongkong Middle Street, Quingdao, Shandong Province 266071, China
Tel: +86-532-8063-2517
Email: Info@bestchitosan.com / gtcbio@163.com
Web: http://www.bestchitosan.com/index_en.htmll

Weifang Dongxing Chitosan Factory
Produces $10-50 million of chitin and chitin products annually.
Address: No. 318, Gongjian Rd., Weicheng District., Weifang, Shandong, China
Contact: Ms. Doris Zhang
Tel: +86-536-8915-535
Contact Form: http://dxchitosan.en.alibaba.com/contactinfo.html
Web: http://dxchitosan.en.alibaba.com/

Jinan Haidebei Marine Bioeeing Co., LTD
Produces a variety of chitin and chitosan products.
Address: No. 155, Duandianbei Road, Jinan City, 250022, Shan dong Province, China
Tel: +86-531-8750-0146
Email: jnhdb@haidebei.com
Web: http://en.haidebei.com/index.html

AK Biotech LTD
Produces chitin products.
Address: 168, Quianlong, Jinan, China. Postal Code: 250022
Tel: 0086-531-8711-3078
Email: akbio@126.com / akbio@hotmail.com
Web: http://www.akbio.net/

Dalian Xindie Chitin Co., LTD
Produces chitin for export from shrimp and crab shells. Featured in the Global Industry Analysts, Inc market report on Chitin and Chitosan.
Address: Rm#1616 Grand Hotel, Dalian, No.1 Jiefang St. Zhongshan Dist., Dalian, Liaoning, China
Contact: Ms. Chen Mer
Tel: +86-0411-282-1103
Web: http://dxccl.en.china.cn/

Zhe Jiang Candorly Pharmaceutical Co., LTD
Formerly Taizhou Candorly Sea Biochemical and Health Product Co., Ltd. Develops and manufactures a wide variety of pharmaceutical intermediates, APIs, and marine biological products, including chitin derivatives.
Sales Department:
Address: Zhejiang Wenling Taipingzhen Nanquanyiqi Gongyequ
Tel: +86 576-8614-2507-888

Email: trade@candorly.com
The US Office:
Address: Great Valley Corporate Center, 17 Lee Blvd, Unit B, Malvern, PA 19355, USA
Email: robertlo@candorly.com
Tel: 215-259-3024
Web: http://www.candorly.com/en/

India

Marshall Marine Products

Marine biotech company that manufactures and supplies pure chitin and chitosan derivitives.
Address: 1 Cholan Street, Bhavani Main n Road Erode TN +91 India
Tel: 91-424-222-7986
Contact: Vikram Suthakar
Web: http://marshallmarine.en.ec21.com/

Thahira Chemicals

Produces a range of biotechnology based products including chitin and chitosan.
Address: Chemical Industrial Area, Aroor – 688 534 Alappuzha, Kerala, India
Tel: +91-478-287-3644 / +91 478 287 4462
Email: info@thahirachemicals.com / mailto:thahirachemical@gmail.com
Web: http://thahirachemicals.com/index.html

Chitin India (Mahtani)

Produces a range of chitin and chitosan produces, primarily from shrimp.
Address: Post Box. No. 28, Rayon Post office, Veraval, Gujarat – 362266, India
Tel: +91-2876-650-673
Email: Dgillet@mcpldari.com
Web: http://www.chitinindia.com

Nitta Gelatin India Limited

Indo-Japanese industrial venture that produces chitosan among other products.
India Branch:
Address : 54/1446, SBT Avenue, Panampilly Nagar, Chochin 682 036, India
Tel: +91-484-309-9444
Email: Ro@nittagelindia.com
Web: http://www.gelatin.in/landingpage.html
Tokyo Branch:
Address: 08-12, 2-Chome, Nihonbashi-Honchou, Chuou – Ku, Tokyo 103-0023
Tel: +81-3-6667-8252
Web: http://www.nitta-gelatin.co.jp/

Panvo Organics PVT LTD

Produces a variety of chitosan products.
Address: Panvo Organics Pvt Ltd 25, Bunder Street, 11 Floor, Chennai – 60001 India

Tel: +91-44-3251-6521
Email: info@panvo.com
Web: http://www.panvo.com/index.html

Meron Biopolymers
Producer of Chitin and Chitosan from shellfish.
Tel: +91 484-222-7241 / 222-3703 / 222-0802
Email: info@meron.com
Web: http://meronbiopolymers.com/Default.aspx

Japan & South Korea

Koyo Chemical
Produces a range of chitin and chitosan from crustaceans.
Address: Umeda Asuka Bldg. 9F, 1-17, Taiyuji-cho, Kita-ku, Osaka 530-0051
Tel: +81-6-6365-1666
Web: http://www.koyochemical.jp/english/english

Jakwang
Produces chitosan among other products.
Address: 138 Sinsohyeon-dong Anseong-si Gyeonggi-do (456-380)
Contact: Lee Ho Jin
Tel: +031 677-5044~5 / 080-673-5345
Email: jakwang@jakwang.com
Web: http://www.jakwang.com/eng/

Kunpoong Bio Co., Ltd
Producer and supplier of chitosanoligosaccharides, water soluble chitosan, and bioypolymers from the waste products of crabs and shrimps for use in pharmaceutical, food, and agricultural applications. Featured in the Global Industry Analysts, Inc market report on Chitin and Chitosan.
Address: Wooree Venture Town 903, Deungchon 3-dong, Gangseo-gu, Seoul, 157-754, Korea
Tel: (+82 2) 3662-8565
Email: kunpoong@kunpoong.co.kr
Web: http://kunpoong.co.kr/

