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Trapping Methods for the Invasive European Green Crab in Canada

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

European Green Crab (EGC; *Carcinus maenas*) is a voracious aquatic invasive species (AIS) that threatens Canada's Atlantic and Pacific marine and estuarine ecosystems. It preys on and competes with commercial and recreational shellfish, negatively impacts commercial fisheries, and destroys ecologically- and biologically-significant habitat for native species. Fisheries and Oceans Canada (DFO) has developed substantial knowledge of EGC, particularly regarding trapping for early detection, monitoring, research, and physical removal for control. Information on trapping method considerations (deployment, environment, behaviour, catch) and goal-focussed protocols for different objectives including control measures and mitigation strategies has been compiled to provide advice on detection and control of EGC.

Trapping EGC is critical for early detection, determining impacts on native species and habitat, and rapid response and control efforts to prevent ecosystem degradation and commercial fishery loss. A review of 69 peer reviewed studies and unpublished projects on EGC trapping were reviewed to examine trap types used in Canada (46 studies) and elsewhere (23 studies). Fifteen traps were categorized by type and usage in Canada and 13 additional traps that were used in North America and other parts of the world. The Fukui collapsible crab trap was the most utilized trap in Canada based on the review. Other traps have proven effective and direct trap type comparisons have been conducted in several regions. Trap selection must consider the trapping objective, in particular, the targeted portion of the EGC population, as some trap types can disproportionately catch large adult EGC due to trap design and intraspecific EGC behaviours. Several factors are key in selecting an appropriate trap type based on trapping objectives, which can include habitat type, depth and site location, deployment method, life stage of targeted population, bycatch considerations and available resources. Trapping is an effective methodology for monitoring relative changes in EGC abundances and population dynamics, including changes in co-occurring native species (e.g., rock crab, lobster, and some fish depending on the trap type) that may be impacted by the invasion. Trapping for rapid response and control can effectively reduce EGC numbers and alter population dynamics. Outcomes could include reduction of EGC mean body size and recovery of impacted native species and habitat, but trapping efforts may need to be sustained to maintain low impacts of EGC on ecosystem components.

Knowledge gaps identified include a lack of information on trapping juvenile EGC and determining effective threshold levels or numbers for control to prevent environmental and fishery impacts. This EGC trapping advice could be incorporated by managers into a decision-making tool for guiding action related to early detection, rapid response, and control management activities.

1. BACKGROUND

The European Green Crab (*Carcinus maenas* L.), hereafter referred to as EGC, is a voracious aquatic invasive species (AIS) that poses a serious threat to Canada’s marine and estuarine ecosystems on the Atlantic and Pacific coasts (Therriault et al. 2008; DFO 2011). It preys on and competes with commercial and recreational shellfish, negatively impacts commercial fisheries, and destroys ecologically and biologically-significant habitat for native species, particularly eelgrass (Matheson et al. 2016). EGC is native to the eastern Atlantic from Europe and North Africa, with a broad distribution extending from Iceland and Norway in the north, the Baltic Sea in the east, and to Morocco and Mauritania in the south (Klassen and Locke 2007). Described as one of the world’s 100 worst invasive species (Lowe et al. 2000), EGC has several qualities that make it a particularly effective invader. The species is highly aggressive, competitive and omnivorous (Williams et al. 2006; Rossong et al. 2012) with a wide tolerance to temperature (-1.5^{o}C to 30^{o}C), salinity (4 ppt to 40 ppt), and oxygen levels as low as 10% saturation (Taylor 1982; McGaw and Naylor 1992; Cuculescu et al. 1998). EGC primarily feeds on molluscs, marine worms, and other small crustaceans (e.g., juvenile lobster), nevertheless, its diet is broad and includes everything from marine plants to carrion (Yamada 2001; DFO 2011). EGC has the ability to survive in a damp environment (out of the water) for up to three weeks (Darbyson et al. 2009). It also has high reproduction rates (Best et al. 2017) and wide larval dispersal, both naturally through currents and through ship ballast water (Grosholz and Ruiz 1996; Yamada 2001). This species has been referred to by the media and the public as the “cockroach of the sea”.

EGC was first observed on the east coast of North America in 1817 in Massachusetts and was probably introduced from Europe in ship’s solid ballast (Say 1817). The population moved northward over several decades reaching southern New Brunswick (NB) (Passamaquoddy Bay) by 1951 and spread to southern Nova Scotia (NS) where the northward expansion stalled near Halifax (Roman 2006). A second lineage of EGC arrived in northern NS in the late 1980’s or early 1990’s from northern Europe (Roman 2006) and the EGC in this invasion was more cold water tolerant and aggressive (Blakeslee et al. 2010; Rossong et al. 2012). Subsequently, the first known expansion of EGC into the Gulf of St. Lawrence was in 1994 at Aulds Cove (Canso causeway in the Canso Strait). This population spread eastward along the western shores of Cape Breton Island, westward to eastern PEI (Georgetown in 1996), and along the Northumberland Strait and to the Magdalen Islands, Quebec (QC) (2004) (Simard et al. 2013). This population was detected in western Newfoundland (NL) (2009) with the northern established location in the northwest Atlantic at Point Saunders, NL (C.H. McKenzie, unpublished data).

These two separate genetic lineages have hybridized and formed an even more hardy and aggressive strain that has spread southward through NS, NB, and into Maine (Jeffery et al. 2017, 2018). This hybrid population invaded southern NL and was detected first in Placentia Bay (2007) then Fortune Bay (2013) (Blakeslee et al. 2010; Lehnert et al. 2018). Jeffery et al. (2018) pointed out that “Understanding environmental thresholds associated with intraspecific diversity will facilitate the ability to manage current and predict future distribution of this aquatic invasive species”, suggesting that understanding the environmental differences between these populations and their hybrids is important to their control.

On the Canadian west coast, EGC was first reported in British Columbia (BC) in 1999 from Barkley Sound on the southwest coast of Vancouver Island and Esquimalt Harbour on the southern tip of Vancouver Island near Victoria (Gillespie et al. 2007). These introductions were attributed to northern spread by larval drift from EGC populations first detected on the Pacific coast in San Francisco Bay in California (1989) (Cohen et al. 1995). The highest concentrations were found in Pipestem Inlet, Barkley Sound (Gillespie et al. 2007) and by 2006 EGC was abundant in the inlets on the west coast of Vancouver Island. EGC was first reported from Sooke Basin in 2012, likely colonized through accidental introduction rather than larval spread (Curtis et al. 2015). In the fall of 2016, it was first reported in US waters of the Salish Sea proper (Yamada et al. 2017) and evidence from ocean modeling and genetic analyses suggests coastal origins via larval transport (Brasseale et al. 2019). Current flow reversal and warmer temperatures allowing for larval survival associated with periods of El Niño were thought to be factors in this invasion into the Salish Sea. In July 2020, EGC were first reported from Skidegate Inlet, Haida Gwaii. There have been various reports of EGC from parts of British Columbia’s Central Coast although survey efforts are limited. Larval EGC were detected in plankton tows in Prince Rupert harbour in 2018 but trapping for adults has failed to detect this species (T. Therriault, unpublished data).

When EGC invades new areas, it can potentially have devastating effects on the environment and local economy. Since EGC is hardy and can occur in very high numbers, it can decimate productive shellfish fisheries and can outcompete native species for food and space (Grosholz et al. 2000; Audet et al. 2003; Miron et al. 2005; Pickering and Quijón 2011; Matheson and Gagnon 2012a; Matheson and McKenzie 2014; Tan and Beal 2015). Lobster harvesters have expressed concern (DFO 2016, 2017) for the future of the lobster fishery based on their EGC observations and mitigation activities in NL. For example, recent research suggests that EGC detects bait more rapidly than lobsters and interferes with the lobster’s ability to enter the trap (Rayner 2018; Rayner and McGaw 2019). There is also evidence from NL, NS, and New England (USA) that adult EGC may be important predators on juvenile lobster (McKenzie 2011; Haarr and Rochette 2012) while on the West Coast predation by EGC on juvenile Dungeness crab (*Cancer magister*) is a concern (McDonald et al. 2001). In areas such as NB and NS where EGC has been present for many years, lobster appear to recognize EGC as prey and have been found to consume EGC, as demonstrated in laboratory studies (Rossong et al. 2006) and EGC have been used as bait for commercial lobster fisheries. In NL, several trials by fish harvesters and experimental studies by researchers have found less attraction by EGC than traditional bait used in lobster traps (Rayner and McGaw 2019; Zargarpour et al. 2019). EGC is not allowed to be used as bait in the commercial lobster fishery in NL to prevent the introduction and spread of EGC to other areas of the province.

EGC is considered an ecosystem engineer as it digs in sediments to bury and forage for prey, which has been linked to the destruction of eelgrass beds that are essential habitat for many commercially important juvenile fish and shellfish on both coasts of Canada (Miron et al. 2005; Garbary et al. 2014; Matheson et al. 2016; Howard et al. 2019).

Fisheries and Oceans Canada (DFO) Science has been trapping EGC for early detection and/or monitoring (Gillespie et al. 2007; DFO 2011; McKenzie 2011; Vercaemer et al. 2011; Simard et al. 2013; Bernier et al. 2020) and impact research (Rossong et al. 2012; Matheson et al. 2016; Best et al. 2017; Zargarpour et al. 2019) since the establishment of DFO’s Aquatic Invasive Species program in 2006. DFO, in partnership with stakeholders and Indigenous groups have developed substantial knowledge of EGC and its trapping. The standardized survey and monitoring EGC protocol developed in 2008 uses the Fukui crab trap which was previously used by Gillespie et al. (2007) in BC.

Following the discovery of EGC in Placentia Bay, NL in 2007, a EGC workshop was held with stakeholders including fish harvesters to consider response actions to take in Placentia Bay and after considering several options, removal by trapping was recommended. A NL AIS advisory committee was established in 2007 to coordinate communications between stakeholders, Indigenous groups and other partners and to set priorities for early detection, monitoring, research and response for AIS in the province (McKenzie et al. 2016). A Canadian Science Regional Advisory Process (RAP) on the invasive EGC was held in St. John's, NL on March 17, 2010. This RAP was conducted at the request of NL DFO Policy and Economics and Oceans sectors to provide scientific advice on the status of the invasive EGC and options for mitigation and control for this high-impact invader. The Science Advisory Report (SAR) (DFO 2011) identified critical research gaps to support scientific advice needed by managers to make decisions regarding spread, impact, mitigation, and control. NL DFO Science has been issuing experimental licences for EGC research and control studies since 2008, to fish harvesters in partnership with the Fish Food and Allied Workers (FFAW), the NL fish harvester union, for mitigation trials in 2008-2009, 2014-2016, 2017-2021. Individual fish harvesters, First Nations, not-for-profit organizations and concerned citizens have been provided experimental licences as part of a province-wide stewardship program. Any captured EGC were destroyed as a condition of these licences (either freezing for seven days or crushing) and were not permitted as bait. Some pilot studies have been conducted on utilization for compost, fertilizer, and chitin (Khiari et al. 2020).

EGC in DFO Gulf Region became a particular concern to the eel fishery and shellfish aquaculture with its increased northward spread and abundance in the southern Gulf of St. Lawrence from 1994-2015. From 2001 to 2017, a Nuisance Species Control Policy allowed individuals and organizations who were negatively impacted by EGC to apply for a licence under this policy for control purposes. Due to the increasing abundance of EGC and the reduction in American eel catches in some areas, a pilot EGC fishery was implemented from 2015-2017, where commercial eel harvesters could temporarily exchange their eel fishing licences for EGC licences. However, a limited market for EGC led to suppressed interest and participation in this pilot fishery as it progressed, which eventually led to its termination in 2018. No restrictions were implemented on the end use of EGC by harvesters during this pilot fishery (2015-2017).

DFO Maritimes Region launched a pilot EGC fishery in 2011, similar to DFO Gulf Region. This pilot fishery successfully led to the implementation of a commercial EGC fishery (open in southwestern and eastern NS only) in 2014 in which fishers can fish and sell their EGC catch live or dead and retain any size and sex. Commercial harvesters in SW and eastern NS can also retain EGC bycatch for their own use (bait or sale). DFO Maritimes Region also allows EGC to be fished with bait licences, where they are to be used exclusively for the licence holder as bait.

The initial discovery of EGC in the Salish Sea in 2016 invoked a similar response to the discovery in NL. Representatives from DFO Science, Washington Department of Fish and Wildlife, WA Sea Grant's Crab Team and the University of Washington developed a Bilateral Action Plan for European Green Crab in the Salish Sea. This Plan ensures a consistent, coordinated response to EGC in the Salish Sea across multiple jurisdictions and facilitates engagement with First Nations, stakeholders, and the public. The Plan outlines 6 overarching, action-oriented objectives with specific Strategies, Actions, and Performance Measures embedded including, 1) Collaborative Management Response, 2) Prevent Human-Mediated Introduction/Spread, 3) Detect EGC As Early As Possible, 4) Rapidly Eradicate New Populations, 5) Control Infested Sites, and 6) Conduct Research To Improve Management. This plan has been officially endorsed by the founding agencies and efforts are ongoing to monitor and control EGC in the shared waters of the Salish Sea. Following the detection of EGC in Haida Gwaii in 2020, DFO Science and AIS Management worked via an existing Haida Technical Working group to undertake delineation trapping (via a contractor due to COVID) and set management objectives.

Conditions of issuing experimental and control licences under Section 52 of the Fishery (General) Regulations specify that EGC cannot be sold (for bait or otherwise) and that catch needs to be destroyed and disposed of by the licence holder (often in landfill or other upland locations). In the Gulf Region, bycatch of EGC in the commercial Rock crab (Cancer irroratus) and fyke net American eel fisheries can be retained, but there are currently no requirements as to the end use of EGC from these particular fisheries and they can still be used as bait.

The Fukui trap has also been used for mitigation and control studies (McKenzie 2011; Vercaemer et al. 2011; Simard et al. 2013; Duncombe and Therriault 2017). Other traps have been used by DFO and their partners to compare and optimize control and removal (Cosham et al. 2016a, 2016b; Vercaemer and Sephton 2016; Bergshoeff et al. 2018, 2019; Bernier et al. 2020; Poirier et al. 2018, 2020). In 2014, several DFO regions compared different traps used for intense EGC trapping and the results were presented at the 2016 EGC workshop in St. John's (Vercaemer and Sephton 2016; Bernier et al. 2020; C.H. McKenzie, N. Simard, T. Therriault, unpublished data reported here). In addition to the published studies there are several other mitigation trapping activities that have been conducted or are being planned but are currently unpublished observations which can provide additional information on trapping EGC.

Knowledge acquired through these studies includes information on species life history and biology, population dynamics, gear types, and, in some cases, Catch per Unit Effort (CPUE) of trapping gear (e.g., Fukui traps, fyke nets), as well as bycatch, control measures, and mitigation strategies. However, much of this knowledge has yet to be captured formally in a comprehensive review that can be applied to AIS management.

The AIS NCP has requested science advice on trapping EGC as it is critical for management and mitigation activities including early detection, determining impacts on native species and habitat, and control efforts to prevent ecosystem degradation and commercial fishery loss. In order to transfer DFO's scientific knowledge into management action, information on various removal techniques and strategies must be incorporated into decision-making and be adaptable to different situations and trapping goals, balanced with operational capacity.

