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Research Article

# Break-even analysis for a green crab fishery in PEI, Canada

Sophie St-Hilaire[1,*], Juergen Krause[2], Karen Wight[2], Luke Poirier[3] and Kehar Singh[1]

[1]*Department of Health Management, Atlantic Veterinary College, University of Prince Edward Island, 550 University Ave., Charlottetown, PEI Canada C1A 4P3*
[2]*School of Business, University of Prince Edward Island, 550 University Ave., Charlottetown, PEI Canada C1A 4P3*
[3]*Department of Biology, University of Prince Edward Island, 550 University Ave., Charlottetown, PEI Canada C1A 4P3*

**Corresponding author*
*E-mail: ssthilaire@upei.ca*

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## Abstract

The Department of Fisheries and Oceans in Canada is experimenting with a commercial fishery on the European green crab (*Carcinus maenas*), an invasive species in North America, to help reduce the negative impact this animal has on ecosystems and native shellfish populations. We determined the break-even price that fishers would require for green crabs under different fishing scenarios (i.e. different gear and catch per trap per day). We also determined, for a 21 day season, the minimum catch per trap per day for fishermen to break even at market prices of $0.50/lb,$1/lb, and $3.50/lb. Several scenarios were profitable, but our results suggest the price of crab (dockside) would have to be sufficiently high to motivate fishers to continue the fishing pressure needed to reduce populations of this invasive species. The most economically profitable scenario was a fyke net by-catch fishery, similar to what currently exists on Prince Edward Island during the eel fishing season.

**Key words:** European green crab, *Carcinus maenas*, fisheries; invasive species, break-even analysis

## Introduction

The European green crab (*Carcinus maenas* (Linnaeus, 1758)) is one of the most aggressive invasive aquatic animals on the Atlantic coast of Canada. It preys on small shellfish and crustaceans (Cohen et al. 1995; Pickering and Quijon 2011; Rossong et al. 2012) and is thought to be responsible for the decline of the soft-shelled clam industry in New England, U.S.A. (Lovell et al. 2007). In addition, the green crab competes with other crustaceans for resources and damages sea grass root systems by digging in sediment, which compromises the stability of ecosystems (Davis et al. 1998; Locke and Hanson 2004: Klassen and Locke 2007; Malyshev and Quijon 2010). The direct and indirect economic impacts of the green crab on shellfish industries is density-dependent (Mach and Chan 2014), and likely to be substantial in Atlantic Canada (Miron et al. 2005).

Short-term, experimental harvests of green crab in Atlantic Canada and the U.S. have been successful at temporarily reducing local populations (DFO 2010). But unless the fishing effort reduces the population below the minimum viable population size and is done on a sufficiently large enough spatial scale to prevent recolonization from surrounding areas, crab populations are likely to rebound (Pasko and Goldberg 2014). This suggests that a fishery for the green crab may be a viable option for controlling, but not eradicating populations of this invasive species.

A commercial fishery has been developed to help reduce Asian carp populations in the southern U.S. (Kentucky Department of Fish and Wildlife Resources 2014), but until 2012 a commercial fishery had never been used in Canada for invasive species control. In 2012, Department of Fisheries and Oceans (DFO) approved commercial fishing of green crab in Nova Scotia. Since then, DFO has issued several other experimental fishing licenses for green crabs in the Atlantic region in order to reduce their numbers (CBC 2014; CTV 2014). DFO regulates the method of capture and the climate dictates the season for fishing this invasive species. Licenses currently

have no limits on quantity, size, or sex of animals trapped. In Prince Edward Island (PEI), eel fishers, as well as several others, have by-catch permits for green crab that allow them to sell green crabs caught while they are fishing under other licenses; however, specific green crab licenses are only issued by DFO to eel fishers in exchange for their existing eel licenses (CBC 2014).

The current market for green crabs in Canada is as lobster bait, and its market value is between $0.30 and $0.90 per lb., depending on the availability of other bait products (CTV 2014). This product is sold directly between fishermen. Other possible markets for the green crab are as a seafood-flavoring concentrate product for human consumption, similar to that created from rock crabs; however, product and market development will be required for this to become a commercially viable option in Canada.