III European Chitin & Chitosan Producers

European Chitin Society
Non-profit organization which encourages study of all aspects of chitin.
Contact form: http://euchis.org/contact.php
Web: http://euchis.org/index.php

France Chitine
Produces 500 tons annually of a variety of chitosan products made from shrimp shells and squid bones in two factories, one in Africa and one in India.
Address: Chemin Porte Claire, 84100 Orange, France
Contact: J.P. Say
Tel: 00 33 (0) 4 90 51 68 11
Email: FRA.CHI@wanadoo.fr
Web: http://www.france-chitine.com/index-2.html

NovaMatrix: Ultrapure Biopolymer Systems
Subsidiary of FMC BioPolymer. Produces and supplies bio-compatible and bio-absorbable biopolymers for use in the pharmaceutical, biotechnology, and biomedical industries. Chitosan salts are manufactured in Sandvika, Norway.
Address: Head Office, Operations, and R & D, Industriveien 33, N-1337 Sandvika, Norway
Tel: +47-6781-5500
Email: novamatrix.info@fmc.com
Web: http://www.novamatrix.biz/Home.aspx

Primex
Icelandic marine biotech company that manufactures and supplies pure chitin and chitosan derivatives used in numerous areas including nutritional, cosmetic, food, and biomedical markets. Chitin and chitosan is manufactured in Siglufjordur Iceland. Featured in the Global Industry Analysts, Inc market report on Chitin and Chitosan.
Address: Primex ehf, Oskarsgata 7, 580 Siglufjordur, Iceland
Contact: Mrs. Sigridur Vigdis Vigfusdottir
Tel: +354-460-5521 / +354-696-8787
Email: sigga@primex.is
Web: http://www.primex.is/

Heppe
Germany
Produces chitosan for use in water and waste water treatment, agriculture, paper and textile industry, bioplastics.
Address: Gewerbegebiet Queis, Max-Planck-Ring 45, 06188 Landsberg, Germany
Tel: +49 (0) 34602 95 27 0
Email: info@nanokapsel.de or chitosan@biolog-heppe.de
Web: http://www.biolog-heppe.de/engl/index.html

Heppe Medical Chitosan GmbH
Develops, produces and sells biopolymers, in particular chitin, chitosan and derivatives for the cosmetic and pharmaceutical industries and for custom products. Featured in the Global Industry Analysts, Inc market report on Chitin and Chitosan.
Address: Heinrich-Damerow-Straße 1, D-06120 Halle (Saale), Germany
Tel: +49 (0) 345-27-996-300
Email: sales@medical-chitosan.com

Web: http://www.gmp-chitosan.com/en/home.html

IHC Chempharm
Produces a wide range of products, including but, not specializing in, chitin and chitosan.
Address: IHC-I.H. Chempharm Gmbgh, Ernst-Bloch-Str. 16, 51377 Leverkusen, Germany
Tel: +0049-2171-3994-0
Contact: Dietmar Hamacher
Email: info@ihc-chempharm.com
Web: http://www.ihc-chempharm.com/en

MealFood Europe
Products include chitin.
Address: Ctra. Mardid 13, 1º - Santa Marta de Tormes (37900 Salamanca)
Tel: +34 923 13 36 12 (Ext. 22) / +34 665 678 932
Email: info@mealfoodeurope.com
Web: http://mealfoodeurope.com/

Advanced Biopolymers AS
Norwegian high tech company specializing in the production of high quality chitosan.
Address: Boks 1262 Pirsenteret, N-7462 Trondheim, Norway
Contact: Jan Erik Foss
Tel: 0047-7354-5100
Email: mailto:firmapost@len.no
Web: http://www.advancedbiopolymers.no/

III U.S. and Canadian Chitin & Chitosan Producers

Canada

International Chitin Production Inc.
Address: 8596 Fraser St, Vancouver, BC V5X 3Y3, Canada
Tel: +1 604-301-3119
Contact: Marian Ng
Email: icpimn@yahoo.com
Web: http://www.omri.org/manufacturers/65562/international-chitin-production-inc

The Centre for Aquaculture and Seafood Development (CASD)
Comprehensive industrial response unit within the School of Fisheries at the Fisheries and Marine Institute of Memorial University. CASD employs scientists and technicians and undertakes contractual technical support services to the seafood and aquaculture sectors. CASD has been working to advance chitin extraction and chitosan conversion technologies for specific applications to shrimp and crab species native to Newfoundland and Labrador.

