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# COMPARISON OF TRAPPING METHODS FOR INVASIVE EUROPEAN GREEN CRAB

*European Green Crab (*Carcinus maenas*); Photo credit: DFO.*

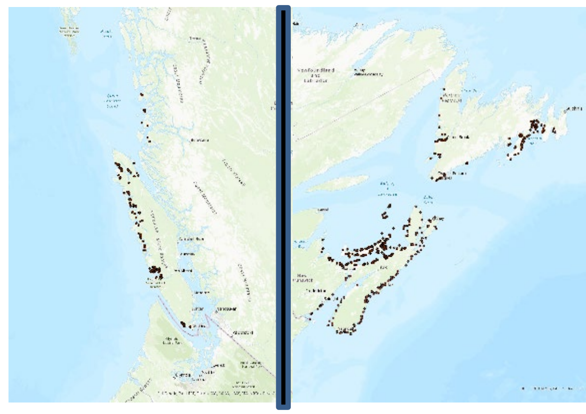

*Figure 1. Map of European Green Crab distribution on the Pacific and Atlantic coasts as of September 2021.*

## Context:

*European Green Crab (Carcinus maenas) is a voracious aquatic invasive species (AIS) that poses a serious threat to marine and estuarine ecosystems on the Atlantic and Pacific coasts of Canada. It preys on commercial and recreational shellfish, competes with commercial fisheries, and destroys ecologically and biologically-significant habitat for native species.*

*Fisheries and Oceans Canada (DFO) has acquired substantial knowledge on European Green Crab, particularly regarding trapping as a form of physical removal to control their spread. Knowledge acquired 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 consolidated formally in a comprehensive review that can be applied to AIS management.*

*DFO's AIS National Core Program has requested science advice because trapping of European Green Crab is critical for early detection, determining impacts on native species and habitat, and control efforts to prevent ecosystem degradation and commercial fishery loss. In order to translate 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, such as variation in habitat, gear type, and trapping goals, balanced with operational capacity.*

*This Science Advisory Report is from the September 28-29, 2021 National Advisory Meeting on the Comparison of Trapping Methods for Invasive European Green Crab. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada (DFO) Science Advisory Schedule](#) as they become available.*

## SUMMARY


- European Green Crab (EGC) (*Carcinus maenas*) 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. Fisheries and Oceans Canada (DFO), in partnership with stakeholders and Indigenous groups, has developed substantial knowledge of EGC and its trapping.
- Trapping has been used for early detection, monitoring, research, and physical removal for control. A review of peer reviewed studies and unpublished projects on EGC trapping was conducted to examine different trap types and their usage in Canada and in other locations where EGC have been trapped.
- Several factors are key in selecting an appropriate trap type based on trapping objectives. Applications of the different trap types, including important characteristics and deployment logistics are provided in a summary table.
- 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 habitat, but trapping efforts may need to be sustained.
- Knowledge gaps and challenges identified include a lack of information on capturing juvenile EGC in Canada and determining effective threshold levels or numbers for control to prevent environmental and fishery impact.


## BACKGROUND

European Green Crab (*Carcinus maenas* L.) (hereafter referred to as EGC) is a voracious aquatic invasive species (AIS) threatening Canada's marine and estuarine ecosystems on the Atlantic and Pacific coasts. It preys on and competes with commercial and recreational shellfish, negatively impacts commercial fisheries, and destroys ecologically and biologically-significant habitat of native species. EGC invasions have potentially devastating effects on the environment and local economies. Fisheries and Oceans Canada (DFO) has developed substantial knowledge on EGC, particularly regarding trapping for early detection, monitoring, research, and control. Information on trapping method considerations (deployment, environment, behaviour, catch) and goal focused protocols for different objectives, including control measures and mitigation strategies, can be compiled and evaluated to provide advice on detection and control of EGC.

EGC is native to the eastern Atlantic with a broad distribution range extending from northern Europe (Iceland and central Norway) to northern Africa (Morocco and Mauritania). EGC is described as one of the world's 100 worst invasive species. This species is highly aggressive, competitive, omnivorous, exhibits wide tolerances for temperature, salinity, and oxygen levels, and can survive out of the water (in a damp environment) for up to three weeks. EGC feeds primarily on molluscs, marine worms, and other small crustaceans (e.g., juvenile lobster), but its broad diet may include everything from marine plants to carrion. It also has high reproductive rates and extensive larval dispersal, via ocean currents and ship ballast water.