Objectives of this examination of trapping methods for EGC are:

1. Review and characterize gear that has been used for trapping the invasive EGC on Canada's Atlantic and Pacific coasts, considering specific trapping goals (e.g., early detection, ecosystem impact evaluation, population control) and how technologies vary by habitat, organism life stage, bycatch, and Catch per Unit Effort (CPUE).
2. Based on this review, provide recommendations on gear type for trapping EGC, considering feasibility and logistics.
3. Knowledge gaps will be identified regarding trapping methods.

The goal of this advice is to provide AIS managers with an overview of existing relevant information regarding trapping EGC. Cost of traps, gear and economic feasibility of any trapping method is not provided as it is beyond the scope of this science advice. This EGC trapping information could be incorporated by managers into a decision-making tool for guiding action related to early detection, rapid response, and control management activities.

2. SOURCES OF INFORMATION (METHOD FOR REVIEW)

Of the 69 research projects reviewed, 54 were peer-reviewed studies, selected from the larger EGC literature, targeting studies that focused primarily on trapping methods and comparisons and trapping information provided as part of an impact or population study. In addition to these primary publications, 15 unpublished Canadian projects that utilized traps to catch EGC to achieve a desired outcome were also examined (Appendix 1 and 2). The focus of the review was on Canadian EGC trapping methods; however, several North American and global studies were included to broaden the comparison. We divided these papers into three categories based on the primary use of the traps: ‘Research’, ‘Early detection and/or monitoring’, and ‘Mitigation’. Studies in the ‘Research’ category were those that directly assessed/compared trap performance, utilized trapping with the primary goal of describing novel aspects of EGC biology (e.g., trapping to determine habitat use), or used traps to collect EGC for laboratory studies. Studies in the ‘Early detection and/or monitoring’ category were those that used trapping to detect the presence of EGC, describe range/distribution/abundance, and/or describe the rate of expansion/spread in areas where EGC is invasive. Finally, studies in the ‘Mitigation’ category were those that used trapping to perform removal/mitigation efforts of invasive EGC populations. Of the 54 peer-reviewed studies and 15 unpublished projects reviewed, 19 used trapping for Research purposes, 33 used trapping for Early detection and/or monitoring, and 17 used trapping for Mitigation purposes (Figure 1).

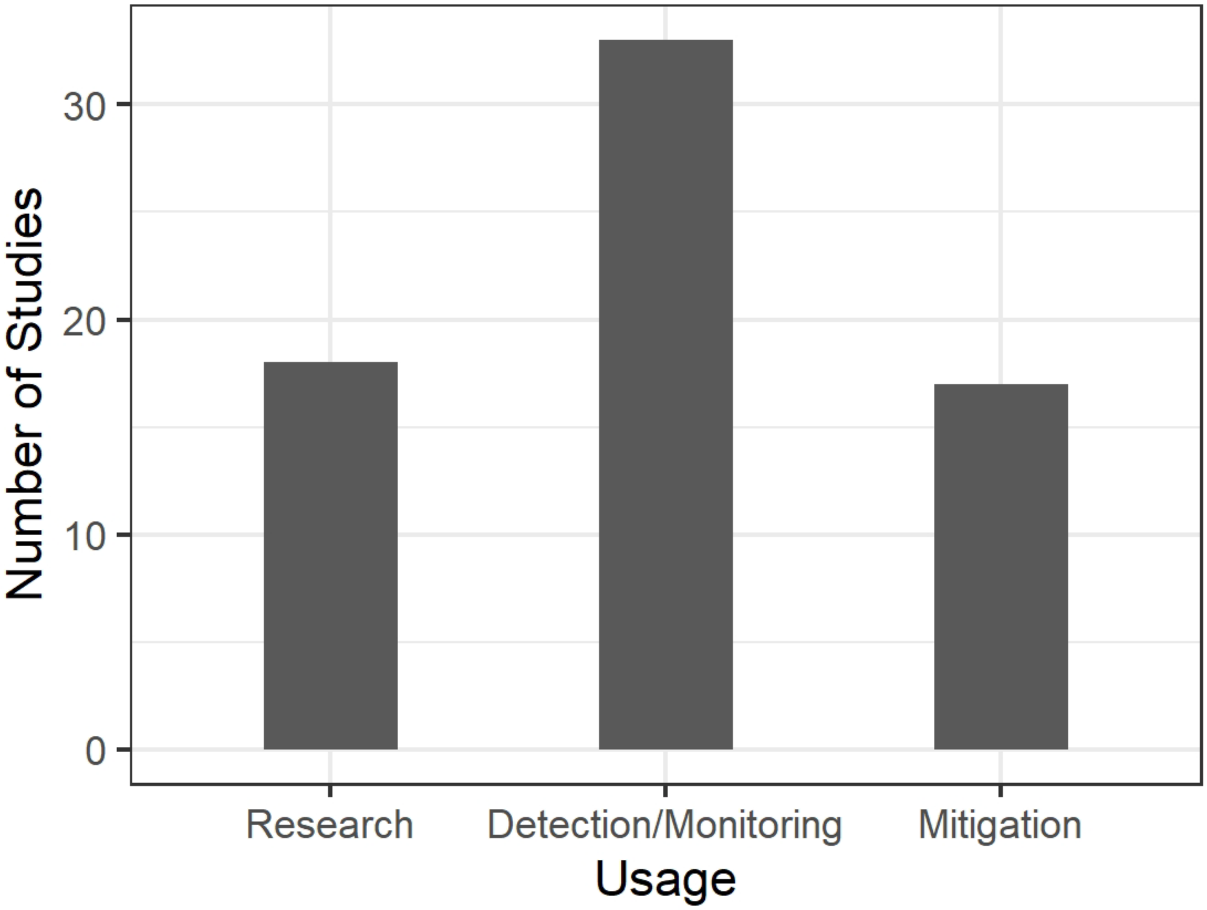

Figure 1. Categorical assignments of peer-reviewed EGC literature using trapping for Research, Detection/Monitoring, and Mitigation purposes.

In the 69 papers and projects reviewed, traps were grouped by physical structure/functionality into eight major trap categories, which included: collapsible fish/crab traps, eel traps, minnow/crayfish traps, box traps, conical traps, cylindrical traps, ‘other’ and nets. Traps grouped into the ‘other’ category either did not match the structure/function of traps in any of the major categories, or lacked sufficient descriptive information within the original document to be grouped into any particular category. There were many instances where traps were modified (Table 1), but still maintained the same functionality as others within the respective trap category, and we therefore grouped these variants into the appropriate general trap category for our description of trap usage. For example, there were three variations of the collapsible fish/crab trap used which include the Fukui, Promar, and Morenot traps, but all are listed under the trap category ‘collapsible fish/crab traps’. Across our three primary use categories, use of trap type varied, but across all studies and projects the use of collapsible fish/crab traps dominated (Figure 2).

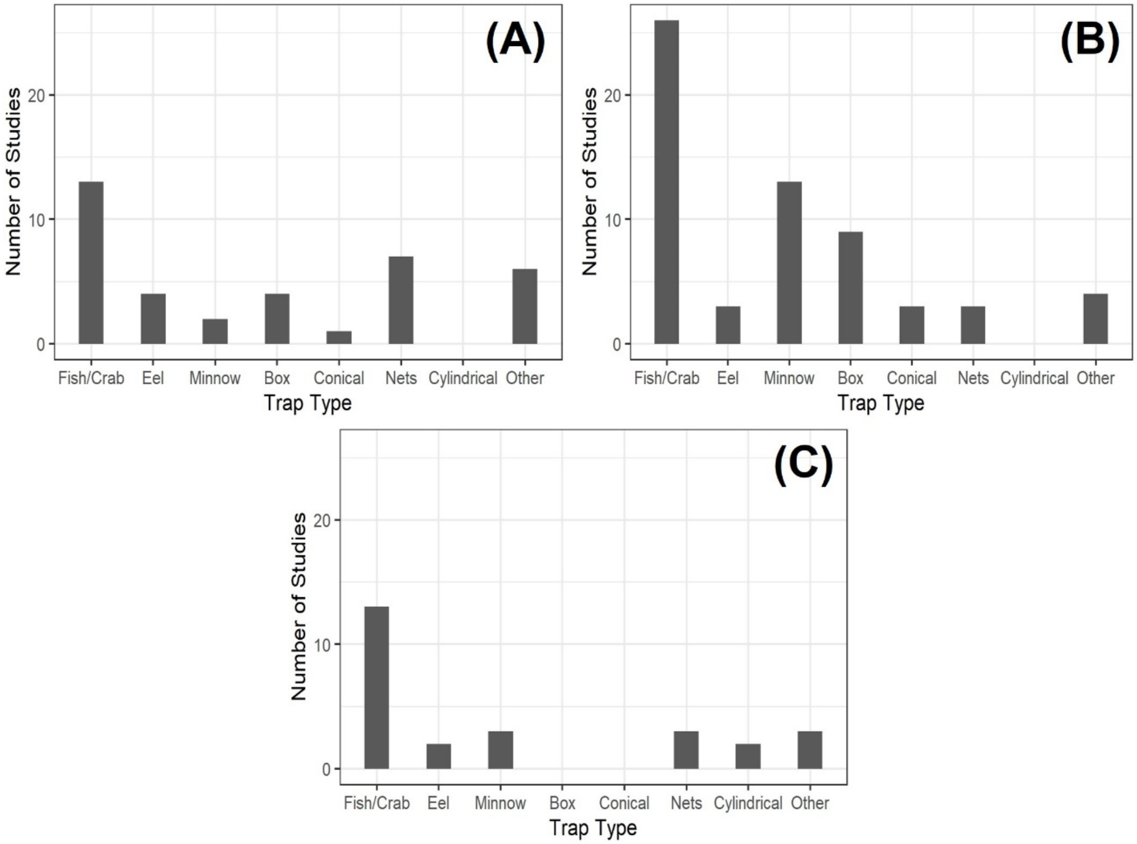

Figure 2. Trap usage by study purpose. Panel (A) indicates traps used for Research, (B) indicates traps used for Early Detection and Monitoring, and (C) indicates traps used for Mitigation.

3. TRAPPING METHODS (RESULTS)

3.1. TRAP TYPE

Fifteen traps were categorised by type and usage in Canada (Table 1) with an additional 13 traps reviewed that were used for EGC trapping elsewhere in North America and other parts of the world (Table 2). The traps are listed according to their functional shape, primary use or trapping style and include: collapsible fish/crab traps, eel traps, minnow (including crayfish) traps, box trap, conical traps, cylindrical traps and nets. The table includes the characteristics of the trap as well as their usage or the trapping purpose. Photographs of the traps used in Canada are shown in Figures 3-9. Table 2 provides information on additional traps used outside Canada and also provides characteristics, trapping purpose and location. No photographs of these are provided, however this information can be found within the cited references.

3.1.1. Collapsible Fish/Crab Traps (e.g., Fukui trap)

Collapsible traps (including Fukui traps) have been used extensively for early detection, monitoring, mitigation, and research in Canada (BC – Duncombe and Therriault 2017; NB – Bernier et al. 2020; NS – Vercaemer and Sephton 2016, Poirier et al. 2020; NL – Bergshoeff et al. 2019; QC – Simard et al. 2013, the USA (Yamada et al. 2005; Kelley et al. 2015; Young et al. 2017), Australia (Hewitt and Martin 2001), and Tasmania (Thresher et al. 2003). Fukui traps are the standard trap DFO uses for EGC surveys, monitoring, and research in Canada (Table 1; Figure 3 A). These traps are light and collapsible, making them ideal for large scale monitoring (Bernier et al. 2020).

Several modifications have been recommended to improve efficiency of Fukui traps to capture EGC (Bergshoeff et al. 2019). The “assist” modification, a thin strip of fiber glass window screen placed inside the trap adjacent to the entrance allowed EGC to pull themselves inside the trap more efficiently and increased CPUE by 81% relative to the standard Fukui trap (Bergshoeff et al. 2019). However, this modification was tedious and lacked durability so the design would need improvement to make it more practical for large-scale removal efforts (Bergshoeff et al. 2019). The “sinker” modification utilized three 1 oz. casting sinkers with brass eyelets attached to the lower lips of each entry slit, increased CPUE 59% compared to the standard Fukui trap (Bergshoeff et al. 2019). This design took the least amount of time and effort, was durable, required no maintenance, and could be a practical tool for large-scale efforts to capture EGC (Bergshoeff et al. 2019). This modification has been adapted for the five-year Marine Institute eelgrass restoration project funded by DFO Coastal Restoration Program in Placentia Bay (M. Clarke, pers. comm.). A different “mesh” modification, panels of fiber glass window screen attached to the top and of each trap entry led to a 29% increase in CPUE over the standard Fukui design (Bergshoeff et al. 2019). However, it may have hindered larger crab from entering the trap and attaching these panels was time-consuming, which may be difficult for large-scale trapping efforts (Bergshoeff et al. 2019). The “string” modification, braided polyester string used to hold the trap entrance open, produced a low CPUE and high frequency of escape events (Bergshoeff et al. 2019). This modification was easy to install but overall impractical as the position of the strings made it difficult to empty crabs from the traps (Bergshoeff et al. 2019).

It should be noted however, that increasing the size of the entrance to increase EGC access can also have unwanted consequences where marine mammals (e.g., River otter, *Lontra canadensis* or American mink, *Neovison vison*) can be trapped and drown. To avoid this, cable or other ties have been used in NL, BC, and Washington State (WA) to reduce the overall size of the entrance to prevent trapping of other larger species, particularly when used by citizen scientists or the public (Grason et al. 2019). Placement of the traps well below the lowest tide, so the traps are not exposed out of water, can also prevent other species entering the traps.

One of the limitations of this trap is that there is no escape port such that the trap could continue to fish indefinitely if lost. AIS NCP in BC is requiring a modification to use rot cord (which breaks over time) as a quick option for control trapping by First Nations and community groups.

Other types of collapsible fish and crab traps such as Promar and Morenot traps (Figure 3 B, C), have been used in Pacific and Atlantic Canada (BC – McGaw et al. 2011; NL – I. McGaw, pers. comm.) for research.

3.1.2. Eel Traps

Cylindrical eel traps have been used in Atlantic Canada (NB, NS, PEI – Pouliot 2009; Vercaemer and Sephton 2016; Bernier et al. 2020) for EGC monitoring and mitigation efforts (Table 1; Figure 4 A). The modified eel trap is the standard trap used by PEI provincial Department of Fisheries and Communities to survey and monitor EGC and is also used by

Parks Canada (Figure 4 B). Kejimkujik National Park uses the Russell modified eel traps for standardized monitoring of EGC (Figure 4C) (Mersey Tobeatic Research Institute and Parks Canada 2015). The Russell eel trap was designed by Port Mouton (NS) fisherman M. Russell Nickerson and has been used for EGC monitoring and mitigation efforts in Atlantic Canada (NS – Pouliot 2009). Eel traps are designed to catch fish, and are not recommended to capture EGC due to large number of commercial fish bycatch (Behrens Yamada and Gillespie 2008).