Address: Marine Institute: P.O. box 4920, St. John's, NL Canada A1C 5R3
Tel: 709-778-0200 / 1-800-563-5799
Web: https://www.mi.mun.ca/departments/centreforaquacultureandseafooddevelopment/

ChitOcean (coming soon)
New company that will be launching production soon of chitin and chitosan from shrimp shells using a process from Enysmm Company.
Email: diane@chitocean.com
Web: http://chitocean.com/

Quinlan Bros.
Seafood processer. Government of Canada invested $2.4 in Quilan Bros. in 2008 to research processing chitin and chitosan from shrimp and crab shells. In 2011, Quinlan Bros. was undergoing the permitting process to establish a chitin and chitosan facility. It is unclear if the project went through.
Address: Box 71, Suite 302, Atlantic Place, 215 Water Street, St. John's NL Canada A1C 6C9
Tel: +1 709-739-6960
Contact: Kim Quinlan
Email: Kquinlan@quinlanbros.ca
Web: http://quinlanbrothers.com/

Omera Shells Inc. / China Atlantic Canada Inc.
Does not produce chitin, but exports the shells of lobster, snowcrab, and shrimp for processing abroad.
Address: 2 Riverview Drive, Montague, Prince Edward Island, C0A 1R0, Canada
Contact: Mr. Yoke Lee Yap
Tel: 1-647-727-2326
Web: http://ca117613692.fm.alibaba.com/company_profile.html

United States of America

Biothera
Biotech company that develops products for improving immune health, including chitin derivatives. Featured in the Global Industry Analysts, Inc market report on Chitin and Chitosan.
Address: Bioethera, 3388 Mike Collins Drive, Eagan, Minnesota 55121
Tel: 651-675-0300
Email: info@biothera.com
Web: http://www.biotherapharma.com/index.html

CarboMer, Inc.

Produces specialty chemicals for the life sciences, including chitin derivatives. Featured in the Global Industry Analysts, Inc market report on Chitin and Chitosan.
Address: CarboMer, Inc., P.O. Box 261026, San Diego, CA 92196, USA
Tel: 858-552-0992 / 800-239-7129
Contact form: http://carbomer.com/contact
Web: http://carbomer.com/

HaloSource
Develops clean technologies to disinfect and purify water, including chitin derivatives. Featured in the Global Industry Analysts, Inc market report on Chitin and Chitosan.
U.S.:
Address: HaloSource, Inc., 1725 220th Street SE, Suite 103, Bothell, WA 98021
Tel: 425-881-6464
China:
Address: HaloSource Water Purification Technology (Shanghia) Co Ltd26E, No 18 Caoxi North Road, Xuhui District, Shanghai, 200030
Tel: (86) 21-6427-6730
India:
Address: HaloSource Technologies Pvt Ltd, Survey No.11 Devanahalli Road Off Old Madras Road, Virgonagar PostBangalore 560 049
Tel: 91-80-2847-2828
Mail Form (All): http://www.halosource.com/Contact/
Web: http://www.halosource.com/index.aspx

V-Labs Inc.
Provides expert consulting, analysis, and synthesis of carbohydrate products, serving the glycobiology, biomass and food industries. Featured in the Global Industry Analysts, Inc market report on Chitin and Chitosan.
Address: 423 North Theard Street, Covington, LA 70433, USA
Tel: 985-893-0533
Email Form: http://www.v-labs.com/index.php?option=com_contactus&Itemid=54
Web: http://www.v-labs.com/

h. Crab Market Information - Worldwide

MAINE INTERNATIONAL TRADE CENTER
Global Resources. Local Expertise.

Crab Industry Overview

I. Crab Producing Countries

Exports of Crab (HS 030614, 030624, 160510) by Country by total USD value 2013

Rank	Description	ANNUAL 2011	ANNUAL 2012	ANNUAL 2013	%2011-2012	%2012-2013
	TOTAL ALL WISER 34 REPORTERS	2,261,012,406	2,513,266,752	2,501,718,470	11.16	-0.46
1	China	876,523,408	1,083,289,527	1,083,849,459	23.59	0.05
2	Canada	779,552,626	764,748,246	818,091,260	-1.90	6.98
3	USA	288,049,179	313,218,329	275,533,663	8.74	-12.03
4	United Kingdom	75,493,940	73,634,170	80,151,270	-2.46	8.85
5	Chile	59,651,394	103,407,957	58,453,340	73.35	-43.47
6	Ireland	42,791,810	42,156,060	46,628,580	-1.49	10.61
7	Belgium	29,644,180	24,426,630	28,252,100	-17.60	15.66
8	France	26,130,970	22,764,050	26,426,280	-12.88	16.09
9	Denmark	20,080,580	20,708,200	25,251,240	3.13	21.94
10	Japan	20,046,229	20,995,027	18,213,468	4.73	-13.25
11	Netherlands	17,733,970	18,558,180	14,841,630	4.65	-20.03
12	Germany	7,399,520	7,760,480	10,278,740	4.88	32.45
13	Sweden	5,945,120	4,638,260	5,452,140	-21.98	17.55
14	Spain	5,575,550	4,308,420	3,958,750	-22.73	-8.12
15	Portugal	3,648,200	2,453,190	3,591,960	-32.76	46.42
16	Greece	200,210	494,470	1,164,870	146.98	135.58
17	Italy	437,170	337,260	577,000	-22.85	71.08
18	Luxembourg	90,280	210,700	314,430	133.39	49.23
19	Austria	329,780	330,990	221,140	0.37	-33.19
20	Estonia	102,670	94,660	147,770	-7.80	56.11
21	Czech Rep.	28,720	36,420	78,290	26.81	114.96
22	Lithuania	220,170	187,670	76,300	-14.76	-59.34
23	Slovenia	24,570	64,550	71,860	162.72	11.32
24	Latvia	68,350	103,120	58,150	50.87	-43.61
25	Hungary	32,580	14,130	10,590	-56.63	-25.05

