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ECOLOGICAL ASSESSMENT OF THE INVASIVE EUROPEAN GREEN CRAB (*CARCINUS MAENAS*) IN NEWFOUNDLAND 2007-2009

Photo: Terri Wells

Figure 1: Map of the Newfoundland Region where ecological assessments were conducted. Red areas indicate green crab presence.

Context:

The European green crab, (Carcinus maenas), native to Europe and Africa, has been reported in the Maritimes since the 1950s, but was only reported for the first time in Newfoundland in 2007. A highly invasive species, green crab has yet to be formally assessed for the extent of its distribution, potential impact, or potential mitigative measures for its control in the Newfoundland environment.

In February 2008, DFO conducted a National risk assessment to determine the potential risk posed by European green crab in Canada. This assessment included evaluating the probability of arrival, survival, reproduction and spread, and potential consequences to determine a risk level based on the best available information on their biology, potential vectors of introduction, and impacts in both native and introduced ranges. The assessment concluded that green crab generally posed a high risk on both coasts depending on the ecological endpoint examined.

Building on the existing National risk assessment, and in recognition of the increasing threat of green crab environmental impact in the Newfoundland Region, a Canadian Science Advisory Secretariat (CSAS) Regional Advisory Process was convened. National and international experts on this species met to discuss and provide information relevant to the ecological assessment of green crab, including distribution, potential impacts and potential mitigations for green crab populations in Newfoundland. Conclusions from this process will provide DFO Policy makers and Oceans managers with information required to refine current licensing policies and to feed into stewardship initiatives and integrated management plans in the Newfoundland Region as they relate to Aquatic Invasive Species (AIS).

SUMMARY

Green Crab Population Dynamics

- Following the first reports of the invasive green crab in North Harbour, Placentia Bay, Newfoundland in August 2007, the species is spreading rapidly throughout several areas of Placentia Bay and St. Georges Bay on the west coast of the island.

- The presence of several size classes, reflecting multiple year-classes, indicates that a reproductive population of green crab has established in northern Placentia Bay in abundances several orders of magnitude greater than populations previously documented in the Maritime provinces and the western United States and Canada.

- Genetic analyses of green crab in Newfoundland indicate a close relationship with a cold-tolerant green crab population introduced into the Maritimes in the late 1980's. Anthropogenic activity through vessel traffic is the most likely vector of introduction into Newfoundland.

- Green crab population density information is a critical knowledge gap in population dynamics.

Biological Impacts of Green Crab on Native Species and Habitats

- In areas of high green crab abundance, the impact of green crabs is substantial on commercial and noncommercial mollusk and crustacean species and the natural habitat.

- A direct relationship between the invasive green crab and the Newfoundland native rock crab, *Cancer irroratus*, is indicated where the native species appears to be displaced or preyed upon by the invasive green crab. Similar declines and impacts on native crabs in other regions of North America have been reported in areas of high or even moderate green crab invasion.

- Shellfish have been determined to be the predominant prey in the Newfoundland environment (as is the case in other regions). Soft-shell clam beds and scallop beds, particularly smaller scallops, are affected in areas where these beds are located in more shallow areas with high green crab concentrations. Predation on American lobster is a significant concern as gut content analysis, laboratory trials and anecdotal reports indicate that green crab can and do prey on juvenile and trapped adult lobster.

- Eelgrass beds have been noticeably reduced in recent years in Newfoundland where green crabs are in high concentration. Green crab burrowing for shelter and digging for prey in eelgrass beds have been shown in many areas of North America to substantially reduce the amount of eelgrass and reduce coverage of this ecologically and biologically significant habitat.

- Although research has shown that green crab do impact biodiversity and habitat, the threshold levels for impact or critical number of green crab per area has not been determined and has been identified as a critical knowledge gap.

Mitigation Measures and Their Effectiveness to Control Green Crab Populations

- Direct removal of green crab by trapping has been determined to be an effective mitigation measure to evaluate. Trapping is the current experimental control method in California, Prince Edward Island and Nova Scotia as well as in Newfoundland.