3.1.3. Minnow/Crayfish traps

Minnow and/or crayfish traps have been used for early detection and monitoring EGC in Canada (BC – Gillespie et al. 2007; NS – Pouliot 2009; QC – Simard et al. 2013) and the USA (CA – Grosholz and Ruiz 1995; MA – Young et al. 2017; OR and WA – Yamada et al. 2005). It is important to note that minnow traps and crayfish traps have different size entrances although they are often referred to interchangeably, even in catalogs. The crayfish traps have larger openings and can allow between 30 and 55 mm EGC to enter (Yamada et al. 2005). The small size and weight of this style of trap, make them easy to transport for deployment (Table 1: Figure 5). However, their small capacity can result in rapid trap saturation with modified traps, particularly in areas with high abundances of EGC, which can allow crabs to escape and reduce entry of crabs due to intimidation (Young et al. 2017). Minnow traps have been modified to catch larger EGC by stretching out the entrance openings to 5 cm (Young et al. 2017) and 6 cm diameter (Gillespie et al. 2007). Unmodified minnow traps that exclude larger EGC may capture smaller, juvenile EGC but then direct comparison of CPUE with other traps like the Fukui is problematic and not advised, because the traps target different portions of the EGC population. In BC, the AIS NCP surveillance program uses (modified) minnow traps for early detection in new locations and are often deployed in combination with the standard Fukui trap with the objective to target a wider size range of EGC.

3.1.4. Box trap

The Russell modified shrimp trap was designed by Port Mouton (NS) fisherman M. Russell Nickerson and is commonly known as the Russell shrimp trap or Russell’s trap (Table 1; Figure 6A). This trap has been used in Atlantic Canada (NB, NS, PEI – Pouliot 2009; Vercaemer and Sephton 2016; Bernier et al. 2020) for EGC monitoring and mitigation, including large scale removals (Mersey Tobeatic Research Institute and Parks Canada 2015). It has been used regularly by Parks Canada in estuaries within Kouchibouguac National Park and was used for intensive trapping in Kejimkujik National Park Seaside Adjunct (Little Port Joli estuary) where 1.5 million EGC were removed between 2010 and 2014 (C. McCarthy, pers. comm. In Vercaemer and Sephton 2016). The Delbert trap has also been used in PEI for early detection and mitigation (Joseph et al. 2021, Figure 6B). The Russell trap and similar regular ship box traps are also used in WA as the larger size and robust construction are a good alternative to the lighter, smaller Fukui trap (P.S. McDonald, pers. comm.).

3.1.5. Conical traps

The conical shaped Luke trap has been used in PEI for early detection and mitigation (Joseph et al. 2021, Table 1, Figure 7A).

The modified whelk pot has been used in eastern Canada by DFO NL (Blakeslee et al. 2010; McKenzie 2011) and QC Region (Simard et al. 2013) in early monitoring and mitigation for EGC. This pot was found to be heavy, difficult to handle, and EGC were able to sit on the top of the trap and feed on the bait without entering the trap (C.H. McKenzie, unpublished data), (Figure 7B). However, a person formerly from Grey River Netting (NL) currently in BC has manufactured a modified version of the whelk pot using a lighter metal frame. These traps are said to capture higher numbers of crabs compared to the Morenot collapsible crab traps. Further, bycatch of mammals, such as River otters has not been an issue with these traps as the otters can escape from the top opening and in some cases, otters have used these traps as feeding stations (D. Anderson, pers. comm.).

The modified snow crab pot has been used in eastern Canada (NL – C.H. McKenzie, unpublished data) by DFO NL Region in early monitoring and mitigation. Other similar crab pots have been used for early detection and monitoring in the Magdalen Islands (Paille et al. 2006; Simard et al. 2013). These pots were also found to be too large and heavy for handling and moving around on shore and for using and deploying on small (e.g., < 6 m) vessels.

3.1.6. Other traps

Wooden lobster traps have been modified so that the wooden slats were placed closer together and they did not have exhaust (escape ring) vents to make them suitable for fishing for EGC (Simard et al. 2013). These traps have been used for early detection and monitoring in Atlantic Canada (QC – Paille et al. 2006; Simard et al. 2013) but were found to be too large and heavy for handling and moving around on shore and using and deploying on small (e.g., < 6 m) vessels.

3.1.7. Nets

Fyke nets are typically used for fishing of American eel but have been used in Atlantic Canada (PEI – Audet et al. 2008; Poirier et al. 2020; QC – Simard et al. 2013) for EGC monitoring and research (Figure 9 A). Fyke nets capture whatever is passing by the net regardless of size (Audet et al. 2008), contrary to baited traps that are more size selective, this makes them more effective to study populations. However, because of its non-selectivity, they also capture significantly more bycatch compared to baited traps. There have been some variations of this used in terms of the length of the leader. For example, Poirier et al. (2020) used a 10m leader while Audet et al. (2008) used a 4.6m leader.

Beach seines have been employed for early detection, monitoring and habitat/impact research in Atlantic Canada, particularly during pre-2013 EGC biodiversity surveys (NL – Blakeslee et al. 2010; Matheson et al. 2016; QC – Simard et al. 2013; Gulf – R. Bernier, pers. comm.). In BC they have captured EGC opportunistically when targeting other species/habitats (T. Therriault, pers. comm.). Beach seines were used during early surveys in NL but they were found to be relatively ineffective in capturing EGC. To examine the effectiveness of beach seines in capturing EGC a SCUBA diver followed behind a beach seine to observe what proportion of EGC were not captured in the seine. The diver observed that the beach seine was only effective in capturing about 20% of the EGC as many buried in the mud under the net or climbed over the net to escape (C.H. McKenzie, pers. comm.). In addition, there is a high rate of bycatch and effort involved in deploying beach seines (C.H. McKenzie, pers. comm.).

3.1.8. Traps used outside Canada

Additional traps used outside of Canada are listed in Table 2. Please note that traps from Table 1 used in other parts of the world are noted in the text under each trap type. Several modified traps have been developed in Maine and reviewed by Young et al. (2017).

The “Acer” trap was designed and built by the Maine Clammer’s Association’s Ace Simmons and Russel Brazier of the Brazier Trap Company; it is similar to modified cylindrical eel traps but is much larger. Of similar dimensions, the “Blanchard” trap was designed and manufactured by Andy Blanchard, Scarborough, ME, USA. Both traps have been used for EGC monitoring and mitigation efforts in the eastern USA (MA – Beal 2014; Young et al. 2017). They suggest that these traps would be suitable to use commercially in New England, especially if used in waters with strong currents with a collecting boat and vehicle of sufficient size (Young et al. 2017).

A rectangular eel trap is manufactured by Brooks Trap Mill (Thomaston, ME, USA) and has been used to monitor and control EGC populations in eastern USA (Young et al. 2017).

The standard ventless lobster trap has been used for monitoring, education, and research related to EGC in the eastern USA (ME – Webber 2013; NH – Goldstein et al. 2017).

The "Terminator" trap is based on the Russell trap design by Russell Nickerson, Port Mouton, NS and has been used to monitor and mitigate EGC in the eastern USA (Young et al. 2017). It has been suggested that it would be suitable for commercial harvest of EGC in New England, especially if used in waters with strong currents with a collecting boat and vehicle of sufficient size (Young et al. 2017).

The "Ketcham" trap is a modified Cuttyhunk Island (Massachusetts) style box trap, designed, manufactured, by Ketcham Traps Company, New Bedford, MA, USA (Young et al. 2017). It has been used to monitor and mitigate EGC in the eastern USA (Young et al. 2017). This trap is small, which allows easy transportation and hauling, but because of its limited capacity it is not recommended for large scale removal efforts (Young et al. 2017).

The "Slanted-sides" box trap is manufactured by Brooks Trap Mill (Thomaston, ME, USA), and has been used to monitor and mitigate EGC populations in eastern USA (MA – Young et al. 2017).

Fulton traps were used to study the spatial and temporal distribution and population demographics of EGC in New Hampshire, USA (Fulton et al. 2013). Whereas, Mabin traps were used to study the distribution and abundance of EGC in South Africa along with artificial settlement collectors, and "crab condos" for larvae and smaller crab (Mabin et al. 2017; Mabin 2018).

Pitfall traps have been made using 20 L buckets that are embedded in the substrate of a shoreline in the high intertidal to sample primarily young-of-the-year EGC. They are buried and filled with seawater so that the rim of the bucket is flush with the surface of the substrate (Yamada et al. 2005). The pit trap has been replaced with the more effective crayfish traps in WA for small EGC (S. Yamada, pers. comm.). They have been used for monitoring EGC in the western USA (CA – Grosholz and Ruiz 1995; OR and WA – Behrens Yamada). These traps also require attention to prevent death of bycatch, sediment infill and as a hazard for human injury.

The "Trapezoidal" trap is manufactured by Brooks Trap Mill (Thomaston, ME, USA) and has been used to monitor and mitigate EGC populations in eastern USA (MA – Young et al. 2017). This is a low-profile trap with moderate weight, reasonably easy to transport, catches a large number of crabs, and is suggested for commercial trapping in New England or large-scale removal efforts of EGC (Young et al. 2017). The Drop net also known as a hoop net has been used for EGC research in Europe (Denmark – Aagaard et al. 1995; England – Rewitz et al. 2004; Portugal – Queiroga 1993).

3.2. TRAPPING METHOD CONSIDERATIONS

Several factors should be considered in addition to trap type when trapping EGC including logistics of deployment, variations in environment, EGC behaviour, and use of catch information (e.g., CPUE, size, sex, bycatch) as an indicator of trapping success.

3.2.1. Deployment

Deployment of traps should consider factors such as bait, location of deployment, depth (which varies with life stage), spacing or concentration of traps, and duration of deployment (soak time). EGC are generalists and opportunists, which is an important consideration when evaluating bait for attracting them to traps. Although a wide range of bait has been effectively used to capture EGC, including squid, fish (herring, mackerel, cod ‘frames’, flounder), shellfish, green and rock crab, canned tuna or cat food and even bottled moose, there are several types that seem to be preferred or most effective to increase CPUE. A bait comparison study was conducted in NL (Favaro et al. 2020) where four commonly available baits were used in Fukui traps to compare capture of EGC. Cod and squid provided the highest CPUE of the baits tested. In practice, bait suitability will be a local decision based on availability and cost. Although frozen bait is often used, the scent plume is quite important for attracting EGC so defrosting and cutting up the bait provides additional scent. Users should be aware of freezer burn or “shelf life” which may reduce the effectiveness of frozen bait. A study conducted in North Harbour, NL using bait refreshed daily and bait left more than 24 hours found that the fresh bait had a higher catch rate over the course of three-day experiments (C.H. McKenzie, pers. obs.). Also, users should be aware of bait competition. During a major sardine kill in Pipestem Inlet, BC, many EGC were noted feeding on this novel supply of available prey and CPUE was dramatically lower than expected as EGC were not being enticed to follow the bait plume into the traps (T. Therriault, pers. obs.). A similar situation has been observed in NL when trapping near local wharves and marinas where fish frames (carcasses) and excess bait from commercial fisheries are discarded. This abundance of food outside the trap can reduce catches. However, it also provides a good location for early detection as EGC in the area are drawn to the site. Proper bait disposal when planning EGC trapping can also be important in some areas and should not be discarded in sensitive habitats. The disposal of trapped EGC is also an issue and must be considered, particularly if large volumes of catch are expected.

EGC is a shore crab and is primarily located in coastal waters < 3m deep. Therefore, traps are typically placed in the shallow subtidal regions, most often just below the low tide, based on the target trapping depth used for many surveys in BC (Gillespie et al. 2007). In NL, traps exposed at low tide have also observed increased mammal bycatch and are therefore deployed below low tide (C. McKenzie, pers. comm.). Citizen science programs in WA placed the traps in intertidal areas during rising tide and recovered at the next ebbing tide before exposure (Grason et al. 2018). Trapping EGC in shallow waters from the shoreline (e.g., beach or other intertidal areas) is convenient for citizen scientists because they do not require a vessel for trap deployment. Much of the mitigation and stewardship trapping has occurred close to shore and was conducted by lobster and eel harvesters and First Nations using either their vessels or simply deploying traps from the shoreline. Use of vessels to deploy and retrieve traps also increases geographical coverage and can access more remote coastal areas and those not accessible from shore. As the invasion proceeds, and EGC abundances increase, EGC tend to spread into slightly deeper waters (displacing native rock crab in Atlantic Canada) and can be frequently found in lobster traps (McKenzie 2011). A combination of shoreline and vessel trapping has been effective in detecting and trapping EGC, especially considering fluctuating environmental factors (see below).

The number of traps needed for different trapping strategies (early detection vs. control) has been studied and the balance between covering an area and overcrowding of traps for ultimate efficiency depends on the degree of infestation and site geography. Early studies (2008, 2009) in North Harbour (NL) found that using 60 traps in a highly invaded cove was not necessary and that 30 traps captured similar numbers of crabs with less effort. The balance between effective trap numbers in an area and reduction of trap interference would be a local decision based on invasion status, habitat and logistics. Tagging studies of EGC found that the crabs either drift or travel a distance of several hundreds of meters over the course of a tidal cycle and are easily attracted to traps located 100 meters apart (McKenzie 2011). The standard soak time for DFO monitoring has been 24 hours, but based on experiences from fish harvester's traps were often hauled twice daily (e.g., ca. 12-hour soak times) during mitigation in Placentia Bay and Fortune Bay, NL, which tended to increase catch in areas with high abundances due to trap saturation after only a few hours (Matheson et al. in prep; C.H. McKenzie, pers. comm.). However, during mitigation efforts in BC, soak times were a bit longer – 18 to 22 hours (Duncombe and Therriault 2017) and depended on the logistics of the mitigation. Furthermore, in QC trap soak times during monitoring were 24 hours and during mitigation were 24-48 hours. In highly invaded areas however there has been indication of trap saturation after only a few hours and the advantages of shorter soak times are being investigated as part of the Marine Institute eelgrass restoration and trapping project (C. Ryan, pers. comm.). However, with a longer soak time there is a greater risk of bycatch mortality.

3.2.2. Environment

Environmental factors which have an effect on EGC trapping include temperature, salinity (e.g., freshwater source), substrate, and vegetation. The local knowledge by fish harvesters and First Nations regarding the local environment is often invaluable when conducting early detection surveys in new areas and mitigations (Cosham et al. 2016).

Temperature and salinity have been indicators of when and where to target trapping for EGC. Although there are regional differences, maximum catches tend to be during months with warmer seawater temperatures when foraging activity levels in both males and females are high. Acoustic tracking studies in North Harbour, NL (2008 and 2009) indicated that as temperatures decrease in late October and November, tagged female EGC moved into deeper waters (DFO 2011). In the winter, EGC has been reported beneath the ice along the shoreline in western NL (B. Hooper and K. Best, pers. comm.) and have been trapped in BC with males making up a greater percentage of the catch. During the same female acoustic tracking study (DFO 2011), female EGC seemed to prefer lower salinities as they were found clustered around the freshwater source near mud flats. Other reports have shown that females and juvenile EGC were found in lower salinity areas compared to adult male crabs (Best 2015). Interestingly, the majority of trapped EGC in NL, NS, NB, PEI and QC during the summer are predominately male, the only exception was trapping during the same time period in the Bras d'Or lakes, NS, where the predominant catch was female and could be related to the lower salinity at that location. In BC, surveys tend to prioritize estuaries or beaches with a constant freshwater source as these habitats have been shown to be favourable to EGC over co-occurring native crabs such as Graceful crab (*Cancer gracilis*) and the Red rock crab (*Cancer productus*) which are important for influencing habitat use by EGC where they coexist (Hunt and Behrens Yamada 2003; Jensen et al. 2007).