Source: Wiser Trade

2014 Market Trends of Pasteurized Crabmeat

Indonesia is the biggest player in the pasteurized market and as Indonesia goes, so goes the rest of the market. Therefore, when Indonesia is producing half of what they normally produce, and they are raising prices weekly since early November, the other producing countries (Vietnam, Thailand Philippines) are quick to follow suit. Colossal will crest the $23 mark in 2014 and pasteurized jumbo will not be far behind. Eventually all superlumps will approach the $16 level. These are all price territories not seen since 2007. Fresh Venezuelan crab meat is trying to keep pace with the pasteurized market pricing but is generally a dollar or two under. Domestic blue crab production last year, both in the Chesapeake Bay and in the Gulf, was one of the absolute worst on record. Crabs have a very short life cycle (3 years), so the good news is that this year could be totally different. Currently, picking houses in Bayou La Batre and Louisiana are struggling to gather up enough crabs to pick once or twice a week. This will be the pattern though February, or until it starts to warm up. We have nitrogen frozen Maryland lump and jumbo lump. Source: Congressional Seafood Co.

Other Sources: The Crabmeat Market is Changing Fast - What Are Your Options?

II. Crab Meal Producers

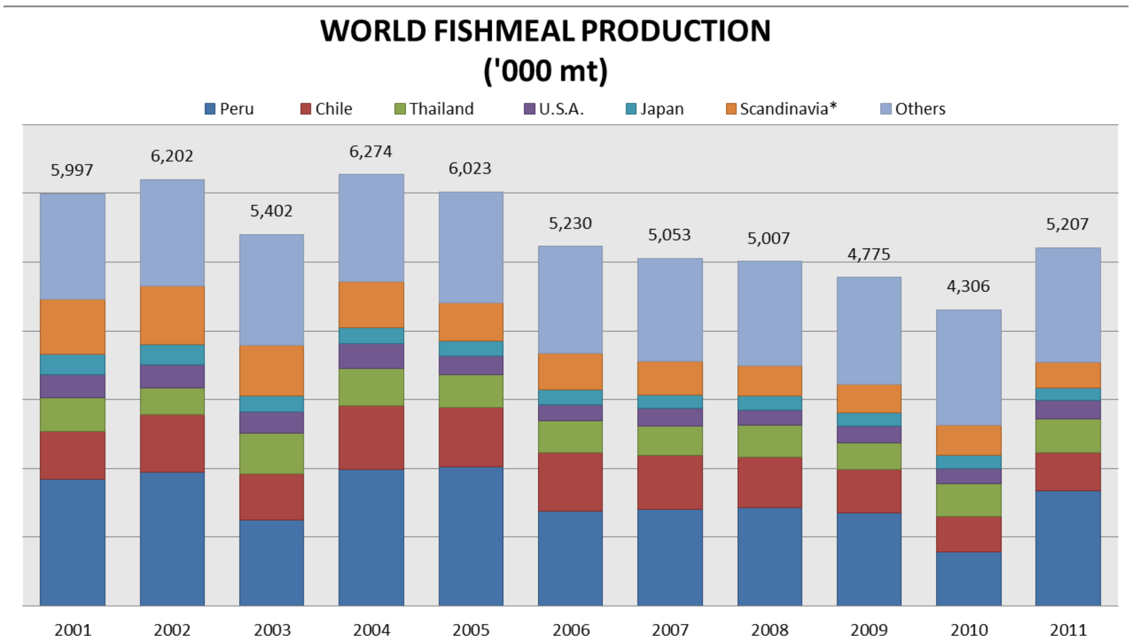
Exports of Crustacean flours, meals and pellets (HS 030629) by Country by total USD value 2013

Rank	Description	ANNUAL 2011	ANNUAL 2012	ANNUAL 2013	%2011-2012	%2012-2013
	TOTAL ALL WISER 34 REPORTERS	168,241,711	39,172,424	37,728,595	-76.72	-3.69
1	United Kingdom	69,874,890	2,922,550	7,836,650	-95.82	168.14
2	Denmark	36,808,210	4,644,800	4,507,970	-87.38	-2.95
3	Netherlands	13,923,290	11,303,410	4,368,860	-18.82	-61.35
4	China	1,174,670	1,524,985	4,138,923	29.82	171.41
5	Italy	4,058,750	2,967,770	3,437,150	-26.88	15.82
6	Belgium	6,306,180	1,922,220	3,380,330	-69.52	75.86
7	France	5,234,060	2,533,880	2,593,100	-51.59	2.34
8	Ireland	8,649,930	2,865,470	1,526,040	-66.87	-46.74
9	Germany	6,819,510	3,290,020	1,039,860	-51.76	-68.39
10	USA	392,172	1,140,347	898,741	190.78	-21.19
11	Spain	2,711,160	1,030,490	882,170	-61.99	-14.39
12	Portugal	3,776,900	469,450	813,760	-87.57	73.34
13	Colombia	794,054	755,465	802,825	-4.86	6.27
14	Luxembourg	1,579,370	991,270	551,330	-37.24	-44.38
15	Sweden	3,791,510	406,440	457,620	-89.28	12.59
16	Canada	81,997	130,293	225,883	58.90	73.37
17	Japan	359,018	131,312	151,473	-63.42	15.35