- In all cases (across regions), analyses of trapping methods indicate that catch rates decrease with concentrated trapping. Continuous trapping gradually reduces the average size of green crab, eventually shifting the green crab from being primarily a predator to a more vulnerable size as prey for several native predators, e.g. shorebirds and some larger crustaceans.

- In areas where intense trapping takes place, the native rock crab species numbers often increase over time.

- Intense trapping appears to be an effective control method for mitigation of green crab invasions; however, threshold levels of green crab population densities, timelines for action relative to impact, and measures of success still need to be well-defined based on specific environments.

- Even with incomplete or inadequate information and with many uncertainties, control of this species by whatever means appropriate, is supported by the precautionary approach as green crab has been flagged as a high risk species both ecologically and economically through National risk assessment exercises.

INTRODUCTION

Many of the science issues facing Fisheries and Oceans Canada (DFO) are associated with significant knowledge gaps and uncertainties. This, however, does not relieve the Department of the need to make decisions on these issues. Under these conditions, decisions must balance the risks and uncertainties while ensuring the sustainability of Canada's aquatic ecosystems. With the potential for Aquatic Invasive Species (AIS) to impact species at risk, biodiversity, aquaculture or fisheries resources, AIS are now considered one of the lead threats to native biodiversity (Sala *et al.* 2000, Dextrase and Mandrak 2006).

Green crab was first discovered in Newfoundland in North Harbour, Placentia Bay by a local fish harvester in August of 2007. A rapid response assessment was carried out by DFO Science within 48 hours of the report. Following confirmation and preliminary assessment, more detailed ecological surveys, assessments and research on the invasive green crab were conducted in 2007, 2008 and 2009. These studies were initiated by Fisheries and Oceans Canada as part of its AIS monitoring and research program and were in collaboration with the Ocean Sciences Centre, Memorial University of Newfoundland, the provincial Department of Fisheries and Aquaculture, the Newfoundland Aquaculture Industry Association, the Fish Food and Allied Workers and fish harvesters in affected areas.

The primary focus for the ecological assessment of green crab in Newfoundland was to explore the species' ecology (distribution and abundance, habitat preference, behaviour, and reproduction), ecological impact in high concentration areas (on biodiversity and habitat), and to investigate potential control methods.

A green crab mitigation workshop held in St. John's in February 2008 reviewed and discussed various methods of response and control according to the DFO AIS Rapid Response Framework. This framework outlines the management options as eradication, containment, management or control of populations to keep abundance below a threshold of effect, mitigation of any problems caused by the species, monitoring of the species, and/or tolerance.

In the context of the workshop, mitigation was discussed as an action which included the control of the population to keep the abundance low in order to slow the spread or limit the impact of the invading species. At that time, direct removal by trapping was determined to be the most appropriate control method to evaluate. In 2008 and 2009, trapping projects administered by the FFAW, and supported by DFO and DFA, were conducted in northern Placentia Bay – an area with high concentrations of green crab and where the observed and potential impact of this invasive species was of great concern.

DFO subsequently held a Regional advisory process on March 17, 2010 in St. John's, to review the current scientific knowledge related to green crab populations in Newfoundland, to assess the potential biological impact of green crab on biodiversity and habitat, and to report and compare the effectiveness of trapping as a control method in Newfoundland. Additional international, national and regional scientific experts were invited to attend the meeting, and to present their research and compare their findings to those of the Newfoundland studies. The purpose of the meeting was to provide scientific advice and the information required by DFO to refine current licensing policies, enable stewardship initiatives and integrated management plans for the NL Region as they relate to AIS. Information provided at this regional meeting on AIS could have implications for other regions as well.

ASSESSMENT

Green Crab Population Dynamics

Studies directed toward understanding the ecology of green crab include those for distribution and abundance, habitat preference, behaviour and reproduction. Distribution (Figure 1) and abundance is determined using traps (modified whelk pots and Fukui), SCUBA diver transects, shoreline surveys, beach seines, acoustic tagging experiments, and discussions with fish harvesters, harbour authorities and the general public. Supporting environmental data is also collected. Acoustic tagging experiments indicate patterns of the movement of the green crab within the bay and the overlap of range of the green crab with native crab and lobster.