Other important environmental factors are substrate and vegetation. Rossong (2016) studied the different substrates (sand, gravel, fine sediment or "puck" mud) and EGC impact on invaded areas in NL. In her study and during survey and research trapping, it was observed that areas that have higher concentrations of EGC usually consist of fine sediments or what is called locally "puck mud", with eelgrass meadows, a freshwater stream flowing into the area and the presence of a shellfish bed (i.e., clams, mussels or scallops). If vegetation such as seaweed (e.g., *Fucus* sp., *Ascophyllum nodosum*) along the shoreline is present, it provides excellent protection for recently settled EGC and vulnerable moulting and recently moulted females. When surveying a new area, important questions for the public with good local knowledge include the known location of shellfish beds, freshwater sources, eelgrass meadows, and any location referred to as “the hole” or the “muddy hole”. For example, following a survey of Port Harmon on the west coast of NL, it was discovered through scuba diving that the highest concentrations of EGC were associated with large mussel beds in the area. In addition to this local knowledge, maps, bathymetric date, and aerial photographs are important sources for identifying potential habitat suitability (e.g., freshwater sources, eelgrass meadows, sediment type, and variations in water depth).

Another environmental observation that has been mentioned by fish harvesters during their mitigation trapping and by DFO is that increased EGC activity and higher catch rates may be correlated to cloudy, overcast weather and that sunny days seem to dampen EGC activity.

3.2.3. Behaviour

Considering the behaviour and biology of EGC is also important in developing trapping strategies. Preferences or adaptations to depth, level of activity during time of day (day versus night), and spatial movement vary by life stages or maturity and sex of EGC.

An investigation of EGC distribution in the newly invaded area of North Harbour, NL (2007), conducted using scuba diver transects perpendicular to the shoreline, found that small juveniles and vulnerable females, particularly recently molted individuals, were often found hidden in the vegetation or under rocks. As the transect extended into deeper waters, there was a change in size and sex with medium sized males and females inhabiting the middle of the transect, and the deepest areas of the transect being dominated by the larger adult males (C.H. McKenzie, unpublished data). In BC, larger EGC, especially males, can be found in deeper waters as they are better able to compete with large native crabs. Catch bias towards male crabs can also follow seasonal reproduction patterns in female crabs when energy is allocated towards reproduction instead of foraging, and female EGC are inactive, avoid predation, and are unlikely to enter traps (Klassen and Locke 2007; Audet et al. 2008; Best et al. 2017; C.H. McKenzie, unpublished data). In Atlantic Canada, colder spring and winter temperatures (0-2^{o}C) coincide with later and shorter breeding seasons (3-4 months) for EGC, spawning in NL from June to August, with the majority of berried females present in late July (Best et al. 2017; M. Clarke pers. comm.). Trapping in June or July in Atlantic Canada generally yields more males in most locations, which can decrease the male proportion of the population. Trapping in the same location at different times of year will capture different demographics, based on the life cycle and seasonality of EGC in the region. For example, waiting to deploy traps until after females have released their eggs can target females when they begin foraging for food. However, on the western coast of North America ovigerous females develop earlier (January-February) due to the warmer water (DiBacco and Therriault 2015; Best et al. 2017). Females are more likely to approach and enter traps that have sheltering material rather than bait, but relative catch rates for berried females remain low (Best et al. 2017). Once females have spawned, the number of females in baited traps generally increased. There is some evidence for synchronous male moulting in PEI and Washington State which could also have implications for focussed female trapping and reduction in number of males attracted to traps (Poirier et al. 2016; P.S. McDonald, pers. comm.).

Female and small EGC may also avoid traps that have already captured large male crabs. Intensive trapping efforts to control EGC abundances have observed initial catches that bias for large males, but as trapping continues within and across years, the bias towards males and large crabs decreases (Duncombe and Therriault 2017; Matheson et al. in prep). As male EGC are typically larger than females, when large males are trapped and removed from the ecosystem first, the average difference in size between male and female crabs decreases, and it is less likely that males entering traps first will deter actively foraging females and other smaller crabs (Crothers 1968).

There are reported differences in trapping based on day-vs-night soak periods. Several fish harvesters have trap data to confirm that higher catch rates occur during night trapping. Bergshoeff et al. (2018) conducted video observations during both day and night periods and confirmed more activity during night soaks.

3.2.4. Use of Catch Information

It is critical to realize, that although trapping can remove large numbers of EGC, removal trapping surveys do not necessarily determine absolute abundances or density of a population, but can instead provide a comparable standard method to monitor and research population dynamics based on foraging activity (Miller 1980). When conducted in a standardized and repeated design. trapping can provide a relative index of population changes over time. However, not all EGC in a population are vulnerable to trapping at any one time (Crothers 1968). For example, crab abundances may not change between seasons, but fluctuations in feeding activity levels parallel changes in seawater temperature (Breen and Metaxas 2008; Matheson and Gagnon 2012b) and can result in different catches, in absolute numbers and size or sex ratios. Therefore, understanding crab behaviours (as described above) and the purpose of trapping efforts are critical to determine optimal timing and trapping strategies.

To maximize control efforts, catching the largest number of crabs will typically occur when crabs are most actively foraging for food (during warmer months and at night) and likely to enter a baited trap (Young et al. 2017; Bergshoeff et al. 2018; C. McKenzie unpublished data). Large male EGC regularly dominate traps (McKenzie 2011; Vercaemer et al. 2011; Simard et al. 2013; Duncombe and Therriault 2017; Matheson et al. in prep). Although some traps, such as Fukui traps, do not capture small (< 30 mm CW) EGC well (Vercaemer et al. 2011; Simard et al. 2013; Duncombe and Therriault 2017; Matheson et al. in prep), partly through potential escapement, this can be further amplified by competitive intraspecific interactions with large crabs for prey and shelter that can lead to increased avoidance behaviours in small crab (Matheson and Gagnon 2012a). The disproportionate capture of males over females or capture of large size classes can alter population dynamics and represent early indicators of success in control trapping efforts as small EGC are more likely to become prey to native species and have lower ecosystem level impacts, such as predation on bivalves and destruction of eelgrass (Malyshev and Quijón 2011; Matheson and Gagnon 2012b; Matheson and McKenzie 2014; Matheson et al. 2016). However, removing the larger EGC can also lead to increased numbers of smaller EGC (overcompensation) once the cannibalistic larger EGC are no longer preying on smaller size classes (Grosholz et al. 2021).

Overall, CPUE is a straightforward and standard metric to report and compare trap results and relative abundances and success of trapping control efforts is primarily measured by decreased CPUE. It is important to realize that CPUE is specific to each design and cross validation and intercomparisons are complicated, but consistent deployment of gear can allow estimations of relative abundances based on CPUE. Establishing the threshold level for impact on native species or habitat is critical for functional eradication (abundance reduced below a threshold of effect) and must be determined locally as vulnerability to impact can vary across native ecosystems. Since catch and catchability are influenced by a number of factors (e.g., molt and reproductive stage, sex, size, time of day, seawater temperature, gear, bait, population density, etc.) (Miller 1990), CPUE will not be an effective tool to compare trapping results across different and non-standardized monitoring and research designs. Careful attention must be given to standardizing trap variables, such as, but not limited to, bait type and quantity, trap type, time of day, season, trap spacing, and soak time (Miller 1990). Understanding limitations of traps and subsequent assessments of population dynamics using CPUE is a critical step when evaluating trap catches.

4. TRAP COMPARISON / FEASIBILITY OF METHODS (DISCUSSION)

4.1. TRAP COMPARISON AND USAGE

4.1.1. Goal Focused Protocols

Trapping is a critical component of early detection / rapid assessment surveys following a reported new EGC sighting, and monitoring efforts, and is most often the only way to adequately sample for mobile AIS (see Table 3 for summary of types of traps used in Canada). These surveys and monitoring activities provide information which can lead to the development of subsequent rapid response and control protocols. Primary objectives of rapid response trapping surveys and monitoring efforts are 1) early detection of EGC individuals before populations are established in an area, and 2) assessment of existing populations. For early detection, baited traps offer an advantage to attract rare individuals within an area. However, this is ultimately influenced by the catchability of EGC and the effectiveness of the bait as an attractant, which may be further influenced by a variety of ecological variables, as described above. Baited traps are typically used for rapid assessment surveys and monitoring plans because they are easy to deploy, transport, and can cover a large geographical area, if logistically feasible. Trapping targeted locations is critical and may be established from reported sightings, projected range expansion, larval drift modelling, or prospective invasion hotspots using current vector and local knowledge. Across Canada, early detection has been approached using baited traps in both rapid assessment surveys and consistent and repeated monitoring.

4.1.2. Early Detection and Rapid Response Surveys

To conduct early detection surveys in a new area, DFO Science often deploy baited Fukui traps to evaluate potential presence of individuals and status of EGC populations. The standardized DFO EGC trapping protocol (Gillespie et al. 2007; McKenzie 2011; Vercaemer et al. 2011; Simard et al. 2013; Bernier et al. 2020) has been used for both rapid assessment surveys and monitoring in DFO in BC, QC, NL, NS, NB and PEI (Table 3). In NL, additional rapid targeted trapping consists of deploying a small number of traps (3-5) at a location for a relatively short soak time (0.5 to 3 hours) when covering a large bay or area in a recently invaded areas to determine relative abundances. These areas are targeted as they are often sites of introduction due to various vectors (e.g., vessels, gear). Typically, these rapid assessment surveys are conducted in small harbours and wharves where used bait and frames have been discarded and serve as a “hot spot” for any new population. To enhance attractant during short soak times, bait is placed directly in the trap (or in the accompanied mesh bag) rather than perforated bait cup to enhance diffusion of bait cues into the environment although perforated bait cups are also used and are more effective over a 24-hour period as the bait cannot be accessed unlike the mesh bag. If EGC are abundant at the location, a short soak time has been determined to be adequate to confirm presence of EGC, although not the absence of EGC. This approach is advantageous because it can cover a large geographic area (> 100 km of coastline) in a short period of time (i.e., within a day) to provide a rapid assessment across multiple locations (i.e., bays/coves), including those that can be logistically difficult to access multiple times during longer soak times. However, because of the short soak time and limited number of traps deployed, this method is less likely to capture rare individuals and is more likely to detect and confirm presence of established EGC populations. If logistically feasible, longer soak duration (24 hours), multiple trap types, or repeated trap sets will provide improved opportunities to capture rare individuals. To effectively utilize this rapid targeted trapping method and detect rare individuals, it is critical to understand recognized EGC ecological knowledge to target locations based on characteristics of coastal geography (e.g., protected embayments), habitat type and preference (e.g., eelgrass, soft sediments, shellfish beds), seawater temperature, and potential introduction vectors (e.g., active wharves).

Local environmental knowledge from First Nations, fish harvesters, and citizen scientists can provide critical insight into a new area. Often, locations referred to as “muddy hole”, known clam or mussel beds, tide channels or pools, and eelgrass meadows with a freshwater source can indicate optimal habitats. Different types of traps will also have variable strengths and limitations that are critical to understand during rapid assessments using short soak times. For example, the use of Fukui traps by DFO typically targets larger adult EGC (i.e., > 50 mmm CW) and can limit capture of small young-of-year crab, particularly if established populations of large crab are present (Gillespie et al. 2007; Blakeslee et al. 2010; McKenzie 2011; Vercaemer and Sephton 2016; Bernier et al. 2020). Other traps, such as modified minnow, or the use of multiple types of traps, can target broader size ranges of EGC and may be more effective in specific habitats (Gillespie et al. 2015; Grason et al. 2018). Pit-fall traps can also be utilized, and reduce trap size selection bias, but remain a passive strategy to trap crabs, and without an attractant, are less likely to capture rare individuals (Davidson et al. 2009). Supplementary non-trapping observations, such as shoreline walks to search for molts or recently settled juveniles among intertidal vegetation can further enhance rapid assessment trapping surveys (Davidson et al. 2009; Blakeslee et al. 2010; Gillespie et al. 2015; Vercaemer and Sephton 2016; Best et al. 2017; Bernier et al. 2020. These additional methods can augment detection of individuals, and may be particularly effective for use with students and citizen scientists since no special equipment is required, but, unlike trapping, they are not easily standardized to compare abundances and population dynamics between surveys.

DFO, on both the Atlantic and Pacific Canadian coasts, has conducted rapid response surveys following detection or reports using more comprehensive trapping survey techniques to assess the population. These strategies focus on a specific area and are logistically more complex than the targeted trapping strategy, relying on the deployment of a larger number of baited traps to comprehensively cover the area of concern. Locations are selected based on potential suitable habitat based on both formal habitat suitability models, subject matter experts, and local knowledge, proximity to known EGC populations, and modelled larval movements (Drinkwin et al. 2019). Baited traps are deployed just below low tide in or near physical structures/habitats known to harbour EGC (e.g., seagrasses or other vegetation, shell beds, cobble or rock beds, soft sediments, tide pools or channels), generally evenly and closely spaced (e.g., ~50 m or less, dependent on geography), and soak for approximately 24 hours. It is critical to use the same bait in all traps to standardize the attractant across the survey. Since confirmation of the first established EGC populations in BC in Sooke Basin in 2012, DFO Pacific Region has conducted wide-ranging, systematic, and repeated trapping surveys based on habitat suitability for early detection of spread and new populations of EGC (Drinkwin et al. 2019). During these efforts, a combination of Fukui traps, which have been used by DFO Science, and minnow traps, now used by AIS NCP and some First Nation partners, were used to target a wider size range of EGC (Drinkwin et al. 2019). Furthermore, following an initial report by a fish harvester, rapid response surveys to confirm EGC presence in St. Mary’s Bay (NL) in 2018 were conducted. In 2019, DFO NL Science and AIS NCP jointly conducted a comprehensive rapid response survey and deployed approximately 120 Fukui traps to survey targeted coastal areas of St. Mary’s Bay to determine the EGC distribution and abundances in the area. Traps were baited with herring and cod and soaked for approximately 24 hours. The survey detected low numbers of EGC throughout the survey region, but detected localized areas with high CPUE (up to 36 crab/trap/day) and catches consisted of predominantly large adult crabs (up to 79 mm CW), indicative of an established EGC population in the area (DFO NL, unpublished data). A total of 544 EGC were captured (C.H. McKenzie, unpublished data). Similarly, following the first report of EGC in Haida Gwaii in July 2020, DFO Science worked via an existing technical working group that included the Council of the Haida Nation, Parks Canada, the Province of BC, and DFO (Science and Management) to mount a response. However, due to the onset of the COVID-19 global pandemic, Haida Gwaii was closed to non-residents and so gear (approximately forty-eight Fukui traps) had to be shipped to local partners who initiated delineation trapping in the region.

These examples of strategic approaches to early detection and rapid assessments can be economically and logistically limiting and may require boat access to effectively reach large areas of coastline to deploy and retrieve traps and reduce dependency on tide levels. However, the thorough coverage of an area and extended soak times allows this strategy to target rare individuals more effectively in the ecosystem and better understand potential spread and dynamics of a population compared to targeted trapping. If logistically feasible, repeated trapping using the same traps and locations, may be recommended for multiple days. For example, crabs may not enter traps initially and remain outside of the trap or have to figure out how to enter the trap (Bergshoeff et al. 2018). It may take repeated efforts to catch very rare individuals. It remains a challenge of ecology and conservation biology to adequately determine the number of samples required or necessary effort to detect rare species.

While the use of large numbers of traps can more effectively detect rare individuals and identify localized areas of higher abundances, the type of trap used can bias capture, as previously mentioned above. Pitfall traps can also be effective during longer duration surveys (i.e., 24 h fishing periods), in particular to sample 0+ cohort crabs in the upper intertidal areas, but will require more maintenance and surveillance than baited traps, to avoid bycatch mortality and prevent the trap from filling with sediment (Davidson et al. 2009). Similar to rapid response surveys, comprehensive surveys can be further improved by accompanying shoreline surveys for molts and newly settled recruits under rocks and vegetation in upper intertidal areas (Davidson et al. 2009; Blakeslee et al. 2010; Simard et al. 2013; Gillespie et al. 2015; Vercaemer and Sephton 2016; Best et al. 2017; Bernier et al. 2020).