There have been multiple invasions of EGC to Atlantic Canada. A southern European lineage invaded the northeastern United States in the early 1800s and migrated northward until it stalled in Nova Scotia (NS) (near Halifax) in the 1980s. A second lineage arrived in northern NS in the late 1980's or early 1990's from northern Europe. The EGC in this invasion was more cold water tolerant and aggressive. The cold tolerant lineage spread northward in Atlantic Canada to northeaster and northwestern NS, Prince Edward Island (PEI), eastern New Brunswick (NB), the Magdalen Islands, Quebec (QC), and western Newfoundland (NL), as far north as Point Saunders.

These northern and southern lineages hybridized in Nova Scotia forming a hardier and more aggressive lineage that spread southward through NS, NB, and Maine and northward to Placentia Bay (2007) and Fortune Bay (2013) in southern Newfoundland.

In western Canada, the invasion of EGC has been attributed primarily to northward larval drift from populations first detected in San Francisco Bay, California (1989). It is now present on the west coast of Vancouver Island, the Salish Sea, the islands near Bella Bella, and as far north as Skidegate Inlet, Haida Gwaii (2020).

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. DFO Science has been trapping EGC for early detection and/or monitoring and impact research since the establishment of DFO's Aquatic Invasive Species program in 2006. In partnership with stakeholders and Indigenous groups, DFO has developed substantial knowledge of EGC and its trapping. A standardized survey and monitoring EGC protocol developed in 2008 uses the Fukui crab trap. This trap has also been used by DFO for mitigation and control studies, but other traps have also been used by DFO and its partners to compare and optimize control and removal.

In addition to published studies, observations from other mitigation trapping activities can provide additional information on EGC trapping. 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) by trapping gear type, bycatch, control measures, and mitigation strategies. However, much of this knowledge had yet to be consolidated formally in a comprehensive review that could be applied to EGC management.

The DFO AIS National Core Program requested science advice on EGC trapping 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.

Objectives of this examination of trapping methods for EGC were to:

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 CPUE.
2. Based on this review, provide recommendations on gear type for trapping EGC, considering feasibility and logistics.
3. Knowledge gaps identified regarding trapping methods.

The goal of this advisory process was to provide AIS managers with an overview of existing relevant information regarding EGC trapping. Cost of traps and gear and economic feasibility of any trapping method is not provided as it is beyond the scope of 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.

# METHODS

A review of 69 peer reviewed studies and unpublished projects on EGC trapping was conducted to determine trap types used in Canada (46 studies) and elsewhere (23 studies). 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. 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 the research papers and projects into three categories based on the primary use of the traps: ‘Research’, ‘Early detection and/or monitoring’, and ‘Mitigation’. Studies in the ‘Research’ category (n = 19) 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 (n = 33) 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 (n = 17) were those that used trapping to perform removal/mitigation efforts of invasive EGC populations.

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 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.

Several factors were considered in addition to trap type when trapping EGC including logistics of deployment, variations in environment, and EGC behaviour. The use of catch information (e.g., CPUE, size, sex, bycatch) was considered and reviewed as indicators of trapping success.

# ASSESSMENT

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. 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. 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 studied in several regions. Trap type selection must consider the trapping objective, in particular the targeted portion of the EGC population, as trap types can disproportionately catch large adult EGC due to trap design, and intraspecific EGC behaviours.

Fifteen traps were categorized by type and usage in Canada (Table 1) as well as 13 additional traps that were used in North America and other parts of the world. 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. McKenzie et al. (2022) provides additional information on the characteristics of the trap as well as their usage in various Canadian provinces and the trapping purpose. Several factors are key in selecting an appropriate trap type based on trapping objectives. Table 1 evaluates the applications of the different trap types, and includes important characteristics and deployment logistics.

*Table 1. 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

Several factors should be considered in addition to trap type when trapping EGC including logistics of deployment, variations in environment (including shoreline characteristics), EGC behaviour, and use of catch information (e.g., CPUE, size, sex, bycatch) as an indicator of trapping success. Deployment of traps should include factors such as bait, location of deployment, depth (this varies with life stage), spacing or concentration of traps, and duration of deployment (soak time). EGC is a generalist and opportunistic species, which is an important consideration when evaluating bait for attracting them to traps.

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 mark. 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.