An existing green crab product in Europe, where the green crab originates, is the soft-shelled crab. As a product for human consumption, it retails for more than €51.14/kg in Italy, which is approximately equivalent to $35CAD/lb (Comune di Venezia - servizio per la tutela dell'utente e del consumatore 2014), but involves a significant time investment from the fishermen because crabs are held in floating cages, and sorted and harvested daily as they molt (Silvestri et al. 2006; Pellizzato 2010). This industry is also seasonal (Varagnolo et al. 1968; Pellizzato 2010), revolving around the spring and fall molting periods. In the United States, there is a well-established soft-shell blue crab industry where, although it is based on the same biological principles as the Venetian green crab industry, the molting process is done predominantly in closed systems (Plummer 1987).

Italy also has a ripe female green crab market that fetches approximately €5/kg ($3.50 CAD/lb dockside (anonymous communication Italian fisherman). In Asia, there is a similar market for ripe female mud crabs; however, these species tends to be larger crabs than the green crab (Wickens and Lee 2002).

In PEI, Canada, we are exploring the potential for a green crab commercial fishery as a sustainable method of control that will reduce densities of crabs and their negative impacts on our coastal ecosystems. The quantity of green crab in PEI coastal waters is unknown; however, based on provincial surveys conducted since this species invaded in 1997, we estimate at least 32 tons of crab could be harvested annually from the eastern and southern estuaries of the Island (McNiven et al. 2013). This estimate is based on harvests done in 2011 and 2012 in Wilmot River and Basin Head, PEI, which yielded approximately 2 tons of crabs each, and the fact that there are at least 16 estuaries on the southern and eastern shores of PEI with crab densities similar to or higher than these two systems. The catch rate per trap per day on the southern and eastern coasts of PEI during the 2012 provincial survey ranged from 8 to 32 crabs per trap per day (McNiven et al. 2013). The northern and westerns shores of PEI had much lower catch rates for green crabs and, in general, fishermen in our focus group did not complain about negative impacts in these areas. The objective of this study was to determine under what conditions a commercial green crab fishery would be economically viable for this invasive species. Specifically, we determined how many crabs a fisher would need to catch per trap to `break even`, given different market prices and expected costs.

## Methods

### *Data source*

We invited 8 PEI commercial fishers of oysters, silversides, or eels to a focus group meeting at the Atlantic Veterinary College to identify cost inputs for a green crab fishery. From this meeting, we developed a questionnaire to capture economic information and current green crab catch rates using fyke nets (the traditional method of catching crabs in Europe) and baited traps. We administered this survey to eel fishermen in PEI, but had only 2 individuals return the questionnaire, so we presented the study at a fishermen`s green crab meeting held by the PEI Fishermen`s Association and asked the audience for ranges of expected values. This more productive source of information, in addition to the two surveys provided by individuals, along with input from our initial focus group meeting, was used to estimate costs for our break-even analyses. Three market prices for green crabs were used in our analysis ($0.50/lb, $1.00/lb, and $3.50/lb), based on the current market value of similar seafood products (i.e. crab bait, crab for concentrate, and lobster).

We used 2012 trapping surveys on PEI, published by the provincial government (McNiven et al. 2013) and anecdotal reports from fishers on estuaries that were and were not negatively impacted by green crabs in PEI to establish trapping rates that would correspond to crab densities associated with minimal impacts on the ecosystem.

*Data analysis*

We created a tool, using partial budgeting, to estimate the minimum number of crabs per trap to break even, given different cost and return scenarios. We also calculated the break-even market prices for fishers at specific numbers of crabs per trap and with associated costs of fishing, under different scenarios.

To calculate break-even prices we used four fishing scenarios: dedicated catch using fyke net; fyke net by-catch; dedicated catch using baited trap; and auxiliary catch using baited trap. The types of fishing gear used in our models were based on existing license requirements (baited traps) and gear (fyke nets) used by local eel fishers and Italian fishermen to catch green crabs.