4.1.3. Monitoring

Rapid assessment surveys can be resource intensive and logistically challenging, but are an important tool to identify priorities and allocate resources to develop subsequent standardized monitoring (i.e., repeated surveys) at consistent locations or sentinel sites to detect further spread and observe populations changes. Standardized monitoring protocols are used to determine and compare CPUE, size distributions, crab characteristics (e.g., morphometrics), and spatial and temporal variability (Table 3). Locations are established for repeated sampling (e.g., monthly or annually) based on numerous factors and objectives, including, but not limited to, known established populations of EGC, habitat suitability, and early detection or areas of concern to stakeholders, First Nations, fishing industry (lobster, eel, crab, shellfish) and community groups. As per DFO protocol (established nationally in 2008), Fukui traps (3-9) are baited with herring or mackerel, attached to a ground line separated by ~ 3 m (10 m in BC) and each string of traps is positioned parallel to the shoreline, or in a 3 x 3 square, deployed in the shallow subtidal zone (1-2 m depth) and soaked for 24 hours (Simard et al. 2013; Gillespie et al. 2007, 2015; Vercaemer and Sephton 2016; Bernier et al. 2020; C.H. McKenzie unpublished data). EGC data for each trap include counts, carapace width and sex, and often indicators of maturity (claw size or female abdomen size and colour) and weight. In most DFO regions bycatch present in each trap is recorded, particularly native crabs, as that can be an indication of EGC establishment in new areas and also trapping success.

In Newfoundland, initial rapid assessment and monitoring surveys in 2007 and 2008 utilized modified whelk pots, but due to the large size, weight, and handling difficulty these were replaced by the Fukui trap following a EGC trapping workshop at DFO Nanaimo in 2008. In QC, NS, NB and PEI other traps were used but were also replaced with the Fukui trap and used standardized DFO protocols in 2008 (Table 3). Monitoring using Fukui traps has increased understanding of EGC population dynamics in Canada, including male and female behaviour, interactions with native species, habitat preference, effects of temperature and/or season, and recruitment (Gillespie et al. 2007; Simard et al. 2013; Vercaemer and Sephton 2016; Matheson et al. 2016; Best et al. 2017; Bernier et al. 2020).

4.1.4. Research

DFO Science has been trapping EGC for impact research even before the establishment of DFO's Aquatic Invasive Species program in 2006 (Table 3; Klassen and Locke 2007). Research in NL has primarily been directed toward impact on eelgrass (Matheson et al. 2016); predation on shellfish (Matheson and McKenzie 2014), impact on lobster (Rayner and McGaw 2019; Zargarpour et al. 2019) and EGC reproduction (Best et al. 2017). Although DFO's EGC trapping activities in NB, NS and PEI have been primarily for early detection and monitoring (Audet et al. 2003; Tremblay et al. 2006; Vercaemer et al. 2011; Vercaemer and Sephton 2016; Bernier et al. 2020), they have also been used for research conducted on population structure, habitat (MacDonald 2014; McDonald et al. 2018), impact and reproductive strategies (Audet et al. 2008), predator-prey interactions (Rosson et al. 2006; Wong 2013; Gehrels et al. 2016), foraging behaviours (Rossong et al. 2012), trap efficiency and by-catch reduction (Poirier et al. 2018, 2020; Bernier et al. 2020), impacts on Irish moss (Tummon Flynn et al. 2019), eelgrass and benthic invertebrates (MacDonald et al. 2018; Locke and Bernier, unpublished data). In QC, EGC were captured by scuba divers and stomach content collected and analyzed to determine diet using both classical and genetic methods (Simard, unpublished data). In BC, trapping has been used to document changes in distributions (Gillespie et al. 2015), evaluate control options (Duncombe and Therriault 2017), and inform species distribution models.

4.1.5. Control

When rapid assessments and monitoring detect EGC presence, typically, the next step is to determine what rapid response and control options are available for removal. The objective would be either to remove EGC before a population becomes established to diminish potential localized ecological impacts and reduce or prevent further spread. One foremost advantage of trapping is that it is deemed an adaptable and environmentally safe method to control EGC (Duncombe and Therriault 2017). Trapping can target EGC habitats, strategies and modifications can limit bycatch, allow for live release, and have negligible impact on native ecosystems, in particular, compared to other chemical or biological control options (see in Duncombe and Therriault 2017). Various efforts and experiments have occurred on the Atlantic and Pacific coasts to determine if depletion efforts by trapping is a potential effective mechanism to control or eradicate established populations of EGC. Table 4 provides a summary of the mitigation or control activities in Canada conducted since 2008 by DFO Science, their partners or concerned third parties and provides information on trap type, bait when known, number of trapping days, number of traps, CPUE, total catch and any indication of CPUE, EGC size or increase in native species following targeted trapping. Indicators for success typically include reductions in EGC numbers, reduction in average EGC size, changes in sex ratios, and increase in the number of native species or biodiversity (DFO 2011; McKenzie 2011) (Table 4). Control efforts conducted by the Fish Food and Allied Workers (FFAW) with DFO NL and funded by VALE in Placentia Bay in 2014-2016 aimed to reduce CPUE by 95% or < 5 crabs/trap/day and reduce average size to below 30 mm based on known size of reproductive maturity (Best et al. 2017; C.H. McKenzie unpublished data). For control efforts in Little Port Joli Estuary (Kejimkujik National Park Seaside Adjunct, NS), threshold levels for success were set at < 15 crabs/trap/day or ≥ 15 crabs/trap/day, but no crabs > 35 mm CW (Mersey Tobeatic

Research Institute and Parks Canada 2015). These thresholds were set to reduce probability of significant impacts on eelgrass and bivalves and enhance potential recovery of native abundances. Small EGC are also more likely to become prey to native species instead of predators and thus may further restore the balance to the ecosystem.

DFO-led case studies conducted annual trapping (Fukui) efforts in Pipestem Inlet (Vancouver Island), BC from 2010-2014 (Duncombe and Therriault 2017), in Placentia Bay (Fair Haven and Boat Harbour), NL from 2014-2016 (Matheson et al. in prep), and Magdalen Islands, QC from 2008-2014 (Simard et al. 2013; N. Simard unpublished data). The trapping in the Magdalen Islands could be an example where early detection and immediate rapid control prevented the EGC abundances from increasing and becoming established. In addition to the monitoring program using Fukui traps conducted every year in August, (and also June at the beginning of the program), targeted Fukui traps used by DFO and Marinov (2008-2012). Fyke nets used by fishermen (2007, 2010-2014) were used to control the population by disposing of EGC bycatch in their Fyke nets. The duration of the fishing period was approximately 2 months every year (mid-August to mid-October for most years). Mean CPUE reached a maximum in 2011 and decreased every year since and since 2015 very few (< 9 crabs per year). However, there is some reason to believe that the harsh winter of 2015 may have also had an impact on the population as reduced numbers were found in St. Pierre and Miquelon and western NL. These locations had similar EGC abundance and were a similar genetic lineage (cold tolerant) (Lehnert et al. 2018).

In NL, strategies were developed and modified based on preliminary mitigation trapping efforts in 2008-2009 (Table 4). In NL during 2008, modified whelk and snow crab pots were used in addition to Fukui traps. However, these larger traps could exceed 50 kg with EGC, while Fukui traps typically reach a maximum of 15 kg (C.H. McKenzie, unpublished data). Based primarily on feasibility and logistics, the use of modified whelk and snow crab pots was replaced with the foldable Fukui trap in NL and QC. Overall, recent control experiments in Pipestem Inlet, BC and Placentia Bay, NL attempted to standardize catchability by using the same methods throughout, such as same trap (Fukui trap), bait, and methodology, to the extent possible. In the NL experiments, bait was switched from only herring in 2014 to a combination of herring and cod frames in 2015 and 2016 after it was determined that cod frames led to higher CPUE than herring alone (Favaro et al. 2020; Matheson et al. in prep). Trapping control efforts require high numbers of traps that are consistently deployed for an extended duration of time (e.g., repeated over multiple days and years) (Simard et al. 2013; Duncombe and Therriault 2017; Grosholz et al. 2021; Matheson et al. in prep). In Pipestem Inlet, 72 traps were set for 24 hr soak periods for between 8 and 16 trapping days per year (Duncombe and Therriault 2017). In NL, 30 traps were distributed to fish harvesters at each site in 2014, but was increased to 60 traps in 2015 and 2016 because of trap availability. These traps were retrieved twice daily (e.g., morning and late afternoon based on tide timing) for approximately 20 days per year, except in 2015 and 2016 in Fair Haven traps soaked for 24 hrs, based on recommendations from a Fair Haven fish harvester indicating he captured more EGC by hauling traps only once daily (Matheson et al. in prep). Fukui traps in Pipestem Inlet (BC) captured > 62 000 EGC (Duncombe and Therriault 2017) and traps set in Fair Haven and Boat Harbour (NL) captured over 11 000 kg of EGC (Matheson et al. in prep). Although it was not feasible to count all crabs during NL experiments, it was estimated that over 225 000 EGC were captured (Matheson et al. in prep). Between 2014 and 2016, in NL across all 10 sites that had some degree of trapping efforts, nearly 24 000 kg of EGC were captured using Fukui traps (K. Matheson and C.H. McKenzie, unpublished data). In Placentia Bay, trapping efforts have continued and captured over 330 000 kg of EGC (2017-2020) across up to 10 locations, fishing 70 Fukui traps at each location, up to 70 days per year (M. Clarke, pers. comm., Table 4).

During both trapping control experiments (e.g., Pipestem Inlet, BC and Placentia Bay, NL), CPUE decreased over time within years, but this trend was not consistently observed between years (Duncombe and Therriault 2017; Matheson et al. in prep). However, control trapping efforts have demonstrated reductions in carapace width and decreased bias towards male crabs, suggesting significantly altered population demographics due to consistent intensive trapping efforts (Duncombe and Therriault 2017; Matheson et al. in prep). In Pipestem Inlet, crabs < 30 mm were caught routinely in August 2013 for the first time since trapping began in 2010 (Duncombe and Therriault 2017). In Boat Harbour, between 2014 and 2016, average CW decreased from ~ 60 mm to almost 40 mm CW, but Fukui traps did not capture a large proportion of small (< 30 mm) crabs (Matheson et al. in prep). Less than 5% of crabs at the end of 2016 were < 30 mm. However, later in 2016, crabs < 40 mm made up almost 40% of those captured, compared to only 5% of samples at the onset of trapping in 2014 (Matheson et al. in prep).

Findings from EGC trapping control efforts in Canada have paralleled results elsewhere. In Seadrift Lagoon, California, a 10-year trapping effort used a combination of Fukui and minnow traps and decreased a localized EGC population by 90% (~125 000 to < 10 000 crabs) steadily over 5 years. However, in the subsequent 6th year, these control efforts observed an explosion of small EGC, a density-dependent process known as overcompensation (Abrams and Ginzburg 2000; Grosholz et al. 2021). Trapping efforts initially target large adult crabs, which can inadvertently reduce population control of smaller crabs by adults via cannibalism, and combined with EGC high fecundity can facilitate dramatic increases in small individuals (Turner et al. 2016; Grosholz et al. 2021). Seadrift Lagoon may be a special case for these control results because it is a largely closed system with high larval retention and EGC is the likely primary predator. In Pipestem Inlet, it is unknown if juvenile abundance changed from year to year (e.g., overcompensation), or if it was affected by trapping efforts (Duncombe and Therriault 2017). Further research and analyses are required to assess the potential for overcompensation during EGC trapping control experiments in Canada. Trapping can remove a large number of EGC rapidly (Simard et al. 2013; Duncombe and Therriault 2017; Grosholz et al. 2021, Matheson et al. in prep; M. Clarke, pers. comm.), but overall success of control efforts, determined by decreases in size of EGC, overall abundances, and increases in native species and biodiversity, will be largely influenced by geography (open or closed location), strength of recruitment processes from nearby populations, size of EGC population, and feasibility of long term, repeated, and intensive removal efforts. Periodic increases observed in the estimated population size in Pipestem Inlet, despite intensive trapping efforts, was likely because of strong recruitment years from nearby populations (Duncombe and Therriault 2017). Small and less open locations such as Kejimkujik National Park, NS, have demonstrated increased likelihoods of successfully achieving decreases in EGC populations, through decreased CPUE, than larger more open systems (Duncombe and Therriault 2017; Grosholz et al. 2021; Matheson et al. in prep; C. McCarthy, per. comm.). Trapping can successfully deplete EGC numbers, but currently, no trapping studies have demonstrated eradication of EGC and continued and sustained trapping efforts are likely necessary to manage and maintain populations and low abundances. For example, intensive trapping efforts in Little Port Joli Estuary (Kejimkujik National Park Seaside Adjunct, NS) from 2010-2014 using the Russell trap removed ~ 2 million crabs and have observed decreases in CPUE (~80%), diminished proportion of large males, and increases in native species abundances (Mersey Tobeatic Research Institute and park Canada 2016). Ongoing work has aimed to determine the level of trapping that is required to maintain low numbers of EGC and continue to encourage recovery of native biodiversity (Mersey Tobeatic Research Institute and park Canada 2015, 2016). However, special consideration must be given to potential population increases through periodic overcompensation during long term trapping efforts (Turner et al. 2016; Grosholz et al. 2021).

4.2. KNOWLEDGE GAPS

Knowledge gaps identified include a lack of information on trapping juvenile EGC and determining effective threshold levels or numbers for control to prevent environmental and fishery impacts. There is a lack of knowledge on effectiveness of varying trap types and trapping strategies that target juvenile EGC. A clear definition of what constitutes juvenile EGC must also be considered. Although a variety of traps have been effectively used for early detection of EGC, there is limited knowledge on the threshold for trapping to detect low abundances of EGC and how differing traps vary in their effectiveness at early detection of EGC. There is also limited knowledge on how CPUE and other trapping metrics directly relate to ecological impact thresholds, densities, and absolute EGC numbers in the environment.

4.3. OTHER CONSIDERATIONS

There are several other considerations regarding trapping EGC that should be highlighted when considering this method for early detection, monitoring, or to control EGC populations. These considerations include trap limitations and unwanted consequences of trapping strategies. 1) There should be an understanding that for various reasons EGC may not approach traps, thus, trapping strategies and interpretation of CPUE must take these considerations into account. As mentioned in the behaviour section (3.2.3) EGC may not approach the trap if larger EGC are already present in the trap. It should also be mentioned that EGC may not approach the trap if an abundant food source is already present outside the trap such as naturally occurring shellfish beds or discarded fish offal near wharves and marinas. Therefore, trap placement is important relative to exterior factors. 2) EGC are cannibalistic. By removing larger EGC, a predator of small EGC, predation on small EGC can be reduced allowing smaller crabs, to survive and grow, which can cause large population increases. Sustained trapping over time is required to target these smaller EGC once large EGC are removed. 3) Finally, traps may need to be designed or modified to prevent the unwanted trapping of small mammals and birds (e.g., otter, mink, raccoons, and cats in urban areas). This can be done by reducing the opening size of Fukui traps using zip ties (used in NL and BC) or use of escape ports in the design. Deployment below the low water tide mark and short deployments can reduce this unwanted impact.

