

Chinese mitten crabs (*Eriocheir sinensis*) in the St. Lawrence River and Estuary, Canada: new records and risk of invasion

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Abstract

Recent reports of Chinese mitten crabs (*Eriocheir sinensis*) in the St. Lawrence River and Estuary were compiled to assess the possible sources of the species based on genetic analyses and data on shipping traffic. Between 2004 and 2007, nine specimens were captured in both the fresh and estuarine waters of the St. Lawrence; a number unprecedented in the 40 years since the mitten crab was first sighted in the Great Lakes–St. Lawrence Basin. These sightings, added to those of the eastern United States, are indicative of a large-scale wave of introduction of the mitten crab to Eastern North America. Genetic analyses have suggested that the St. Lawrence specimens likely originated in Europe. No significant changes have been noted in maritime traffic to the St. Lawrence in recent years, but analyses have revealed that 42% of ships came from European countries where established populations of Chinese mitten crab have exhibited recent bursts in abundance. It is suggested that the recent wave of introduction of mitten crabs to Eastern North America is related more to changes in the abundance of European populations than to changes in shipping vector activity. These recent sightings are of major concern with regard to the establishment and spread of the species. It is therefore recommended that long-term monitoring programs be set up immediately to track the progress of the mitten crab invasion in the St. Lawrence River basin.

Key words: ballast water, Chinese mitten crab, genetic variation, maritime traffic, Eastern North America, propagule, spread, St. Lawrence River, introduction

Introduction

Native to China and North and South Korea, the Chinese mitten crab, *Eriocheir sinensis* H. Milne Edwards, 1853, is an internationally recognized aquatic invader that has successfully established itself in rivers and estuaries in 11 different countries in Western Europe (Herborg et al. 2005), as well as San Francisco Bay in the

United States (Cohen and Carlton 1997; Rudnick et al. 2003). When abundant, mitten crab populations can significantly affect local biodiversity and cause structural damage to shorelines due to their burrowing activities (Rudnick et al. 2000). The crab can also affect commercial fisheries by damaging or fouling fishing nets and eating fish bait (Panning 1938; CMCWG 2003). Its introduction is generally

associated with shipping via ballast-water discharge and importation for consumption (Cohen and Carlton 1997; Gollasch et al. 2002; Herborg et al. 2007).

The presence of the Chinese mitten crab in the North American Great Lakes (Canada and United States) was first reported in the Detroit River in 1965 (Nepszy and Leach 1973), only six years after the opening of the St. Lawrence Seaway gave transoceanic vessels access to these inland waters. Over the next forty years, fourteen additional crab sightings were reported in the Great Lakes, mostly in western Lake Erie where there are major commercial fisheries (Tepolt et al. 2007). This catadromous species never became established in the Great Lakes, however, because sightings were nearly 1200 km away from the nearest potential breeding habitats (seawater >15 PSU – Anger 1991) in the St. Lawrence Estuary (SLE). The occurrence of a Chinese mitten crab in the St. Lawrence River (SLR) was first noted in Lévis, Quebec, in September 2004, almost 40 years after the first report of the species in the Great Lakes (de Lafontaine 2005). This was a major cause for concern because of the close proximity (65–80 km downstream of the capture site) of the brackish or salt waters of the estuary, which are vital to the reproduction and early larval development of the mitten crab (Cohen and Weinstein 2001).

In this paper, we document additional sightings of the Chinese mitten crab in the St. Lawrence River and Estuary (SLRE) system and assess possible sources based on genetic analyses of captured specimens. Given the recent changes in the shipping trade between North America and Asia (Normille 2004), we also examined inbound maritime traffic in the SLR and how this might have contributed to the introduction of the crab. We tested the hypothesis that the frequency of inbound ships originating from countries with existing Chinese mitten crab populations has changed in recent years.