The cost components of our models included fixed and variable costs (Table 1). Fixed costs were comprised of depreciation using straight-line method on the price of gear purchased for the sole purpose of fishing green crab, and opportunity cost, which was set at 3% of the fixed capital costs. For all scenarios we assumed the green crab fishery was an incremental revenue source for fishers and, therefore, they would not purchase a boat in order to fish green crabs. In the case of the by-catch fishery using fyke nets, we had no fixed costs because eel fishers would already have this gear, and it would be set regardless of the green crab catch. For all other scenarios we assumed fishers would purchase traps or fyke nets and a minimal amount of "other fishing gear." When fishers used baited traps we assumed they had approximately $1000 of boat modification costs, as green crab licenses are currently only given to eel fishers who have boats that are not equipped to deal with these types of traps. Our estimates for boat modifications and "other gear" were based on our survey results. We also included the cost of the license fee in the fixed costs; however, in our scenarios this was set at 0 because currently there is no fee for a green crab license.

Our variable costs or operational costs included bait costs (i.e., cost of bait × amount of bait used per trap × number of traps set × number of days fished); labour costs, which were informed by the results of our survey and interviews; and other miscellaneous charges per trip (extra fuel and ropes, etc.). Fishermen were asked to estimate the cost of fishing (i.e. labor and other variable costs) if they set 60 baited traps or 20 fyke nets as part of an auxiliary fishery and as a dedicated fishery. These labour estimates were then multiplied by the number of days fished. A standard hourly wage of $20 per hour was used for all scenarios, based on the fishermen survey to estimate labor costs. All our cost calculations are presented in the spreadsheet provided with this note (https://data.upei.ca/islandora/object/researchdata:290). The opportunity cost of the variable expenses estimated in our model was considered negligible and, therefore, excluded. Total costs were calculated by summing the fixed and variable costs.

Gross returns were calculated by taking the total catch (i.e., number of traps or nets × number of crabs caught per net or trap) over the season (21 days) and multiplying it by the average weight of crabs and the estimated market price. Average crab weight (40g) was based on findings from a recent study conducted on PEI (McNiven et al. 2013). We estimated the number of fishing days in the season based on the eel fishing season and the molting periods, in spring and autumn, reported in Italy (Varagnolo et al. 1968; Pellizzato 2010).

We varied the price of crabs between $0.50, $1.00, and $3.50 per lb in our analysis in order to calculate a range of potential returns scenarios. The latter price is, approximately, the amount per pound that PEI fishers receive for lobsters, so we assumed that was the upper value limit for green crab. Currently, fishermen are reporting receiving approximately $0.50 per lb for green crab from lobster fishermen for use as bait, so we assumed this to be the lower value limit. The Asian food market on PEI has recently paid $1.00/lb for large fresh green crab, so we also included this value in our model. The range of market prices for green crabs used in this study provides estimates of likely minimum and maximum scenarios.

We estimated the number of traps or nets used and the number of crabs per trap or fyke net per day on the basis of our survey results. The daily numbers of crabs per trap/fyke net were also confirmed, for some areas in PEI, by the 2012 provincial survey (McNiven et al. 2013).

Net returns for different scenarios were calculated by subtracting total costs from gross return. The minimum number of crabs per trap per day to break even (i.e. when gross return equals total costs) was calculated using the following equation:

$$\text{no. of crabs per trap per day} = \frac{\text{total cost}}{\text{no. of days in season} \times \text{no. of traps per day} \times \text{price of crabs per lb} \times \text{av. wt. of crabs (g)} \times 0.0022}$$

We estimated the break-even price for fishermen, given a specific number of crabs per trap per day (i.e., 40 crabs per trap per day and 250 crabs per fyke net per day) and a 21 day season, using the following equation:

$$\text{price per lb} = \frac{\text{total costs}}{\text{total wt. of crabs caught during the season (kg)} \times 2.2}$$

Note that because the price of crabs is in pounds and the average weight and total weight of crabs are in g and kg, respectively, we had to convert these units to pounds.

## Results and discussion

The tool developed in this study highlights the fact that as green crab population densities decrease a higher retail price will be needed to encourage fishers to continue to trap animals. Our tool is useful in determining the approximate market price necessary to maintain fishing pressure on this invasive species, given different catch rates and costs of fishing on PEI in Canada (https://data.upei.ca/islandora/object/researchdata:290).