It is important to note that intermittent trapping alone is unlikely to be fully successful to reduce numbers and prevent impacts from EGC and needs to be ongoing or used in conjunction with other mitigation measures for true functional eradication. In part, because larval supply from nearby populations (not being controlled or mitigated) can continue to supply new recruits. Thus, actual control would need to include all parts of the metapopulation. However, EGC control at local scales can be effective and should be undertaken to mitigate impacts, especially in more vulnerable/valued areas.

5. CONCLUSIONS/RECOMMENDATIONS

A review of 69 peer reviewed studies and unpublished projects on EGC trapping was conducted to compare different trap types and their usage in Canada (46 studies) and in other locations where EGC have been trapped. Fifteen traps were categorized by type and usage in Canada with an additional 13 traps reviewed that were used to trap EGC in the United States and other countries. The Fukui collapsible crab (fish) trap is the most utilized trap in Canada based on this review. Other traps have been effective in trapping and direct comparison of trap type has been studied in several regions in Canada. In addition to this review, additional trapping information was provided from DFO Science and their partners over the last 15 years of experience trapping for early detection, rapid response, research and control mitigation activities in both Atlantic and Pacific coasts. Traps used currently in Canada to capture EGC, and the advantages and challenges of each trap type, is summarized in Table 5. Experience acquired includes information and considerations for trapping methods (deployment, environment, behaviour, catch) and goal focused protocols for different objectives including early detection, monitoring, control measures and mitigation strategies. Trap type selection must consider the objective of trapping, in particular, the targeted portion of the EGC population as trap types can disproportionately catch large adult EGC due to trap design and intraspecific behaviours between EGC. Although trap types vary in design and catchability, they are an effective and simple tool to survey and monitor relative changes in EGC population dynamics, based on ease of use, ability to standardize methodologies, and compare results.

Trapping is an effective method for early detection and monitoring relative changes in EGC abundances, population dynamics and native species. Trapping for rapid response and control can effectively reduce EGC numbers and alter population dynamics. Outcomes could include reduction of mean body size of EGC and recovery of impacted native species and habitats, but trapping efforts may need to be sustained. Fish harvesters, First Nations, and concerned citizens have had and will continue to have an important role in trapping for early detection, monitoring, and control efforts. However, further knowledge is required to determine methods of trapping juvenile EGC and determine ecological thresholds based on trapping results for impact to native species and habitat, prevention of ecosystem degradation, and commercial fishery loss to assess success and determine targets for trapping control efforts. This EGC trapping advice can be incorporated by managers into a decision-making tool for guiding action related to early detection, rapid response, and control management activities.

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7. FIGURES

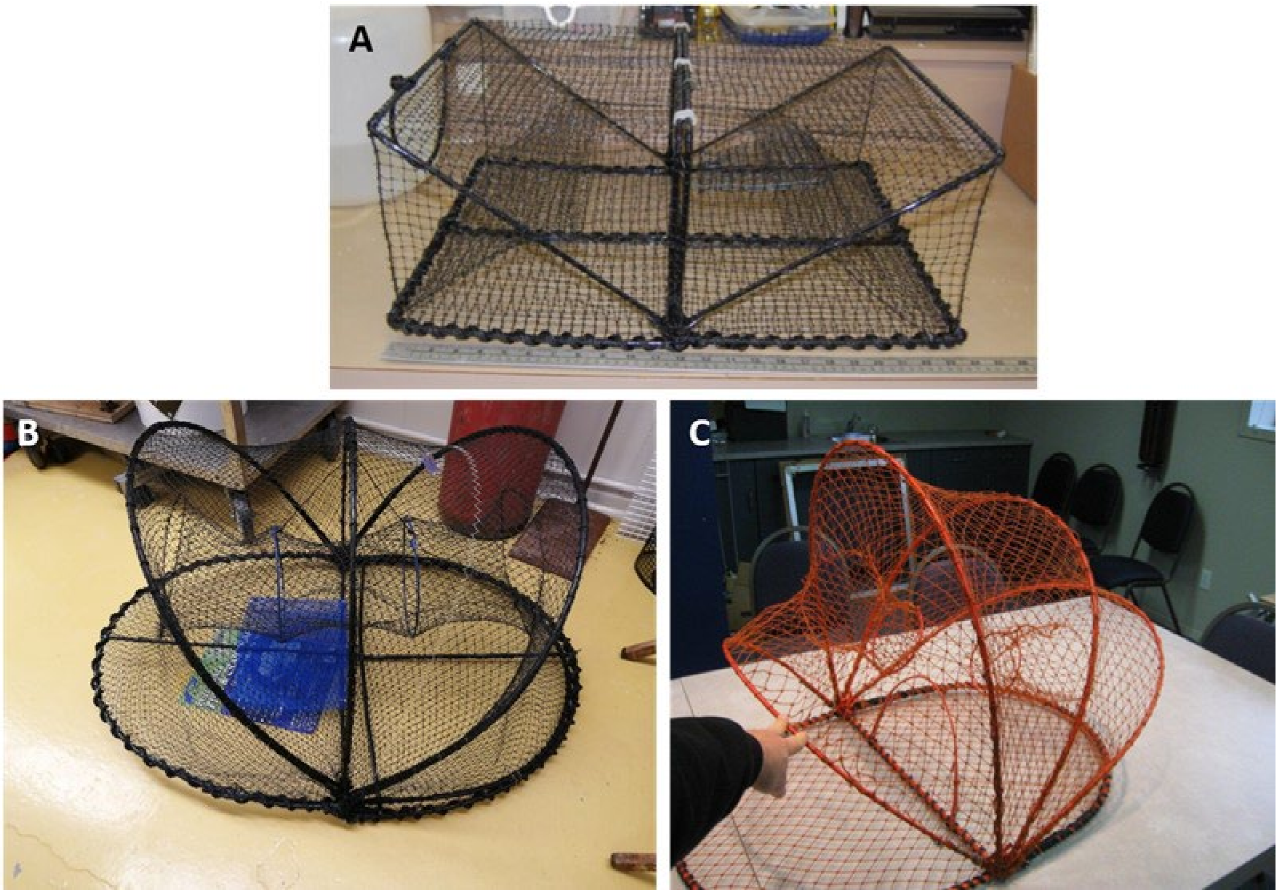

Figure 3. Collapsible fish/crab traps. A. Fukui trap Photo: E. Watson, Fisheries and Oceans Canada, Gulf Region; B. Promar trap Photo: Iain McGaw, Memorial University of Newfoundland; C. Morenot Trap – Photo: Morenot Canada Ltd..

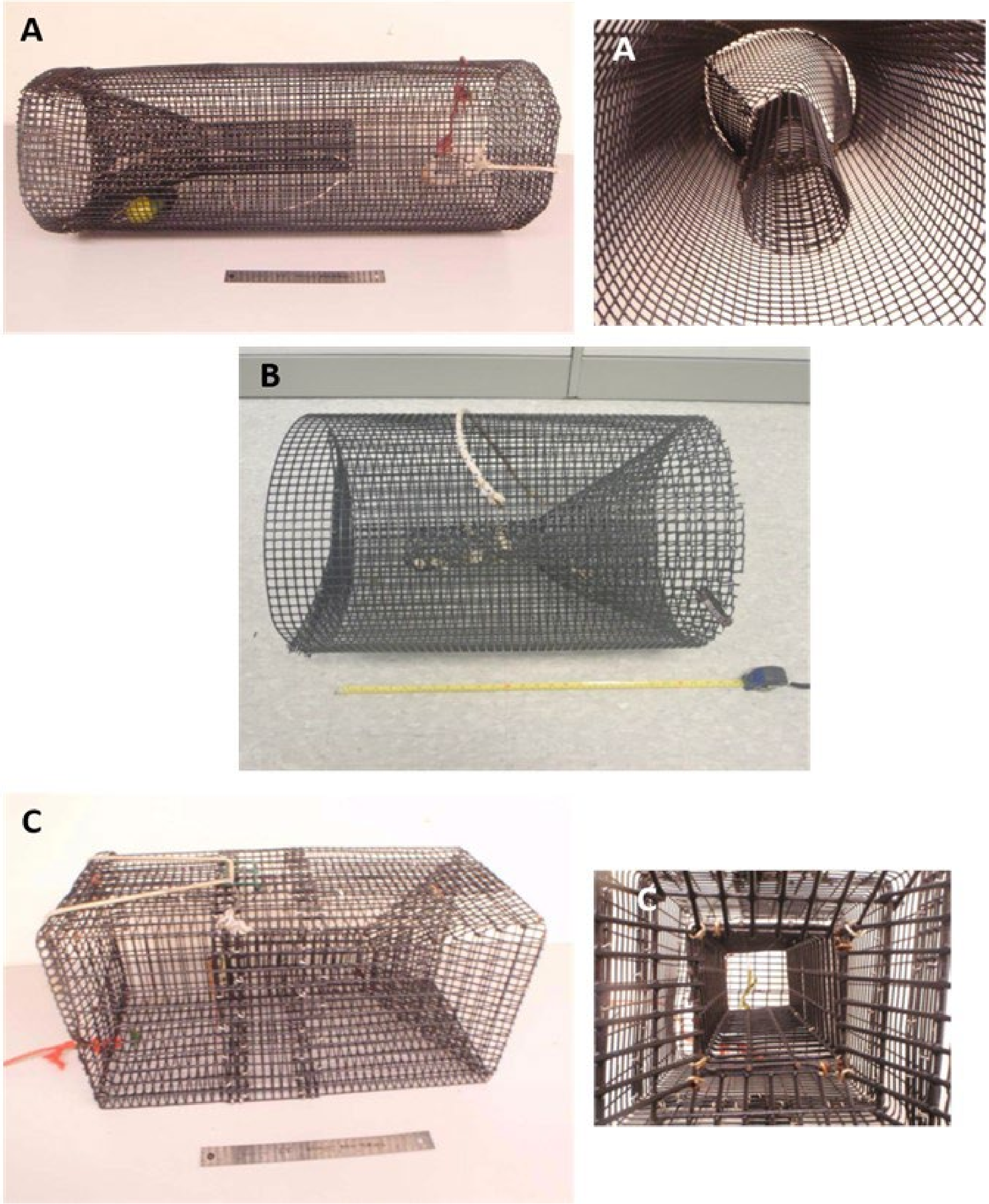

Figure 4. Eel and Modified Eel Traps. A. Cylindrical eel trap Photo: Pouliot 2009; B. Modified eel trap Photo: A. Nadeau, Fisheries and Oceans Canada, Gulf Region; C. Russell modified eel trap Photo: Pouliot 2009.

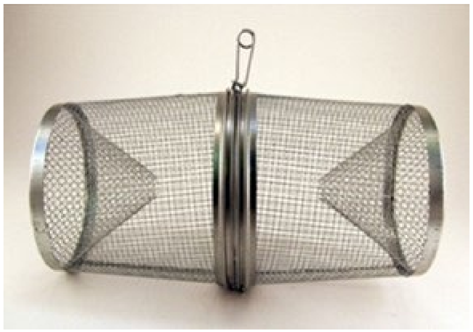

Figure 5. Minnow trap Photo: Wildco.com

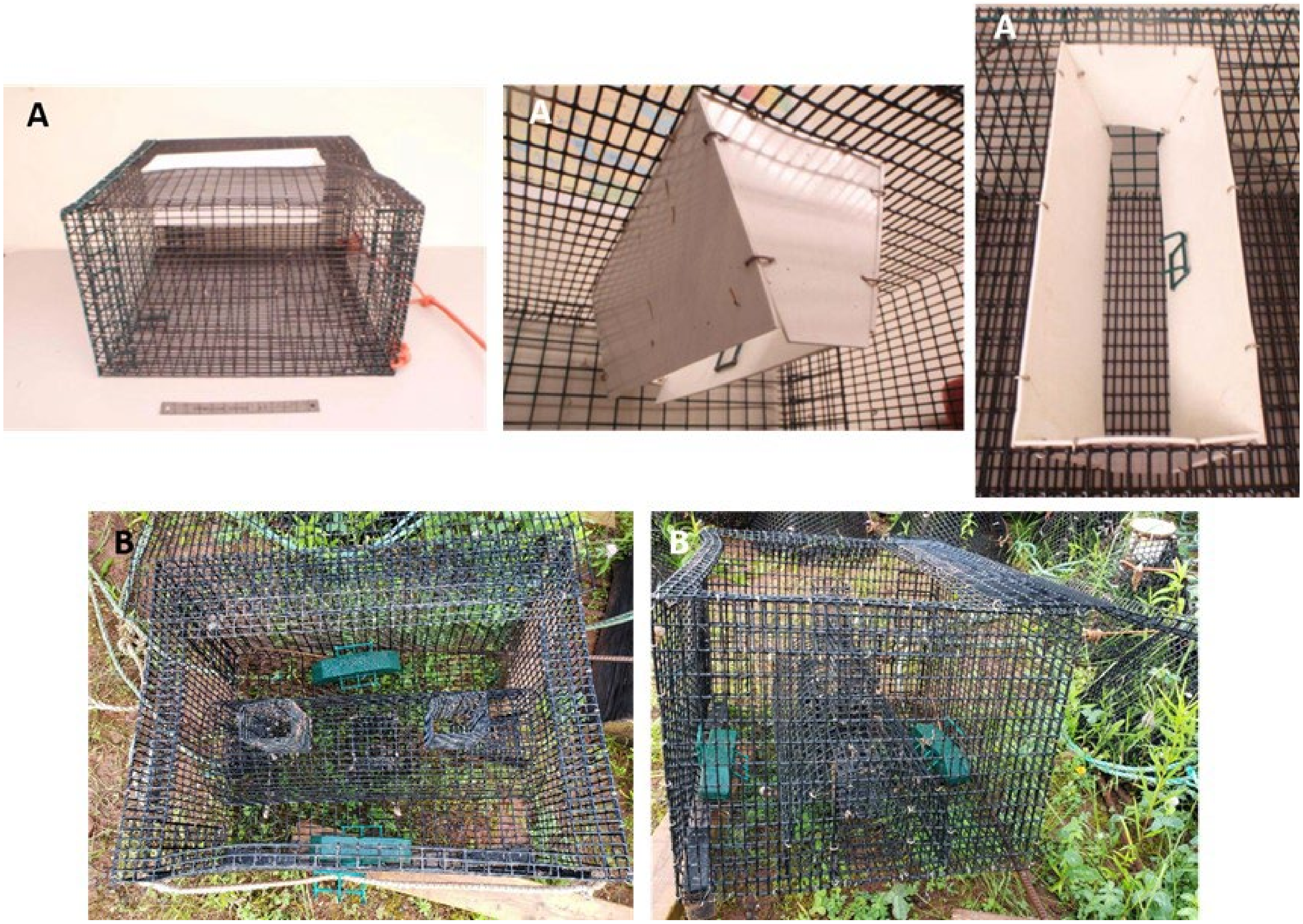

Figure 6. Box traps. A. Russell shrimp trap Photo: Pouliot 2009; B. Delbert trap Photo: Souris and Area Branch of the PEI Wildlife Federation.