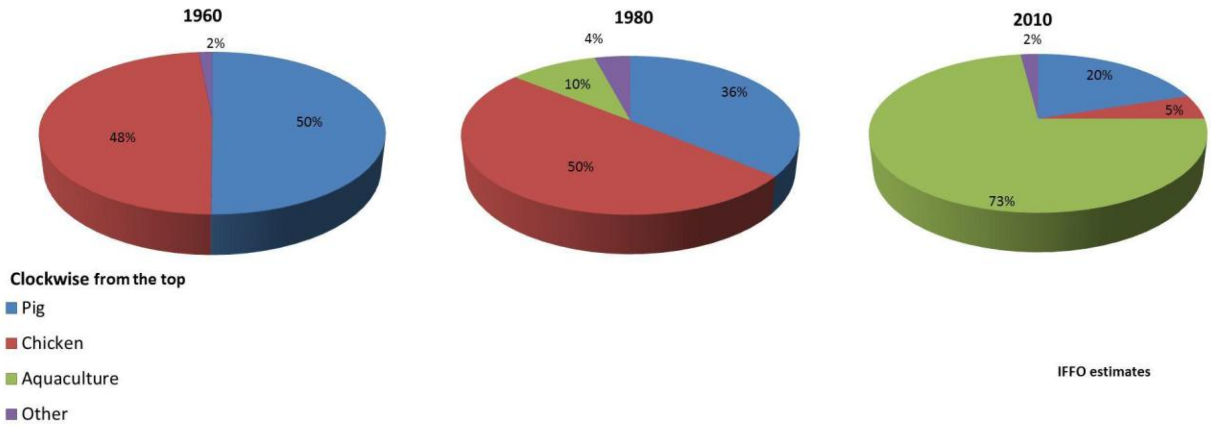
18	Austria	164,200	20,950	43,720	-87.24	108.69
19	Czech Rep.	26,230	36,670	41,840	39.80	14.10
20	Finland	0	0	19,360	NaN	Infinity
21	Croatia	1,175,310	35,200	6,800	-97.01	-80.68
22	Latvia	16,540	2,950	2,810	-82.16	-4.75
23	Slovenia	880	6,460	810	634.09	-87.46
24	Romania	0	10	560	Infinity	5,500.00
25	Poland	0	0	10	NaN	Infinity

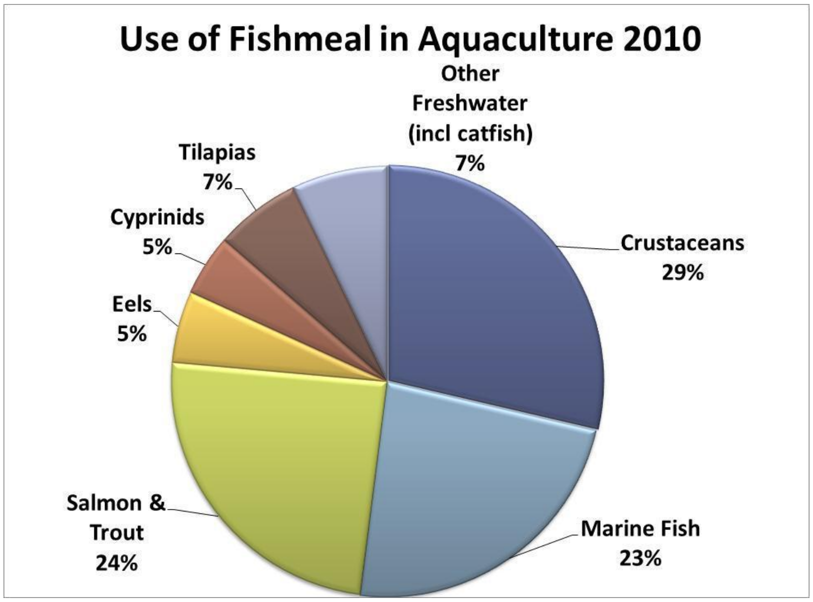
Source: Wiser Trade

Peru is a leading producer of fish meal. Producing 1.5 million MT and earning around 3 billion dollars per year, fishmeal production is Peru's second most important industry. Sold across the globe, the main markets for fishmeal are China, Europe and Chile. In Peru, the annual catch is defined by government quota and controlled through the Discharge Control Programme, being normally in the region of 6 million MT.
Source: SGS



Changing Uses of Fishmeal 1960 - 2010





Source: Seafish.org

A list of Fishmeal exporters and importers can be found in the Trade-Seafood Industry Directory

Other sources: Production and Consumption of Fishmeal

III. Major Fertilizer Markets

Exports of Animal/Vegetable Fertilizer (HS 3101) by Country by total USD value 2013