Our model indicates that there is a range of costs associated with green crab fishing, and these depend on different fishing strategies and gear. Using four potential scenarios for PEI, fixed costs ranged from $0 to $589 per 21 day season, depending on whether the fishers used traps or fyke nets and whether they were fishing crab as a by-catch, auxiliary fishery, or as a dedicated fishery. Although the price per unit is higher for fyke nets than for traps, fyke nets do not require bait and the catch per unit is higher. In addition, eel fishers are familiar with this gear and do not need to modify their equipment. This is also the preferred fishing method for soft-shell crabs in Italy (Varagnolo et al. 1968; Pellizzato 2010); however, the fyke net method is currently not permitted under DFO's green crab licenses.

The least expensive strategy for fishing green crabs is to catch them as by-catch during the existing fyke net eel fishery in the autumn. In this case, there are no fixed costs and variable or operational costs are minimal because there is only a small amount of additional labor involved for collection of the green crabs from fyke nets already set for eel fishing.

Of the scenarios evaluated, the highest variable costs occurred with the dedicated fishery using baited traps, because the fishers would have to launch their boats and set baited traps. The dedicated fyke net fishery is slightly less costly than the baited trap dedicated fishery because fyke nets do not require bait, but this fishery would still require the launching of boats, which increases the variable costs, compared to the by-catch fisheries.

Overall, we estimate the total (fixed and variable) cost of fishing green crab for 21 days to be between $1,365 and $5,866, depending on the time of the year, the gear used, the numbers of traps set, and whether it is a dedicated, auxiliary, or a by-catch fishery. The cost of fishing green crab is low because this is not a primary fishery for any of the licensed fishermen. Anyone with a license already has all or most of the gear to fish these crabs. Despite these relatively low costs of fishing, only some scenarios were profitable.

We determined that at $0.50/lb, the current price for green crab bait identified in our survey, the only fishery that would be profitable, with the numbers of crabs fishers reported in our survey, was the by-catch fyke net fishery (Table 1). In autumn, when eel fishers are catching green crab in their eel nets as by-catch, there is potential for a lobster bait industry, as the lobster fishery is open from August to October in PEI.

The break-even price for the by-catch fyke net green crab fishery, assuming 250 crabs per net per day for 21 days, was estimated at $0.15/lb (Table 1). The break-even price, if fishers were to set baited traps as per the gear prescribed on their green crab fishing licenses while fishing other fish species (i.e. auxiliary fishery), would be $0.87/lb, which would not be profitable if the market price for green crab was $0.50/ lb.

The most expensive scenario in our study involved setting baited traps as a dedicated fishery, where the cost of operating the boat was estimated at $120 per day, $95 per day more than the other scenarios, in which green crab fishing was an auxiliary fishery or by-catch fishery. This is the fishing scenario that would be required if the market for green crab was outside the eel fishing season (end of August to the end of October), because this is the only gear that is permitted on green crab licenses (Personal Communication, C. Mills DFO, Charlottetown PEI). For a dedicated fishery using baited traps, the break-even price for green crab was determined to be $1.32/lb (Table 1), but it is unlikely that fishers could sell green crab as bait for this price.

There are other potential markets for green crab that may be higher in value than bait. For example, crab concentrate, soft-shell crab in the spring, and ripe female crabs in the late autumn could range in value from $0.50 to $3.50/lb. The

**Table 1.** Break-even number of crabs per trap with different market prices for green crab (scenarios 1– $0.5/lb, 2 – $1.00/ lb, and 3 – $3.50/lb) and different costs associated with baited traps and fyke net fisheries. Also calculated are the break-even prices for different numbers of crabs per trap. The long term interest rate was assumed to be 3%.