In 2009, experimental green crab licenses were provided by DFO for fish harvesters to participate in a stewardship program. This program provided additional distribution and abundance information and demonstrated the importance of early control efforts based on how rapidly this invasive species can spread if left unchecked.

Dive transects in the North Harbour area determined that the green crab population has been concentrated in shallow inshore waters (< 5 m). The initial assessment at North Harbour (2007) indicated the presence of a large population and biomass, and provided the motivation to conduct a green crab mitigation workshop which resulted in the experimental trapping projects of 2008 and 2009.

The size distribution of green crabs collected, indicates the presence of multiple year-classes, suggesting green crab have been present in the Placentia Bay area for at least 4-5 years. Genetic analyses of the green crab collected from northern Placentia Bay, indicates that they

are most closely related to green crab populations in Halifax, Nova Scotia, where a second cold-tolerant population was introduced into the Maritimes in the late 1980's.

Oceanographic circulation patterns in Placentia Bay are highly dependant on wind patterns, and may aid in dispersal of green crab larvae and juvenile populations throughout the bay.

In 2009, reports of green crab in St. George's Bay on the west coast of Newfoundland were confirmed. The largest population of green crab there has been observed in Little Port Harmon, and the greatest concentrations encountered have been in an eelgrass and mussel bed. Comparatively, the catches in Little Port Harmon are much lower than those in North Harbour. Key concerns surrounding the green crab invasion in the St. George's Bay area include the potential for impacts on existing initiatives related to the protection of the Banded Killifish, listed as 'endangered' under the *Species at Risk Act* (SARA), as well as impacts on lobster and eel fishing areas.

Findings regarding green crab ecology from monitoring and research programs in the Pacific and Gulf regions are similar to that described for Newfoundland. These similarities include spatial concentrations of green crabs in each habitat, rapid growth and spread, and impact on native species and habitat. Green crab in the Pacific region are larger in maximum size and less abundant overall, but are rapidly spreading northward in British Columbia. Green crab in the Gulf region are also increasing greatly in number and spreading into areas of oyster culture in PEI while areas of high concentration eelgrass beds are also impacted.

Investigating population dynamics can include an analysis of trends in the abundance of a particular population over time. This can involve measures of density (as an indicator of abundance), but also includes measures of spatial distribution, immigration, emigration, recruitment, and mortality, some of which can be assumed or modeled to provide or explain population trends. Several methodologies have been developed and applied to a wide variety of taxa to do this. Accurate population density estimates for green crab was determined to be a critical gap in the current knowledge of population dynamics of this species.

Biological Impacts of Green Crab on Native Species and Habitats

In February 2008, DFO conducted a National risk assessment to determine the potential risk posed by European green crab in Canada. This assessment included evaluating the probability of arrival, survival, reproduction and spread, and potential consequences to determine a risk level based on the best available information on their biology, potential vectors of introduction, and impacts in both native and introduced ranges. The assessment concluded that European green crab generally posed a high risk on both coasts depending on the ecological endpoint assessed. The risk of invasive green crab impact on biodiversity and habitat was highlighted as an area of particular concern and uncertainty in the risk assessment.

A national green crab research network was formed in 2008 to investigate the impacts of green crab on biodiversity and habitat in different regions (Pacific, Gulf, Maritimes and Newfoundland). Research conducted as part of this AIS national green crab research project by several members of the network provides the basis for the assessment of potential impacts posed to Newfoundland ecosystems by green crab when compared to other invaded ecosystems.

In areas of high green crab abundance, the impact of green crabs is substantial on commercial and noncommercial mollusk and crustacean species and the natural habitat. A direct relationship between the invasive green crab and the Newfoundland native rock crab, *Cancer irroratus*, is indicated where the native species appears to be displaced or preyed upon by the

invasive green crab. Similar declines and impacts on native crabs in other regions of North America were reported in areas of high or even moderate green crab invasion.