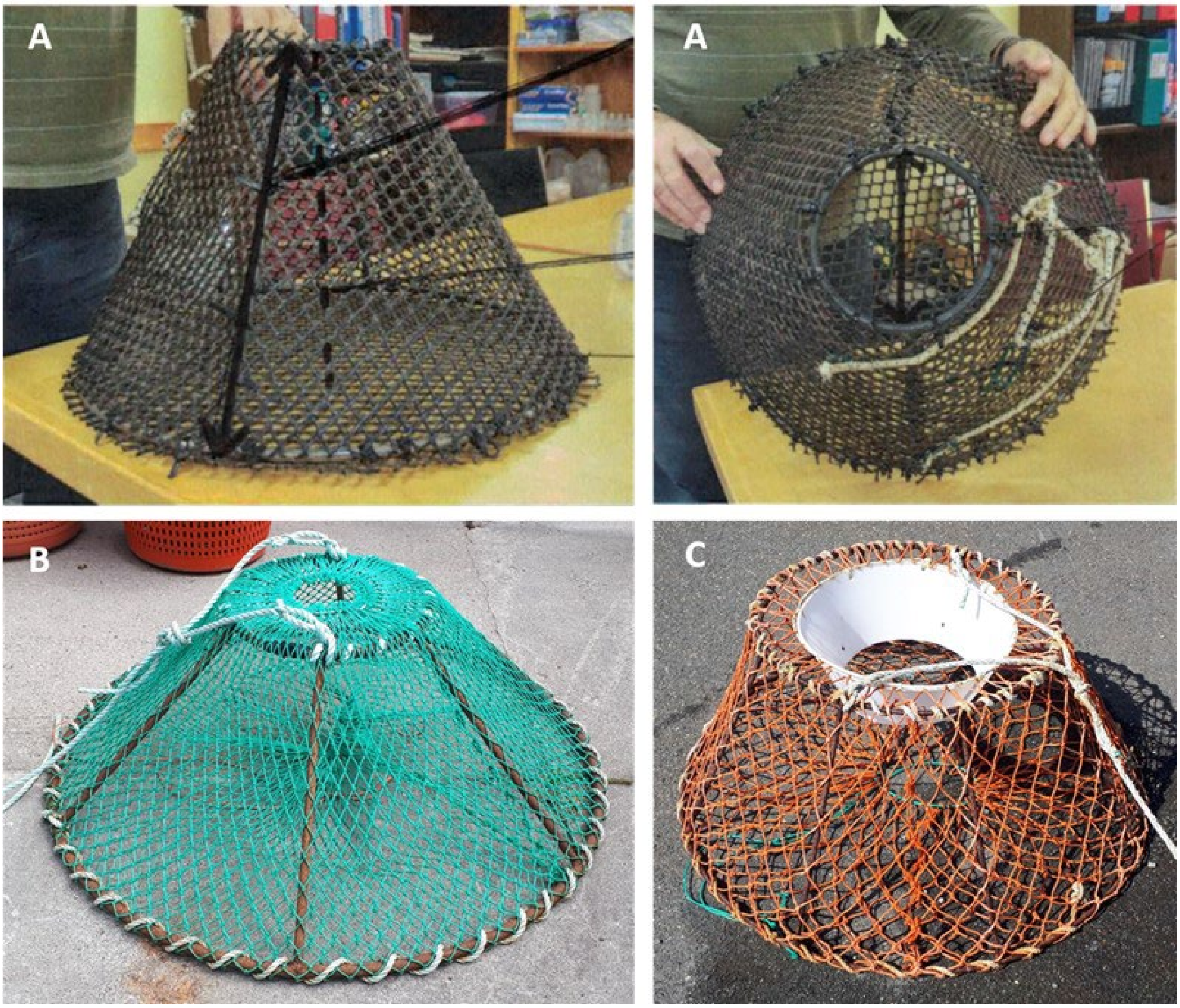

Figure 7. Conical traps. A. Luke trap Photo: Souris and Area Branch of the PEI Wildlife Federation; B. Modified whelk pot Photo: P.S. Sargent. C. Snow crab trap Photo: P.S. Sargent.

Figure 8. Lobster trap Photo: R. Estrada from Simard et al. 2013.

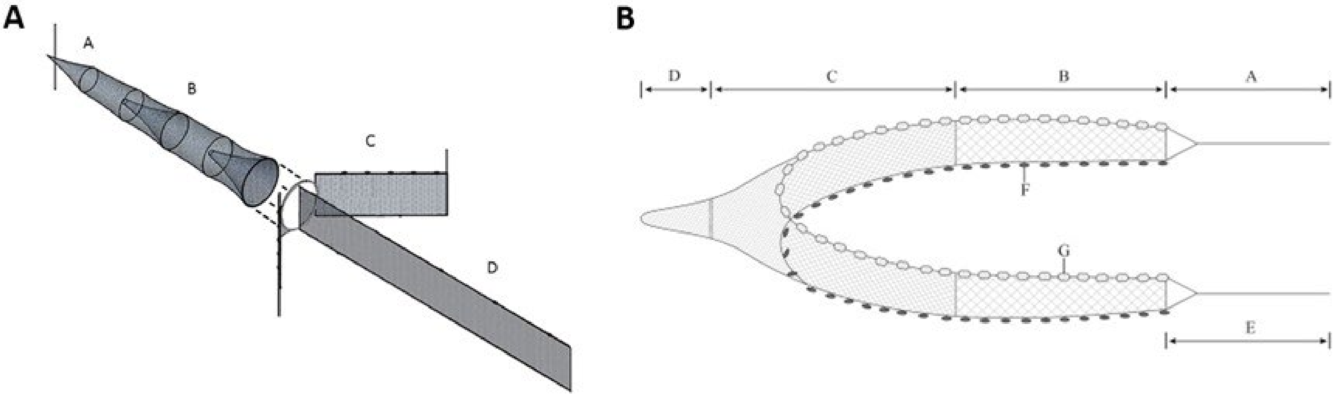

Figure 9. Nets. A. Fyke net Photo: Poirier et al. 2020; B. Beach seine Photo: Ashoka Deepananda et al. 2016.

8. TABLES

Table 1. Trap types utilized in Canada to capture European Green crab. (Order of trap type is from most to less frequently used).

Trap Category	Trap Type	Shape	Dimensions (cm)	Volume (cm^3)	Mesh Size (cm)	Mesh Material	Entrance(s)	Purpose	Region and Reference
Collapsible fish/crab trap (Figure 3)	Fukui trap	Box	60L × 45W × 20H	54,000	1.3 × 1.3	High density UV resistant polyethylene thread	2 sides, inward facing mesh panels with slit openings	Early Detection, Monitoring, Mitigation, Research	BC – Duncombe & Therriault 2017; NB – Bernier et al 2020; NS – Vercaemer & Sephton 2016; NL – Bergshoeff et al. 2019; PEI – Poirier et al. 2020; QC – Simard et al. 2013
	Promar trap	Oval Dome	90L × 60W × 60H	-	2.5	Nylon mesh	2 ends, circular funnels, 15cm D	Monitoring, Research	BC – McGaw et al. 2011; NL – McGaw pers. com.
	Morenot trap	Oval Dome	60L × 45W × 30H		0.9	Polyethylene	2 ends, circular funnels, 7cm D	Monitoring, Research	BC – McGaw et al. 2011; NL – McGaw pers. com.
Eel trap (Figure 4)	Cylindrical eel trap	Cylindrical	91L × 31D	69,000	1.0	Vexar® Plastic	1 side, circular funnel	Monitoring, Mitigation	NB, NS, PEI – Pouliot 2009, Vercaemer & Sephton 2016, Bernier et al. 2020
	Modified cylindrical eel trap	Cylindrical	61L × 37D	66,000	1.3	Vexar® Plastic	1 side, circular funnel	Monitoring	NS & PEI – Bernier et al. 2020
	Russell eel trap	Rectangular	59L × 28W × 28H	46,000	2.5 × 1.0	Plastic coated wire	1 side, square funnel	Monitoring, Mitigation	NS – Pouliot 2009
Minnow trap (Figure 5)	Minnow trap	Cylindrical	40L × 20D	10,000	0.6	Galvanized steel wire	2 sides, inverted cones	Early Detection, Monitoring	BC – Gillespie et al. 2007; NS – Pouliot 2009; QC – Simard et al. 2013

Trap Category	Trap Type	Shape	Dimensions (cm)	Volume (cm^3)	Mesh Size (cm)	Mesh Material	Entrance(s)	Purpose	Region and Reference
Box trap (Figure 6)	Russell modified shrimp trap	Rectangular	61L × 51W × 36H	112,000	2.5	Plastic coated wire	1 top, tapered rectangular	Monitoring, Mitigation	NB, NS, PEI – Pouliot 2009, Vercaemer & Sephton 2016, Bernier et al. 2020
	Delbert trap	Rectangular	61L × 48W × 36H	103,400	1.3 x 2.5	Plastic coated wire	2 sides, inward facing	Early Detection, Mitigation	PEI – Joseph et al. 2021
Conical trap (Figure 7)	Luke trap	Truncated cone	51BD x 14TD x 30H	20,600	1.3	Vexar® mesh on welded steel frame	1 top, circular	Early Detection, Mitigation	PEI – Joseph et al. 2021
	Modified whelk pot	Truncated cone	93BD x 30TD x 30H	99,000	5	Braided polypropylene	1 top, circular	Monitoring, Research	NL – Blakeslee et al. 2010; QC – Simard et al. 2013
	Modified crab pot	Truncated cone	127BD x 69TD x 58H	452,000	2.5	Braided polypropylene	1 top, circular	Early Detection, Monitoring, Research	NL – McKenzie unpublished data; QC – Simard et al. 2013
Other traps (Figure 8)	Modified lobster trap	Trapezoidal				Wooden slats	2 sides, circular funnel	Early Detection, Monitoring	QC – Simard et al. 2013
Nets (Figure 9)	Fyke net	Cylindrical with Flat Panel Wings and Leader	10m leader, 1.5m wings, 5 rings, 3 funnels		2.0	Nylon netting	1 end, circular	Early Detection,Monitoring, Research	PEI - Audet et al. 2008, Poirier et al. 2020; QC – Simard et al. 2013
	Beach seine		25m L, 24.4m headrope, 26.2m footrope	N/A	1.9 stretched in wings & belly, 0.9 in codend	Nylon netting	1 end, circular	Monitoring, Research	NL – Matheson et al. 2016; QC – Simard et al. 2013; Gulf – Bernier, pers. comm,

Table 2. Trap types utilized in area outside Canada to capture European Green crab.

Trap Category	Trap Type	Shape	Dimensions (cm)	Volume (cm^3)	Mesh Size (cm)	Mesh Material	Entrance(s)	Purpose	Region and Reference
Cylindrical trap	Acer/Blanchard trap	Cylindrical	90L × 46D	129,500	1.3 × 2.5	Vinyl coated wire	2 sides, inverted cones	Monitoring, Mitigation	eastern USA: MA – Beal, 2014, Young et al. 2017
	Cylindrical netlon traps	Cylindrical	60L × 30D; 120L × 60D	42,000; 339,000	0.5; 2	Netlon	2 sides, circular funnel	Monitoring, Research	UK – McGaw et al. 2011
Eel trap	Rectangular eel trap	Rectangular	89L × 30W × 30H	77,800	1.3 × 2.5	Vinyl coated wire	1 side, chute	Monitoring, Mitigation	eastern USA: MA –Young et al. 2017
Box trap	Standard ventless lobster trap	Rectangular	90L × 47W × 35H	148,000	2.5 × 2.5	Plastic coated wire	1 square funnel	Monitoring, Research, Education	eastern USA: ME – Webber 2013; NH – Goldstein et al. 2017
	Terminator trap	Rectangular	60L × 60W × 38H	136,800	1.3 × 2.5	Vinyl coated wire	2 top, rectangular	Monitoring, Mitigation	eastern USA: MA –Young et al. 2017
	Ketcham trap	Rectangular	60L × 46W × 23H	63,000	1.3 × 2.5	Vinyl coated wire	1 top, circular	Monitoring, Mitigation	eastern USA: MA –Young et al. 2017
	Slanted-sides trap	Rectangular	60L × 60W × 41H	40,600	1.3 × 2.5	Vinyl coated wire	2 sides, rectangular	Monitoring, Mitigation	eastern USA: MA –Young et al. 2017
	Fulton trap	Rectangular	61L × 31W × 28H	53,000	0.5	Plastic coated wire	1 side, chute	Monitoring, Research	eastern USA: NH – Fulton et al. 2013
	Mabin trap	Rectangular	75L × 25W × 25H	47,000	1 x 1.5	Rigid plastic mesh	2 sides, circular funnel	Monitoring, Research	South Africa – Mabin 2018
Other traps	Pitfall trap	Cylindrical	37L × 30D	26,000	N/A	N/A	1 top, circular	Monitoring	western USA: CA - Grosholz & Ruiz 1995; OR & WA – Behrens Yamada & Gillespie 2008
	Trapezoidal trap	Trapezoidal	90L × 46BW × 28TW × 25H	83,300	1.3 × 2.5	Vinyl coated wire	1 top, rectangular	Monitoring, Mitigation	eastern USA: MA –Young et al. 2017
Nets	Drop net, aka Hoop net	Circular	70D	-	1.0	-	1 top, circular	Research	Denmark – Aagard et al. 1995, England – Rewitz et al. 2004; & Portugal – Queiroga 1993

Table 3. Traps and their usage by Province.

Province	Trap	Early Detection/Rapid Assessment	Monitoring	Research	Control	References
Newfoundland	Fukui	✓	✓	✓	✓	Blakeslee et al. 2010; DFO 2011; McKenzie 2011; Best et al. 2017; Favaro et al. 2020; McKenzie unpublished data
	Minnow	NA	NA	☐	NA	
	Modified whelk/snow crab trap	X	X	NA	X	
Nova Scotia	Cylindrical Eel (modified)	X	X	✓	NA	Pouliot 2009; DFO 2011; MacDonald 2014; MacDonald et al. 2018; Vercaemer and Sephton 2016; Mersey Tobeatic Research Institute and Parks Canada 2016.
	Fukui	✓	✓	✓	NA	
	Minnow (modified)	✓	✓	✓	NA	
	Rectangular Eel (modified)	X	X	✓	NA	
	"Russell" Shrimp Trap (modified)	NA	NA	✓	✓	
New Brunswick	Cylindrical Eel trap (modified)	✓	✓	✓	✓	MacDonald 2014; MacDonald et al. 2018; Bernier et al. 2020; Locke and Bernier unpublished data.
	Fukui	✓	✓	✓	NA	
	Fyke Nets	NA	NA	NA	✓	
	Minnow	NA	X	X	NA	
	"Russell" Shrimp Trap (modified)	✓	✓	✓	NA	
Prince Edward Island	Cylindrical Eel trap (modified)	✓	✓	NA	✓	Klassen and Locke 2007; DFO 2011; Poirer et al. 2018, 2020; Bernier et al. 2020; Locke

Province	Trap	Early Detection/Rapid Assessment	Monitoring	Research	Control	References
	Delbert trap	X	NA	NA	X	and Bernier unpublished; Section 52 control unpublished; R. Bernier pers comm.
	Fukui	✓	✓	✓	NA	
	Fyke Net	NA	NA	✓	✓	
	Luke trap	X	NA	NA	✓	
	Minnow	NA	X	X	✓	
	Modified lobster pot	NA	NA	NA	X	
Quebec	Fukui	✓	✓	✓	✓	Paille et al 2006; Simard et al. 2013
	Fyke Net	✓	✓	NA	✓	
	Minnow Trap	X	NA	NA	NA	
	Modified Whelk Pot	X	NA	NA	NA	
	Wooden lobster pot (modified)	X	NA	NA	NA	
	Modified crab pot	X	NA	NA	NA	Paille et al 2006
British Columbia	Fukui	✓	✓	✓	✓	Gillespie et al. 2007; McGaw et al. 2011; Curtis et al. 2015; Gillespie et al. 2015; Duncombe and Therriault 2017
	Minnow	✓	✓	NA	NA	

NA – not used ✓– used X – no longer used

Table 4 Summary of mitigation or control activities by Province.