| Assumptions | Baited traps auxiliary fishery | | | Fyke net by-catch fishery | | | Baited traps dedicated fishery | | | Fyke net dedicated fishery | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Scenarious | | | | | | | | | | | |
| | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| i) Days in Season | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 |
| ii) Bait cost per lb of bait ($) | 0.50 | 0.50 | 0.50 | 0.00 | 0.00 | 0.00 | 0.50 | 0.50 | 0.50 | 0.00 | 0.00 | 0.00 |
| iii) Average bait per trap (lb) | 0.50 | 0.50 | 0.50 | 0.00 | 0.00 | 0.00 | 0.50 | 0.50 | 0.50 | 0.00 | 0.00 | 0.00 |
| iv) Cost per trap/fyke net ($) | 40 | 40 | 40 | 400 | 400 | 400 | 40 | 40 | 40 | 400 | 400 | 400 |
| v) No. of traps/fyke per day | 60 | 60 | 60 | 20 | 20 | 20 | 60 | 60 | 60 | 20 | 20 | 20 |
| vi) Average crabs caught per trap/fyke per day (no.) | 40 | 40 | 40 | **250** | 250 | **250** | 40 | 40 | 40 | **250** | 250 | **250** |
| vii) Labour per day (man hrs) | 6 | 6 | 6 | 2 | 2 | 2 | 6 | 6 | 6 | 6 | 6 | 6 |
| viii) Labour cost per man hr($) | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| ix) Price of crab per lb ($/lb) | **0.50** | **1.00** | **3.50** | **0.50** | **1.00** | **3.50** | **0.50** | **1.00** | **3.50** | **0.50** | **1.00** | **3.50** |
| x) Other charges per trip (i.e gas, other…) | 25 | 25 | 25 | 25 | 25 | 25 | 120 | 120 | 120 | 120 | 120 | 120 |
| xi) Average weight per crab (g) | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 |
| xii) Cost of other gear used in fishing | 300 | 300 | 300 | 0 | 0 | 0 | 300 | 300 | 300 | 300 | 300 | 300 |
| xiii) Cost of boat modification | 1000 | 1000 | 1000 | 0 | 0 | 0 | 1000 | 1000 | 1000 | 0 | 0 | 0 |
| xiv) License fee | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| xv) Interest rate on bank deposits (%) | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| **Net returns [gross returns -total costs]** | **$(1,653)** | **$ 564** | **$11,652** | **$3,255** | **$7,875** | **$30,975** | **$(3,648)** | **$(1,431)** | **$9,657** | **$(1,009)** | **$3,611** | **$26,711** |
| **Break-even number of crabs per trap or fyke net for given costs (#)** | **70** | **35** | **10** | **74** | **37** | **11** | **106** | **53** | **15** | **305** | **152** | **44** |
| **Break-even price per lb given assumed no. of crabs/trap (or fyke net) and costs ($)** | **$0.87** | **$0.87** | **$0.87** | **$0.15** | **$0.15** | **$0.15** | **$1.32** | **$1.32** | **$1.32** | **$0.61** | **$0.61** | **$0.61** |

soft-shell and ripe female crab markets are seasonal and neither coincides with the eel fishery on PEI, so a dedicated crab fishery would be required to target these markets. If a fisher was to receive $3.50/lb for green crab at the dock, all scenarios evaluated in this study would be profitable, with net returns ranging from $9,657to $30,975 for a 21-day fishing period, given the catch rates and other parameters assumed in the models (Table 1). At $1.00/ lb, all but the dedicated baited trap fishery would be profitable for the fishers (Table 1).

In order for a green crab fishery to exist in PEI the number of crabs caught would have to be sufficient for fishers to break even, otherwise individuals will not continue to harvest this species.

The minimum number of crabs per trap per day for individual fishers to break even would depend directly upon the price received for their product. In this study, we estimated the minimum catch per trap/net per day for a 21 day fishery to be between 70 and 74 crabs per baited trap and fyke net, respectively, when the price was set at $0.50/lb and the crab fishery was done in conjunction with another fishery (i.e. by-catch or auxiliary fishery). Under the same type of fisheries, but with the price of green crab at $3.50/lb, the minimum number of crabs per trap or net to

break even would be 10 and 11, respectively. At a similar market value, but using a dedicated fyke net and baited trap green crab fishery, where gear is set for the sole purpose of catching green crabs, the minimum number of crabs per trap or net to break even increases to 15 and 44, respectively (Table 1). Based on the provincial surveys, these lower numbers are likely achievable in the southern and eastern estuaries of PEI, but it might be difficult to consistently catch 70 crabs per baited trap per day for 21 days even in the eastern estuaries where populations are the densest.