Shellfish are the predominant prey type for green crab in the Newfoundland environment (as is the case in other regions) where soft-shell clam beds and scallop beds, particularly smaller scallops, are affected in areas where these beds are located in more shallow areas that contain high green crab concentrations. Therefore, potential impacts on Aquaculture is a concern in several regions (Pacific, Gulf and Newfoundland), particularly for oyster beds and in regard to the movement of aquaculture product from impacted sites. Predation on American lobster is also a concern as gut content analysis, laboratory trials and anecdotal reports indicate that green crab can and do prey on juvenile and trapped adult lobster.

Eelgrass beds have been noticeably reduced in recent years in both North Harbour and Goose Cove, where green crabs are in high concentrations. Green crab burrowing for shelter and digging for prey in eelgrass beds have also been proven in many areas of North America to significantly reduce the amount of eelgrass and reduce coverage of this ecologically and biologically significant habitat. Eelgrass beds were reduced 43% between 2008 and 2009 at Kejimkujik Seaside, Nova Scotia and this reduction is thought to have resulted from green crab invasions.

Although research has shown that green crab do impact biodiversity and habitat, the threshold levels for impact or critical number of green crab per area has not been determined and has been identified as a critical knowledge gap. Research directed at determining thresholds for impact or critical number of green crab per area is recommended.

Mitigation Measures and Their Effectiveness to Control Green Crab Populations

The green crab mitigation workshop (February 2008) recommended that direct removal by trapping would be the most appropriate control method to evaluate for a pilot study in Placentia Bay, Newfoundland The North Harbour trapping project was administered by the FFAW with funding and in-kind support from DFO and DFA, with DFO Science as the scientific authority for the experiment.

In 2008, four fish harvesters fished with 20 traps each in northern Placentia Bay for 22 days in July and September, hauling traps twice daily (morning and evening). Over 25,000 pounds of green crab (est. 350,000 green crabs) were harvested from this 2 km^2 area. In 2009, two fish harvesters used 30 traps each, twice daily for 9 days in July. Seven thousand pounds of green crab were harvested during this period. In 2009, particular effort was placed on collecting as many berried females as possible in an attempt to reduce green crab larvae release.

Results from trapping showed that catch rates declined in areas where the harvest was targeted over time each year (e.g., 0.90 -0.46 lbs/trap/hr in 2008 and 0.41-0.12 lbs/trap/hr in 2009) during the directed harvest experiment. In areas where the invasive green crab was substantially reduced, the native rock crab, *Cancer irroratus*, increased in number in late 2008 and 2009.

The results of similar control experiments through direct trapping, (by researchers in California and Oregon targeting Bodega Harbor, California) provide similar trends in population reduction. The removal of green crab from a shallow central California estuary from June 2006 to July 2009 resulted in catch per trap dropping by 66% within 6 weeks of intense trapping and catch per effort continuing to decrease over time. In addition, with the removal of the invasive crabs, native species numbers increased in the area. The importance of multi-year harvest mitigation

has been highlighted as being particularly vital to controlling the largest green crab (predators) and leaving behind smaller green crab that can serve as prey for native species.

Other trapping trials, one in Basin Head Marine Protected Area (MPA) in Prince Edward Island and another in Kejimkujik Seaside National Park in Nova Scotia, although in the early stages of experimentation, also support declines in catch rate over time. These trials were attempted in response to a significant decline in native species (Irish moss and mussels for Basin Head and eelgrass for Kejimkujik), thought to have resulted from green crab invasions. While intense daily trapping has resulted in a gradual decline in catch per unit effort in both experiments, it was too early to determine if the reduction in green crab resulted in increases in mussels and Irish Moss. In particular, the establishment of threshold levels for relative abundance of green crab in the Kejimkujik experiment is of particular interest - highlighting the importance of determining accurate threshold levels for action, and for determining levels of success in these control efforts.

Intense trapping appears to be an effective control method, however threshold levels of green crab population densities, timelines for action relative to impact and measures of success still need to be well-defined based on specific environments. Research to determine these thresholds is recommended.