Rank	Description	ANNUAL 2011	ANNUAL 2012	ANNUAL 2013	%2011-2012	%2012-2013
	TOTAL ALL WISER 34 REPORTERS	611,620,005	630,358,636	688,585,933	3.06	9.24
1	Italy	179,663,760	172,080,620	188,498,470	-4.22	9.54
2	Netherlands	110,634,190	124,003,840	139,141,150	12.08	12.21
3	Belgium	72,651,330	65,434,170	75,037,640	-9.93	14.68
4	Germany	30,935,680	40,315,870	36,695,410	30.32	-8.98
5	Canada	26,642,467	33,035,819	34,590,119	24.00	4.70
6	USA	24,580,644	25,334,045	31,019,539	3.07	22.44
7	France	20,627,060	22,978,090	27,386,960	11.40	19.19
8	Spain	28,993,910	25,170,250	26,280,660	-13.19	4.41
9	Austria	20,894,940	22,280,180	24,074,830	6.63	8.05
10	China	40,985,368	24,251,068	23,377,917	-40.83	-3.60
11	Slovenia	1,221,140	7,534,580	21,156,260	517.01	180.79
12	Ireland	12,850,380	13,811,520	18,273,230	7.48	32.30
13	Hungary	5,045,290	7,833,800	10,732,360	55.27	37.00
14	Japan	5,284,480	3,978,273	6,501,677	-24.72	63.43
15	United Kingdom	9,047,540	5,597,320	4,868,070	-38.13	-13.03
16	Denmark	5,649,930	6,291,750	4,409,520	11.36	-29.92
17	Czech Rep.	2,119,040	2,055,020	2,665,640	-3.02	29.71
18	Latvia	75,520	1,015,320	2,545,560	1,244.44	150.72
19	Estonia	43,420	4,008,810	1,993,560	9,132.63	-50.27
20	Lithuania	55,940	264,940	1,985,650	373.61	649.47
21	Romania	39,410	765,580	1,103,090	1,842.60	44.09
22	Finland	279,130	1,590,590	1,039,190	469.84	-34.67
23	Chile	503,362	1,599,823	909,220	217.83	-43.17
24	Portugal	1,143,950	969,970	875,740	-15.21	-9.71
25	Bulgaria	647,580	1,033,340	828,510	59.57	-19.82

Imports of Animal/Vegetable Fertilizer (HS 3101) by Country by total USD value 2013

Rank	Description	ANNUAL 2011	ANNUAL 2012	ANNUAL 2013	%2011-2012	%2012-2013
	TOTAL ALL WISER 34 REPORTERS	447,442,046	433,793,828	446,781,968	-3.05	2.99
1	France	53,231,940	53,597,350	54,605,910	0.69	1.88
2	Italy	59,034,090	44,937,230	48,229,270	-23.88	7.33
3	USA	29,864,190	38,416,619	47,288,615	28.64	23.09
4	United Kingdom	53,739,770	32,716,620	39,325,350	-39.12	20.20
5	Netherlands	34,593,560	32,427,380	30,838,740	-6.26	-4.90
6	Portugal	24,275,540	22,412,220	26,950,800	-7.68	20.25
7	Belgium	21,701,780	19,899,110	25,704,460	-8.31	29.17
8	Spain	26,912,250	51,726,420	25,338,060	92.20	-51.02
9	Germany	21,394,740	26,142,310	24,577,700	22.19	-5.98
10	Austria	23,419,140	20,431,350	21,696,660	-12.76	6.19
11	Japan	15,283,547	15,477,398	16,299,077	1.27	5.31
12	Poland	4,770,940	7,096,950	13,446,610	48.75	89.47

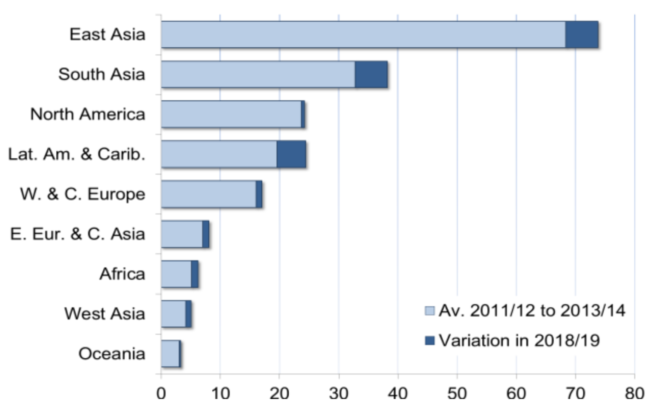
13	Hungary	6,009,220	6,504,520	7,544,730	8.24	15.99
14	Sweden	4,121,670	11,028,160	7,529,480	167.57	-31.72
15	Bulgaria	8,262,000	5,654,800	5,944,280	-31.56	5.12
16	Chile	5,417,316	5,989,122	4,991,031	10.56	-16.67
17	Romania	6,995,820	4,096,060	4,969,820	-41.45	21.33
18	Canada	3,206,178	3,847,399	4,958,685	20.00	28.88
19	Ireland	8,595,470	4,746,960	4,551,690	-44.77	-4.11
20	Greece	4,466,380	3,028,010	4,434,830	-32.20	46.46
21	China	11,728,448	1,950,845	3,757,669	-83.37	92.62
22	Denmark	3,270,520	2,796,800	3,307,330	-14.48	18.25
23	Lithuania	3,558,410	1,493,800	3,179,830	-58.02	112.87
24	Czech Rep.	2,112,250	2,759,990	2,914,670	30.67	5.60
25	Croatia	2,774,630	2,685,470	2,758,570	-3.21	2.72

Source: Wiser Trade

World fertilizer demand is seen as rebounding firmly in 2013/14

Supported by strong crop prices in the first half of the year and a rebound in South Asia, world consumption in 2013/14 is seen as growing by 3.1% year-on-year, to 184 Mt nutrients. The outlook for 2014/15 is relatively positive, with declining but still fairly attractive prices for cereals and oilseeds, which are anticipated to stimulate fertilizer applications. Fertilizer demand would increase in all the regions but Oceania, where it would slightly retreat following a strong increase in the previous season.