Province	Site	Year	Trap	Bait	# of Days	# of Traps	CPUE	Total Catch	Reduced CPUE	Reduced Crab size	Increased Native species	Reference
NL	North Harbour, Placentia Bay, NL	2008-2009	Fukui Trap Modified Crab Pots Modified Whelk Pots	Herring Mackerel Cod Frames Squid	22 (2018) 9 (2019)	~ 40	MAX: 7 kg / trap / h (modified crab pot) MAX: 2 kg / trap / h (Fukui trap)	14 000 kg	Y	Y	Y	McKenzie 2011
NL	Placentia Bay, NL	2014-2016	Fukui Trap	Herring Cod frames	21 (2014) 17 (2015) 20 (2016)	30 / site (2014); 60 / site (2015-2016)	MAX: 1.4 kg / trap / h	24 000 kg	Y	Y	NA	McKenzie *unpublished*
NL	Placentia Bay, NL	2017-ongoing	Fukui Trap	Cod frames	40 (2017); 70 (2018-2020)	200-350 (2017); 350(2018-2020)	AVE: 1.8 kg / trap / day (site with highest abundances)	330 000 kg	Y; dropped 2018-2019, but increased in 2020	Y	Y	M Clarke (pers comms)
NL	St. George's Bay, Western NL	2012-ongoing	Fukui Trap, MacDonald Trap (Modified Fukui)	Herring Cod	17 (2017) 18 (2018) 16 (2019)	20	Ave 1.49 crab/trap/day range 14-3 crab (2019)	6,115 (2018) 5,497 crab (2019)	Y	Y	Y	Qalipu, First Nations, MAMKA 2020
NL	Fortune Bay, NL	2015-ongoing	Fukui Trap	Herring, Cod	24 (2020)	1 (2015) 3 (2016) 20 (2017) 60 (2019-2021)	NA	125,784 crab (2020)	N	N	N	FFAW unpublished (logsheets).
NS	Kejimkujik National Park (Seaside Adjunct)	2010-2014; Monitoring 2015 -	Russell Trap	Herring	12 / year	14	AVE: ~ 70 crabs / trap / day (2010)	~ 2 000 000 crabs	~70 (2010) to < 15 (2014), Increase observed in 2013	Y (~60 to 40 mm)	Y	Parks Canada 2014; Mersey Tobeatic Research Institute and Parks Canada 2015, 2016; C McCarthy Pers Comms (in Vercaemer and Sephton 2016)

Province	Site	Year	Trap	Bait	# of Days	# of Traps	CPUE	Total Catch	Reduced CPUE	Reduced Crab size	Increased Native species	Reference
NS	SW and E NS (only) Fishery	2011-2015	NA	NA	NA	75 traps per license (5 to 19 licenses/yr)	~ 50 crab per day (overall average)	157 000 kg (~ 3 000 000 crabs)	NA	NA	NA	Vercaemer and Sephton 2016
NS	Gulf Shore Pilot Fishery	2015-2017	NA	NA	NA	NA	NA	715.5 kg (2015) 2500.62 kg (2016) 963 kg (2017)	NA	NA	NA	DFO Fisheries Management, unpublished data[1]
NB	Gulf Region Pilot Fishery	2015-2017	Fyke net	NA	7 (2015) 0 (2016) 0 (2017)	7 for 1 license holder	NA	0 (2015) Fish harvester requested eel license back after 1 yr	NA	NA	NA	DFO Fisheries Management, unpublished data[1]
PEI	Basin Head	2009	Fukui Modified Eel Minnow	Thawed herring, canned herring or tuna	56 11 2	20 4 2	9.54 AVE crabs/trap/day 11.73 AVE crabs/trap/day 1.1 AVE crab/trap/day	12 500 crabs (June-Dec.) 880 crabs (Oct-Nov.) 20 crabs (July)	Y (temporarily)	NA	NA	DFO 2011 (CSAS Proceedings); R. Bernier, unpublished data
		2010	Fukui	Thawed herring, canned herring or tuna	107	NA	19.2 AVE crabs/trap/day	42,949 crabs (Mar.-Nov.)	NA	NA	NA	R. Bernier, unpublished data
		2016-2020	Fukui, Russell, Luke, Delbert	Frozen herring/mackerel	32-46, 88 (2018)	32-53	NA	35,785 (2016) 32,821 crabs (2017) 45,578 crabs (2018) 15,415 (2019); 80,515 (2020)	NA	NA	NA	Joseph et al. 2021; DFO Aquatic Ecosystems, unpublished data

Province	**Site**	**Year**	**Trap**	**Bait**	**# of Days**	**# of Traps**	**CPUE**	**Total Catch**	**Reduced CPUE**	**Reduced Crab size**	**Increased Native species**	**Reference**
PEI	Gulf Region Pilot Fishery	2015-2017	Fyke net Modified lobster trap	NA	48.5 (2015) 43 (2016) 34 (2017)	17 (2015) NA (2016-17)	NA	488 kg (2015) 3248 kg (2016) 595 kg (2017)	NA	NA	NA	DFO Fisheries Management, unpublished data[1]
QC	Magdalen Islands	2008 - ongoing	Fukui Fyke net	Mackerel Herring	See table 1 in Simard et al 2013		AVE CPUE 4 crabs/trap/day: Range 0-9	26,925 crabs (2008-2014) 18 crabs (2015-2020)	Y	N	Y	Simard et al 2013 + unpublished data
BC	Pipestem Inlet, BC	2010-2014	Fukui Trap	Herring	8-13 days	72	MAX: 60 crabs / trap / day (average)	> 62 000 crabs	Y	Y	NA	Duncombe and Therriault 2017

[1] Data obtained and compiled from industry log books submitted to DFO Gulf Region Fisheries Management for Gulf Region’s Pilot Fishery of European green crab (2015-2017).

Table 5. Summary of traps/nets used to capture European Green Crab in Canada with their respective associated advantages and disadvantages.

Trap Type	**Trap Name**	**Collapsible**	**Light Weight**	**Easily Transported in Large Numbers**	**Deployment Shore/Small Vessel**	**Durable**	**High Catch Capacity**	**Bycatch levels low fish/invertebrates**	**Low Risk of Mammal Bycatch**	**Capable of Capturing Small Crabs**
Collapsible fish/crab trap	Fukui	●	●	●	●	○	○	○[1]	○[2]	X
	Promar	●	●	●	●	○	○	○	N/A	X
	Morenot	●	●	●	●	○	○	○	N/A	X
Eel trap	Cylindrical	X	○	X	S	○	●	●	●	X
	Modified	X	○	X	S	○	●	●	●	X
	Russell	X	○	X	S	●	●	●	●	X
Minnow/Crayfish trap	Minnow/Crayfish	○	●	●	S	●	●	●	●	○
Box trap	Russell modified shrimp	X	○	X	X	●	●	●	●	X
	Delbert	X	○	X	X	●	●	●	●	X
Conical trap	Luke	X	X	X	X	●	○	N/A	●	X
	Modified whelk	○[3]	X	○	X	●	○	●	●	X
	Modified snow crab	○[3]	X	○	X	●	●	●	●	X
Other traps	Modified lobster	X	X	X	X	○	○	○	N/A	X
Nets	Fyke net	●	X	X	S	○	●	X	●	X
	Beach Seine	●	X	X	S	○	X	X	●	○

● – Excellent; ○ – Good; X – No; N/A – data Not Available; S – Shore deployment; [1]Can be released; [2]Can be modified to prevent mammal bycatch; [3]Stackable

9. APPENDIX

Table A1. Trap types utilized in peer-reviewed studies.

Reference	Experiment Type	Location	Trap Type (General)
Audet et al. 2008	Research	Canada	Nets, Eel Trap, Other
Bergshoeff et al. 2018	Research	Canada	Collapsible Fish/Crab Trap
Bergshoeff et al. 2019	Research	Canada	Collapsible Fish/Crab Trap
Bernier et al. 2020	Research	Canada	Eel Trap, Collapsible Fish/Crab Trap, Box Trap
Best et al. 2017	Research	Canada	Collapsible Fish/Crab Trap
Blakeslee et al. 2010	Research	Canada	Nets, Conical Trap
CSAS meeting proceedings 2011 - McKenzie	Mitigation	Canada	Collapsible Fish/Crab Trap
CSAS meeting proceedings 2011 - Therriault	Early Detection and/or Monitoring	Canada	Collapsible Fish/Crab Trap
CSAS meeting proceedings 2011-Benoit	Early Detection and/or Monitoring	Canada	Eel Trap, Minnow Trap
CSAS meeting proceedings 2011-Watson	Mitigation	Canada	Collapsible Fish/Crab Trap, Minnow Trap, Eel Trap
Curtis et al. 2015	Early Detection and/or Monitoring	Canada	Collapsible Fish/Crab Trap, Minnow Trap
DiBacco & Therriault 2015	Research	Canada	Collapsible Fish/Crab Trap
Duncombe & Therriault 2017	Mitigation	Canada	Collapsible Fish/Crab Trap
Duncombe 2014	Mitigation	Canada	Collapsible Fish/Crab Trap
Favaro et al. 2020	Research	Canada	Collapsible Fish/Crab Trap
Gillespie et al. 2007	Early Detection and/or Monitoring	Canada	Collapsible Fish/Crab Trap, Minnow
Gillespie et al., 2015	Early Detection and/or Monitoring	Canada	Collapsible Fish/Crab Trap, Minnow Trap
Joseph et al. 2021	Early Detection and/or Monitoring	Canada	Collapsible Fish/Crab Trap, Box Trap, Conical Trap

Reference	Experiment Type	Location	Trap Type (General)
Kelley et al. 2015	Research	Canada	Collapsible Fish/Crab Trap
Klassen & Locke 2007	Research	Canada	Eel Trap, Other
MacDonald 2014	Early Detection and/or Monitoring	Canada	Collapsible Fish/Crab Trap
Matheson et al. 2016	Early Detection and/or Monitoring	Canada	Nets, Collapsible Fish/Crab Trap
McGaw et al. 2011	Early Detection and/or Monitoring	Canada	Collapsible Fish/Crab Trap
Paille et al. 2006	Early Detection and/or Monitoring	Canada	Box Trap, Collapsible Fish/Crab Trap, Minnow Trap, Other
Pickering et al. 2017	Early Detection and/or Monitoring	Canada	Collapsible Fish/Crab Trap
Poirer et al. 2018	Research	Canada	Nets
Poirer et al. 2020	Research	Canada	Collapsible Fish/Crab Trap, Nets
Pouliot 2009	Early Detection and/or Monitoring	Canada	Eel Trap, Minnow Trap, Box Trap
Simard et al. 2013	Early Detection and/or Monitoring	Canada	Conical Trap, Box Trap, Minnow Trap, Nets, Collapsible Fish/Crab Trap, Other
Vercaemer & Sephton 2016	Early Detection and/or Monitoring	Canada	Eel Trap, Collapsible Fish/Crab Trap, Box Trap
Le Roux et al. 1990	Early Detection and/or Monitoring	Africa	Collapsible Fish/Crab Trap
Mabin, 2018	Mitigation	Africa	Minnow Trap
Hidalgo et al. 2005	Early Detection and/or Monitoring	Argentina	Collapsible Fish/Crab Trap
Garside & Bishop 2014	Research	Australia	Collapsible Fish/Crab Trap
Hewitt & Martin 2001	Early Detection and/or Monitoring	Australia	Collapsible Fish/Crab Trap
Thresher et al. 2003	Early Detection and/or Monitoring	Australia	Collapsible Fish/Crab Trap
Aagard et al. 1995	Research	Denmark	Other
Quieroga 1993	Research	Portugal	Nets

Reference	Experiment Type	Location	Trap Type (General)
McGaw et al. 2011	Early Detection and/or Monitoring	United Kingdom	Minnow Trap
Rewitz et al. 2004	Research	United Kingdom	Nets
Beal 2014	Mitigation	United States	Cylindrical Trap
Behrens et al. 2002	Early Detection and/or Monitoring	United States	Collapsible Fish/Crab Trap
Behrens et al. 2005	Research	United States	Collapsible Fish/Crab Trap, Minnow Trap, Other
Behrens et al. 2008	Early Detection and/or Monitoring	United States	Collapsible Fish/Crab Trap, Minnow Trap, Other
CSAS meeting proceedings 2011-Grosholz	Mitigation	United States	Collapsible Fish/Crab Trap, Minnow Trap, Nets, Other
deRivera et al. 2005	Early Detection and/or Monitoring	United States	Collapsible Fish/Crab Trap
Fulton et al. 2013	Early Detection and/or Monitoring	United States	Other
Goldstein et al. 2017	Early Detection and/or Monitoring	United States	Box Trap
Grason et al. 2018	Early Detection and/or Monitoring	United States	Collapsible Fish/Crab Trap, Minnow Trap
Grosholz & Ruiz 1995	Early Detection and/or Monitoring	United States	Minnow Trap, Other
Grosholz et al. 2000	Research	United States	Other
Washington Sea Grant	Early Detection and/or Monitoring	United States	Collapsible Fish/Crab Trap, Minnow Trap
Webber 2013	Early Detection and/or Monitoring	United States	Box Trap
Young et al. 2017	Research	United States	Cylindrical Trap, Box Trap, Minnow Trap, Eel Trap, Other

Table A2. Trap types utilized in unpublished studies.

Study (not in References)	Experiment Type	Location	Trap Type (General)
McKenzie et al. 2007a (1)	Early Detection and/or Monitoring (Science)	Newfoundland, Canada	Collapsible Fish/Crab Trap
McKenzie et al. 2007b (2)	Early Detection and/or Monitoring (Science)	Newfoundland, Canada	Conical Trap
McKenzie et al. 2008 (3)	Early Detection and/or Monitoring (Science)	Newfoundland, Canada	Collapsible Fish/Crab Trap
McKenzie and Baker 2008, 2009 (4)	Mitigation (DFO Science/ FFAW)	Newfoundland, Canada	Collapsible Fish/Crab Trap
Matheson et al. in prep 2014 -2016 (5)	Mitigation (DFO Science/ FFAW)	Newfoundland, Canada	Collapsible Fish/Crab Trap
Street et al. 2014-2017 (6)	Mitigation (FFAW)	Newfoundland, Canada	Collapsible Fish/Crab Trap
Lush et al. 2019 - 2021 (7)	Mitigation/Control (AIS NCP NL)	Newfoundland, Canada	Collapsible Fish/Crab Trap
LeBris et al. 2017-2022 (8)	Mitigation (Marine Institute)	Newfoundland, Canada	Collapsible Fish/Crab Trap
Wiseman and Baker 2020-2022 (9)	Mitigation (FFAW)	Newfoundland, Canada	Collapsible Fish/Crab Trap
Strickland et al. (10)	Early Detection and/or Monitoring (MAMKA)	Newfoundland, Canada	Collapsible Fish/Crab Trap
Peddle et al. (11)	Early Detection and/or Monitoring (ACAP)	Newfoundland, Canada	Collapsible Fish/Crab Trap
DFO 2016-2017 (12)	Mitigation (P&E)	Prince Edward Island, Canada	Nets, Eel Trap, Other
DFO 2016-2017 (13)	Mitigation (P&E)	Nova Scotia, Canada	Nets
Bernier et al. (14)	Early Detection and/or Monitoring	Prince Edward Island, Canada	Collapsible Fish/Crab Trap