CONCLUSIONS AND ADVICE

Green Crab Population Dynamics

The European green crab population is established in extremely large concentrations in northern Placentia Bay and is spreading at a rapid rate throughout the bay. Populations have also been established in St. George's Bay on the western side of the island.

Genetic studies indicate that green crab in Newfoundland is closely related to green crab populations in Nova Scotia, particularly Halifax. Anthropogenic activity through vessel traffic is the most likely vector of introduction into Newfoundland.

Continued monitoring for abundance, measuring the distribution and spread, and studies related to the impact of green crab upon the natural environment are vital to understanding this invasive species and providing timely advice.

The lack of accurate population density estimates for green crab is a critical gap in the current knowledge of population dynamics of green crab. This information is vital to setting levels for response measures, thresholds for impact and measuring the success of control efforts. Research directed toward more accurate estimates of green crab population density has been recommended.

Biological Impacts of Green Crab on Native Species and Habitats

In areas of high green crab abundance, the impact of green crabs is substantial on commercial and noncommercial bivalve mollusk and crustacean species and the natural habitat. Specifically, native bivalve mollusk, native crabs and lobster, are particularly negatively impacted by invasive green crab when their environments overlap.

Biologically and ecologically significant eelgrass beds have been noticeably reduced in areas where high concentrations of green crab are found, as they are primary habitats for this invasive species.

Although research has shown that green crab do impact biodiversity and habitat, the threshold levels for impact or critical number of green crab per area has not been determined and has been identified as a critical knowledge gap. Research directed at determining thresholds for impact or critical number of green crab per area is recommended.

Mitigation Measures and Their Effectiveness to Control Green Crab Populations

Based on current information from regional, national and international research, mitigation by removal of green crab through intense trapping can be an effective method of reducing the abundance of green crab and limiting the impact the species has on the environment.

In all cases (across regions), analyses of trapping methods indicate that catch rates decrease with concentrated trapping. Continuous trapping gradually reduces the average size of green crab, eventually shifting the ecological role of this population from primarily predator to that of prey for several native predators, including shorebirds and other crustaceans. In areas where intense trapping has taken place, the native species (i.e., rock crab in Newfoundland) numbers increased over time.

Intense trapping appears to be an effective control method, however threshold levels of green crab population densities, timelines for action relative to impact, and measures of success will need to be well-defined based on specific environments. Research to determine these thresholds is recommended.

MANAGEMENT CONSIDERATIONS

It is clear that the level of abundance and rate of invasive green crab spread in northern areas of Placentia Bay, Newfoundland are much greater compared to other areas of North America. The “cold-tolerant” population of green crab appears to be particularly suited to the Newfoundland environment in shallow muddy/sandy areas which are also common eel grass habitats. Associated with this high green crab abundance is considerable impact on native biodiversity, both commercial and noncommercial species, and habitat, particularly shellfish beds and eelgrass meadows.

Monitoring abundance, measuring the distribution and spread, and studies related to the impact of green crab upon the natural environment, are necessary to provide timely mitigation and cost effective management plans, to guard against negative effects upon commercial and noncommercial resources. Further research is required and recommended to better define threshold levels of abundance, timelines for action and measures for success.

Harvesters and communities are concerned about the effects green crab will have on local fisheries, the marine habitat, and the ecosystem in general. Education programs have been successful in increasing local knowledge and promoting stewardship. Community and stakeholder awareness and stewardship has been an important aspect of early reporting of green crab presence allowing for early mitigation decisions.

Even with incomplete information and with many uncertainties, control of this species by whatever means appropriate, is supported by the precautionary approach as green crab has been flagged as a high risk species both ecologically and economically through National risk assessment exercises.

SOURCES OF INFORMATION

This Science Advisory Report has resulted from a Fisheries and Oceans Canada, Canadian Science Advisory Secretariat, Regional Advisory Meeting of March 17, 2010 on Newfoundland Green Crab Populations and Mitigations. Additional publications from this process will be posted as they become available on the DFO Science Advisory Schedule at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

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