Materials and Methods

Crab Sightings and Genetic Analyses

Information on recent sightings of Chinese mitten crabs in the SLRE was gathered following the initiation of an alert and monitoring program for this ecosystem. The program was set up in 2005 after the first mention of a crab in the river

(de Lafontaine 2005). Upon capture, specimens were measured for carapace width (CW) and length to the nearest mm, and weighed (± 0.1 g). Sex was determined by examining the shape of the ventral plastron (Veilleux and de Lafontaine 2007); the presence of hair on the claws was also noted. Specimens were either frozen or stored in 70–85% v/v ethanol. Tissue samples were taken from the third or fourth walking leg of individuals and preserved in 90–95% v/v ethanol for genetic analysis. Total DNA was extracted using DNeasy tissue kits (Quiagen). Amplification of the 586 bp fragment of the mitochondrial cytochrome c oxidase (COI) was carried out following techniques detailed in Hänfling et al. (2002) and Tepolt et al. (2007). Both strands of the amplified product were sequenced on an ABI prism 310 sequencer (Applied Biosystems) using the universal primers LCO1490 and HCO2198 of Folmer et al. (1994). Sequences were compared with those of Hänfling et al. (2002) available on GenBank using the software Sequencher (Gene Codes) to identify COI haplotypes.

An analysis was also performed on two specimens captured in Thunder Bay, Ontario, in Lake Superior, in December 2005 and October 2006. One crab collected in the Thames River (UK) in January 2006 was also analyzed for species identification referencing. Haplotype distribution for the SLR specimens was then compared with those reported for the Great Lakes (Tepolt et al. 2007) and elsewhere (Hänfling et al. 2002; Tepolt et al. 2007).

Shipping Data Analysis

Maritime shipping data for Eastern Canada between January 1978 and December 2005 were extracted from two databases maintained by the Canadian Coast Guard: ECAREG (Eastern Canada Vessel Traffic Services Zone), for the period between January 1978 and April 2002, and INNAV (Information System on Marine Navigation) from May 2002 to the present. For each year, vessel trips considered for analysis included: 1) inbound trips of international and unknown origin exclusively and 2) trips for which the first Canadian port of destination was located in the fluvial section of the SLR between Montmagny, Quebec, and the Massena lock in New York (Figure 1). Trips of unknown origin consisted of trips in which the last port of call was not specified; therefore, the last port of call could have been anywhere in the world including

the SLR itself. Such trips were included to estimate the proportion of unidentified traffic in the SLR each year. Pertinent information for each trip included 1) trip start date, 2) trip number, 3) last port visited, 4) port of destination, and 5) estimated time of arrival (ETA). Once the desired trips were extracted from each database, a table of trip frequencies based on the

last country visited was tabulated for each year, as determined by their start dates. For ships that set off in late December of a given year with ETAs in the year to follow, the trip would be tabulated in that following year. The frequency table was verified to eliminate any duplicate mentions in the database (i.e. the same trip counted twice or more).