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 and mitigations in new areas. In addition to this local knowledge, maps, bathymetric data, other previous habitat surveys, and aerial photographs are important sources for identifying potential habitat suitability (e.g., freshwater sources, eelgrass meadows, sediment type, and variations in water depth). Considering the behaviour and biology of EGC is also important in trapping strategies.

Preferences or adaptations to depth, level of activity during time of day (day vs. night), and spatial movement vary by life stages or maturity and sex of EGC. Trapping in the same location at different times of year will capture different demographics, based on the life cycle and seasonality of EGC and associated behaviours 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. 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 large males, but as trapping continues within and across years, the bias towards males and large crabs decreases.

It is critical to realize that, although trapping can remove large numbers of EGC, trapping surveys do not determine absolute abundances or density of a population but instead, when conducted in a standardized and repeated design, can provide a relative index of changes over time. Catch per Unit Effort (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 protocols 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.), CPUE will not be an effective tool to compare trapping results across different and non-standardized monitoring and research designs.

Trapping is a critical component of early detection/rapid assessment surveys following a reported new EGC sighting, and subsequent monitoring efforts, and is often the only way to adequately sample for mobile AIS (see Table 3, McKenzie et al. 2022, for summary of types of traps used in Canadian provinces). 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. 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 is typically 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. Trapping strategies can target specific EGC habitats. Trap modification can limit bycatch and allow for live release of other species. Trapping can have negligible impact on native ecosystems, compared to other chemical or biological control options.

A summary of the mitigation or control activities in Canada conducted since 2008 by DFO Science, their partners or concerned third parties, 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 (McKenzie et al. 2022). Indicators for success typically include reductions in EGC numbers, reduction in average EGC size, changes in sex ratios, and increase in the recovery of native species and biodiversity.

Control efforts conducted by the Fish Food and Allied Workers (FFAW) with DFO NL in Placentia Bay (2014–2016) aimed to reduce CPUE by 95% or < 5 crabs/trap/day and reduce average crab carapace size to < 30 mm based on known size of reproductive maturity in Canadian coastal areas. These thresholds were set to reduce probability of significant impacts on eelgrass and bivalves and enhance potential recovery of native species abundances. Small EGC (< 30 mm) are also more likely to become prey rather than predators of native species.

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). In Pipestem Inlet (BC), 72 Fukui traps were set for 24 hr soak periods for 8 to 16 trapping days per year and have captured > 62,000 EGC. In NL, 60–70 Fukui traps per fish harvester (10 fish harvesters) were used in mitigation activities from 2014–2016, in Placentia Bay, NL. Across all 10 sites that had some degree of trapping efforts, nearly 24 000 kg of EGC were captured. In Placentia Bay, trapping efforts have continued and captured over 400 000 kg of EGC (2017–2021) across up to 10 locations, fishing 70 Fukui traps at each location, up to 70 days per year.

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 fishes 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. 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.

### Sources of Uncertainty

There is a lack of information on determining effective threshold levels or EGC numbers for control to prevent environmental and fishery impacts. 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 thresholds and absolute EGC numbers in the environment.

There is also a general lack of information on trapping juvenile EGC and thus a lack of knowledge on effectiveness of various trap types and trapping strategies to target those juveniles. A clear definition of what constitutes juvenile EGC must also be considered as size at maturity may vary regionally based on genetic lineage.

## CONCLUSIONS AND ADVICE

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) 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 parts of the world. 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 its partners based on 15 years of trapping experience from both Atlantic and Pacific coasts for early detection, rapid response, research and control mitigation activities, Traps used currently in Canada to capture EGC, and the advantages and challenges of each trap type, is summarized in Table 1. Several factors are key in selecting an appropriate trap type based on trapping objectives. Table 1 evaluates the applications of the different trap types, and includes important characteristics and deployment logistics. 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, and 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.

## OTHER CONSIDERATIONS

There are several other considerations regarding trapping EGC that should be highlighted when considering 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. 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 (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. This is 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.

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## SOURCES OF INFORMATION

This Science Advisory Report is from the September 28-29th, 2021 National Advisory Meeting on the Comparison of Trapping Methods for Invasive European Green Crab. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

McKenzie, C.H., Matheson, K., Sargent, P. S., Piersiak, M., Bernier, R.Y., Simard, N., Therriault T.W. 2022. Trapping Methods for the Invasive European Green Crab in Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2022/063. iv + 47 p.

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