Demand would rebound in North America and continuous growth is seen in all the other regions, with rates above 3% in Africa, South Asia and Latin America. The largest increases in volume are anticipated in East Asia, South Asia and Latin America. Global fertilizer demand is anticipated to reach 200 Mt in 2018/19.



1: Medium-term Outlook for Total Regional Fertilizer Demand (Mt nutrients)

The medium-term outlook for agriculture remains favorable overall, with projected persisting tight market conditions and firm prices for the main agricultural commodities. Positive market fundamentals are expected to boost fertilizer use.

The highest growth rates are forecast in Latin America (3.7% p.a.), where cultivated land area is expanding steadily, followed by Africa (3.4% p.a.), where volumes are still very low and several countries subsidize fertilizers to stimulate consumption, and West Asia (+3.1% p.a.), where the geopolitical situation can be expected to improve. Demand is seen as

progressively rebounding in South Asia (2.6% p.a.), assuming transition to a more effective fertilizer subsidy regime, while East Asian demand growth would continue to decelerate (+1.3% p.a.) as China's N and P fertilizer demand reaches a plateau. Demand expansion in the rest of the world would be modest.
Source: International Fertilizer Industry Association

Concentration of world fertilizer production capacity, 2008–09

Fertilizer	Top 5 Countries (% of world in parentheses)	Top 5 Capacity (000 MT)	Top 5 Share (% of world)
Ammonia	China (22.8), India (8.9), Russia (8.5), United States (6.5), and Indonesia (3.9)	84,183	50.6
Urea	China (33.1), India (13.1), Indonesia (5.4), Russia (4.2), and United States (4.1)	95,802	59.9
AN	United States (15.4), Russia (14.7), China (7.7), Uzbekistan (4.8), and Romania (4.5)	28,770	47.1
DAP/MAP	China (23.3), United States (21.2), India (11.4), Russia (6.0), and Morocco (4.0)	22,896	65.9
Phosphoric acid	United States (20.9), China (19.3), Morocco (9.6), Russia (6.2), and India (5.3)	28,274	61.3
Potash	Canada (37.6), Russia (13.2), Belarus (9.9), Germany (8.2), and China (7.7)	39,687	76.7
NPK	China (29.3), India (8.2), Russia (6.0), France (4.0), and Turkey (3.0)	47,186	50.4

Source: International Food Policy Research Institute

Five primary global markets — China, India, other Asia, Latin America and North America — combine to account for nearly 70 percent of the world's population and over 80 percent of total fertilizer consumption.

Most of the growth in the fertilizer industry is occurring in these markets, with the exception of the more agriculturally-advanced North American market where sales are historically more stable. Consumption has more than doubled in China, India, other Asia and Latin America over the past 20 years, closely matching food production trends in that time.

Market fast facts
China

- Population 1.4 billion
- Uses more fertilizer than any country accounting for approximately 30 percent of world consumption
- Per capita renewable water and land resources are well below global average levels
- Has an increasing urban population with a rising standard of living
- Domestic consumption of meat has risen nearly seven-fold in 30 years, while fruit and vegetable consumption is nearly 10 times what it was 30 years ago
- Government has targeted improved agricultural productivity by modernizing equipment and practices, increasing farmer subsidies, allowing transfer of land-use rights, and raising minimum prices for key commodities
- Imports approximately 80 percent of its soybean requirements and is becoming increasingly reliant on grain imports, a factor driving growth in Brazil and US crop production
- Net exports of nitrogen and phosphate but imports over half of its potash requirements

India

- Population 1.3 billion
- 18 percent of world population but only 11 percent of its arable land
- Second largest fertilizer consuming country with around 15 percent of world use
- Annual fertilizer consumption growth of 4.8 percent this decade
- Government heavily subsidizes fertilizer for farmers but system is heavily biased to the use of nitrogen
- Yields typically 20-50 percent of those on equivalent US cropland
- Food consumption per capita is significantly lower than China and many other Asian countries
- Per capita renewable water resources are well below global average levels and farmers are heavily reliant on seasonal monsoon rains to support crop production
- Has no indigenous potash
- Very poor nutrient balances in India’s soils, insufficient potash applied relative to nitrogen, and more than 70 percent of soils have low to medium potassium content

Other Asia (excluding China and India)

- Population 1.3 billion (combined)
- Account for approximately 12 percent of world fertilizer consumption
- World’s leading producer of oil palm, rubber and a major producer of rice, fruits and vegetables
- Abundant water resources but limited per capita arable land

- Indonesia and Malaysia have doubled palm oil production in 10 years
- Has no indigenous potash

Latin America

- Population 600 million
- Account for approximately 11 percent of world fertilizer consumption
- Abundant land, water and labor make it an agricultural superpower
- Produces about half of global coffee and soybean supply and approximately 30 percent of the world's sugar production
- Corn is also grown for export and to feed domestic livestock industry
- Soils in Brazil are naturally deficient in potassium and require potash to remain productive
- Limited domestic potash production capability — approximately 80 percent of potash is imported

North America (US and Canada)

- Population 350 million (combined)
- Account for approximately 13 percent of world fertilizer consumption
- Major suppliers of food, fuel and fiber
- US accounts for about 30 percent of total global trade in wheat, corn, soybeans and cotton
- Both countries are among the world's most efficient agricultural producers
- Rising global food demand and domestic biofuel mandates have created competition for limited farmland