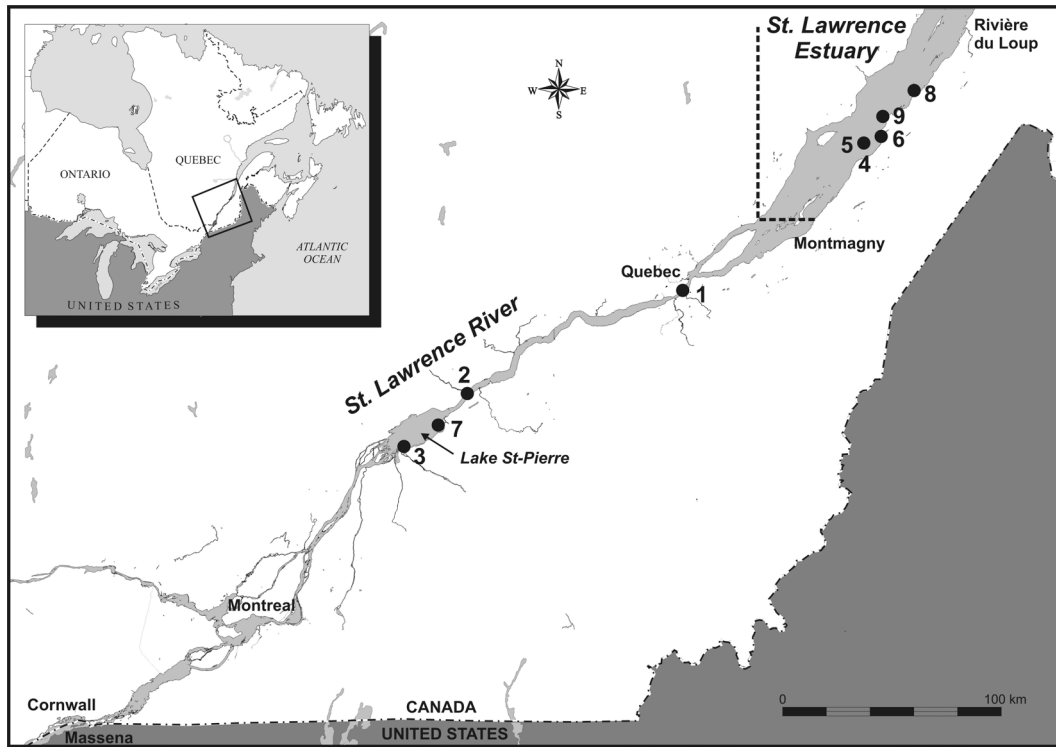


Figure 1. Location map of Chinese mitten crab sightings in the St. Lawrence River and Estuary between 2004 and 2007. Numbers refer to specimen IDs in Annex 1

“Mitten crab countries” were identified as those currently reporting established Chinese mitten crab populations. They include China, South Korea, Great Britain, Germany, Belgium, Holland, France, Portugal, Luxembourg, Finland, Sweden, Poland and the Czech Republic. All have established Chinese mitten crab populations that pre-date 1978, with the exception of Portugal, where the species was first reported in the late 1980s (Cabral and Costa 1999). Inbound trips from the United States originated mostly from the Eastern Seaboard, with ships from San Francisco Bay (where established crab populations exist) being extremely rare. All maritime traffic in the SLR was therefore tabulated and categorized as follows: (1) trips from countries

with existing mitten crab populations, (2) trips from countries with no mitten crab populations, (3) trips from the United States, and (4) trips of unknown origin.

For each category, the mean trip frequency for the 20-year time period 1978–1997 was statistically compared to the mean trip frequency for the eight-year time period 1998–2005, using a Wilcoxon-Mann-Whitney test (one-sided; $\alpha = 0.05$). Significance indicated whether trip frequency in the recent eight-year period differed from the previous 20-year period. These particular time blocks were chosen because the last eight years encompassed the years of crab introductions to the SLR; this time period is also substantial enough to lessen the effect of

atypically high (or low) traffic years. The same test was also performed on the mean trip frequency of individual countries or regions of origin with mitten crab populations, in order to identify potential changes in the inbound traffic from particular regions. Since mitten crabs are native to China and South Korea, trip frequencies from these two countries were combined to represent traffic of Asian origin.

Results

Crab Sightings

From the first mitten crab capture in September 2004 (de Lafontaine 2005), an additional eight sightings in the SLRE were recorded by December 2007. Of these nine observations in three years, four were reported in the freshwater section of the lower SLR (from Lake Saint-Pierre to Québec City), and five in the brackish waters of the upper estuary (between Ile d'Orléans and Rivière-du-Loup) (Annex 1; Figure 1). All nine specimens were caught some time between early summer and mid-fall by commercial fishermen using either fyke nets, eel fishing weirs or sturgeon gillnets. All capture sites were located on the south shore of the river and estuary; it should be noted that no specimen has yet been found along the north shore or in any of the numerous tributaries emptying into the river or estuary. One crab individual captured at Sainte-Angele-de-Laval (SLR) in fall 2004 was released before species confirmation (specimen #2, Annex 1), but the description of this specimen was considered an unequivocal identification by a knowledgeable fisherman. As no other freshwater crab species is native to the SLR, misidentification is highly unlikely.

All specimens were healthy and in excellent condition at the time of capture. Five males and three females (none of which were ovigerous) were found. Their individual size varied from 37.8 to 74.1 mm for carapace width, with the two smallest specimens (37.8 and 43.7 mm CW) being collected in fresh water (Annex 1). These two individuals correspond to immature sub-adults of more than one-year old (1+ year). Specimen #1 captured in 2004 was kept alive in freshwater tanks supplied with SLR water at the Parc Aquarium du Québec, moulted once one month after capture and died in February 2005. Specimen #3 captured in Lake Saint-Pierre in

September 2005 moulted twice during its one-year captivity at the aquarium.