If the government of Canada is relying on commercial fishermen to reduce the size of green crab populations it may need to re-assess the gear permitted for fishing. Fyke nets are much more efficient than baited traps for catching green crabs, but they trap a significant amount of native species by-catch, which would need to be addressed before they could be licensed for the purpose of catching green crabs.

The high number of crabs per trap per day needed to break even makes it clear that to maintain a fishery on the green crab , the price per pound has to be sufficiently high; otherwise it is not profitable for the fishermen. Since there are currently no limits on the numbers or size of crabs caught, if the price was high fishers could drive the numbers down, but at a population density that results in a reduced catch rate of approximately 10 crabs per trap per day they would likely stop fishing. This might happen relatively quickly if there was a market for the product and fishers were allowed to capture whatever they could trap. Although there are no size restrictions on the green crab fishery, the gear used to catch green crabs limits the minimum size of crabs caught so it is unlikely that populations numbers would be driven to "zero". For this reason, it is unlikely that this invasive species will be eradicated through commercial fishing efforts alone; but population numbers may be reduced if the market price is reasonably high.

In order to determine whether a fishery could reduce the green crab population size in estuaries to negligible levels, we need to determine the population threshold where there is no longer a negative impact on the ecosystem. Despite the green crab being considered one of the worst invasive species in Atlantic Canada, we currently do not know what the threshold is for minimal impact (DFO 2010); however, there are areas with green crab, such as the estuaries on the north shore of PEI, where there are no notable negative impacts of green crab reported. The 2012 provincial invasive species survey reported catching green crabs at rates of 2 animals per trap per day (McNiven et al. 2013) in these areas. Based on our model, fishers would require prices higher than $3.50/lb to maintain the fishing pressure when population numbers are this low.

The licenses for this new species are relatively new and the markets for green crab are not well developed so it is difficult to know what the effects and thresholds of this new fishery will be. As we begin to monitor this new fishery, the effects on the ecosystem will become clearer.

One of the limitations of this study was that we estimated the cost to the fishermen based on only a few individuals' input, and the costs of fishing may vary more than we have estimated. However, we believe the cost of fishing green crab would be relatively low, as the crabs prefer shallow estuarine areas that are easy to access with light fishing gear. Whether or not DFO permits different types of fishing gear will have significant impact on the cost of fishing and will change the outcome of our analyses. We also do not know the market value of different green crab products in North America, and this variable will have a large impact on the minimum catch rates needed to break even. Because of the limited number of scenarios evaluated in the study and the uncertainty in the market price of green crab and costs associated with fishing, we have included the basic model in the supplemental materials to enable individuals to make their own assessments of their minimum catch per trap per day and break-even prices, based on their own cost and revenue estimates.

Another limitation of this study was that it evaluated the direct costs and benefits to individual green crab fishers in PEI, but the control of green crab populations also has indirect benefits to the ecosystem, such as reducing habitat destruction and predation on other commercially important species. The indirect economic benefits of reducing green crab densities could be worth substantially more than the catch itself. For example, Mach and Chen (2014) estimated shellfish revenue losses from green crabs in Puget Sound, WA to be between 1 to 23 million USD per year. However, because the fishers with the green crab licenses are not necessarily benefiting directly from the control of green crab, it is difficult for them to justify fishing crabs if it is not profitable; for this reason the indirect benefit of fishing green crab was not incorporated into this analysis.

This study provides an initial tool with which to assess the conditions for when it is commercially

viable for individual fishers to catch this invasive species (https://data.upei.ca/islandora/object/researchdata:290). Once the maximum crab population threshold for minimum impact is determined, a macroeconomic analysis for the province should be done to determine whether it will be feasible to control this species using a commercial fishery and the scale of the fishing effort required for the benefits to be realized. This macro-analysis should include indirect benefits to the economy associated with reduced habitat loss and predation on other commercial species.

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