Source: Potash Corp

IV. Fish Feed for Aquaculture Producers

Exports of Prepared Animal Feed (HS 230990) by Country by total USD value 2013

Rank	Description	ANNUAL 2011	ANNUAL 2012	ANNUAL 2013	%2011-2012	%2012-2013
	TOTAL ALL WISER 34 REPORTERS	10,357,562,149	10,839,076,072	11,486,846,017	4.65	5.98
1	Netherlands	2,296,856,110	2,304,736,800	2,383,294,640	0.34	3.41
2	USA	1,256,153,531	1,411,123,584	1,569,984,309	12.34	11.26
3	Germany	1,252,324,640	1,257,388,100	1,274,040,480	0.40	1.32
4	Belgium	1,031,364,530	1,045,572,330	1,170,052,920	1.38	11.91
5	France	859,166,250	879,916,660	986,156,210	2.42	12.07
6	China	778,418,213	985,295,705	950,202,514	26.58	-3.56
7	United Kingdom	674,075,490	670,202,590	693,165,500	-0.57	3.43
8	Denmark	372,452,330	348,221,610	368,038,610	-6.51	5.69
9	Spain	372,314,380	372,949,900	360,562,750	0.17	-3.32
10	Canada	205,898,617	233,380,654	246,782,236	13.35	5.74
11	Austria	168,354,690	186,164,970	213,341,300	10.58	14.60
12	Hungary	156,298,740	166,286,280	188,564,010	6.39	13.40

13	Poland	145,575,650	135,278,910	154,149,990	-7.07	13.95
14	Italy	109,019,070	114,547,880	138,267,480	5.07	20.71
15	Bulgaria	79,142,530	97,454,480	118,459,010	23.14	21.55
16	Ireland	86,700,910	95,071,510	104,302,110	9.65	9.71
17	Czech Rep.	97,328,480	95,760,480	99,367,620	-1.61	3.77
18	Lithuania	64,292,890	65,565,870	77,265,510	1.98	17.84
19	Japan	67,327,074	78,919,396	58,913,875	17.22	-25.35
20	Portugal	34,040,470	39,399,120	48,492,260	15.74	23.08
21	Sweden	40,077,700	44,105,030	41,992,430	10.05	-4.79
22	Latvia	31,632,970	32,441,800	41,885,650	2.56	29.11
23	Croatia	32,356,190	32,129,740	40,594,350	-0.70	26.35
24	Finland	28,231,920	28,912,290	31,856,070	2.41	10.18
25	Chile	30,337,051	32,224,956	29,568,317	6.22	-8.24

Source: Wiser Trade

Fish Feed

While all animals need to eat and all farmed animals need to be fed, aquaculture represents the most efficient method by which to convert feed to edible protein. Research through the NOAA-USDA Alternative Feeds Initiative has accelerated progress toward reducing fishmeal and fish oil use in aquaculture feeds while maintaining the important human health benefits of seafood consumption. The remarkable progress in developing alternatives has reduced reliance on wild fish caught for this purpose.

Farmed fish and shrimp eat feed that is specially formulated to contain all the essential nutrients they need to keep them healthy and growing and maintain the human health benefits of seafood consumption. The ingredients are formed into pellets, similar in many ways to dry dog food. There are about 40 essential nutrients needed by all animals. Categories of essential nutrient include vitamins, dietary minerals, essential fatty acids and essential amino acids. These are provided by a number of feed ingredients including fish, plant, and processing waste meals and oils.

Fish nutritional needs vary by species. Herbivorous fish eat a feed mixture that may contain plant proteins (e.g., soy, corn), vegetable oils, minerals, and vitamins. In the wild, carnivorous fish such as salmon eat other fish. Therefore, feeds for farmed carnivorous fish (as well as many herbivorous fish) include fish oils and proteins as well as plant proteins, minerals, and vitamins that achieve the nutrition requirements of the fish and offer health benefits to humans. Traditionally, diets for carnivorous fish contained 30-50% fish meal and oil; however, continued research is leading to greatly reduced reliance on these ingredients.

About ¾ of the fishmeal and oil are produced from the harvest of small, open-ocean (pelagic) fish such as anchovies, herring, menhaden, capelin, anchovy, pilchard, sardines, and mackerel. These fish have short life cycles and are capable of rapid reproduction and stock replenishment. The other ¼ is generated from the scraps produced when fish are processed for human consumption.

The United States is a small net producer of both fishmeal and fish oil. The largest U.S. fishmeal and oil production comes from menhaden caught in the east coast and Gulf, the second largest component of US production comes from fish processing trimmings produced in Alaska's seafood industry.

Future growth of marine finfish and shrimp aquaculture will need protein and oil sources greater than current fishmeal and fish oil production can satisfy. NOAA, in partnership with the U.S. Department of Agriculture (USDA), launched the **NOAA-USDA Alternative Feeds Initiative** in 2007 to accelerate the development of alternative feeds for aquaculture. The purpose of the Alternative Feeds Initiative is to identify alternative dietary ingredients that will reduce the amount of fishmeal and fish oil contained in aquaculture feeds while maintaining the important human health benefits of farmed seafood.
Source: NOAA Fisheries

Some of the largest fish feed manufacturers are Biomar, EWOS, and Skretting