There have been a total of 26 sightings throughout the entire Great Lakes–SLRE watershed since 1965, 14 of which were reported since 2004 (Figure 2a). While most past captures

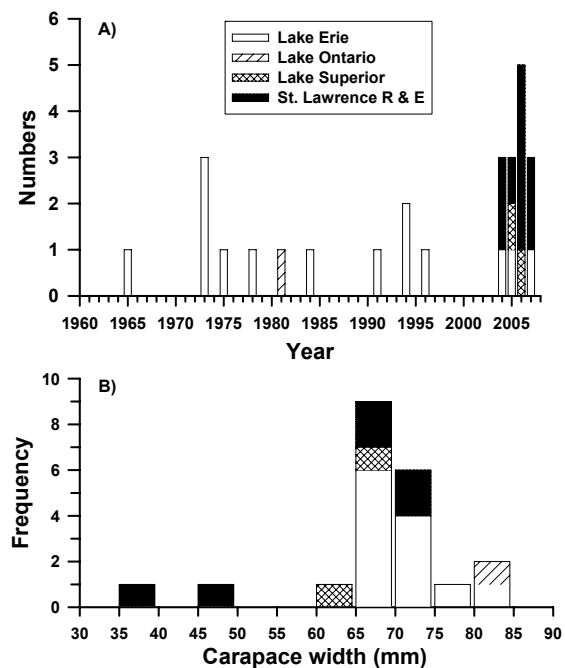


Figure 2. Chronology of sightings (A) and size range (B) of Chinese mitten crabs in the Great Lakes–St. Lawrence River Basin since the opening of the St. Lawrence Seaway in 1959

were made in Lake Erie, recent crab captures were made almost simultaneously in Lake Superior and in the SLRE, corresponding, respectively, to the most upstream and downstream locations within the basin. The two smallest specimens were captured in the river, while the majority of specimens found in the Great Lakes or in the estuary varied between 50 and 82 mm CW. In total, 16 males and 8 females were collected, and the sex ratio did not differ significantly between the lakes and the river (Chi-square test, $\chi^2 = 0.094$, $p = 0.75$).

Genetic Studies

The sequence of the 586 bp fragment of the mitochondrial COI was determined for a total of 12 specimens collected in the Great Lakes and the SLRE (Table 1). Three of the seven

haplotypes described by Hänfling et al. (2002) were found in the Great Lakes–SLR ecosystem: Esin1, Esin4 and Esin5. These three haplotypes are the most common ones observed in Western Europe. Esin1 and Esin5 are also present in China. Esin4 is the only haplotype observed in California (Table 1). Haplotype Esin2 has not been found outside China, while haplotype Esin4, which has not been detected in China, is the sole haplotype found in California and has

also been recovered from several mitten crabs captured in the Great Lakes (Tepolt et al. 2007). Although the number of SLRE specimens analysed to date is still low, haplotype data for SLRE mitten crabs are consistent with a European origin, although the possibility of a Chinese origin cannot be ruled out for all individuals. The hypothesis that SLRE specimens originated from the California population is not supported by the data.

Table 1. Distribution of haplotypes of Chinese mitten crabs found in the St. Lawrence River and Estuary compared to other locations in the world

Country	Location	Mitochondrial (COI) DNA haplotypes							n
		Esin1	Esin2	Esin3	Esin4	Esin5	Esin6	Esin7	
Eastern Canada	St. Lawrence River	1			1	1			3
	St. Lawrence Estuary				1	2			3
	Lake Erie	1			2	1			4
	Lake Superior				2				2
China	Liaohoe	1	3	2					6
	Yangtze	4	3			1		2	10
	Hangzou	3	2			1			6
Europe	Elbe	7			3	5			15
	Lake Laascher See	7			5	3			15
	Weser	8		1	3	2			14
	Thames	7			4	4	1		16
	Tagus	13			2	1			16
Western U.S.	Sacramento				7				7
	San Francisco				16				16

Annual Frequency of Inbound Trips to the SLR

Trip frequency from all mitten crab countries did not vary significantly from the first (mean₁₉₇₈₋₁₉₉₇ = 460.1) to the second (mean₁₉₉₈₋₂₀₀₅ = 464) time period (WMW test, p = 0.461) (Figure 3a). The mean percentage of trips originating from mitten crab countries was 42.1% (s.d. = 4.0) of overall inbound traffic and did not vary significantly (p = 0.353) between the two time periods. No significant difference was noted in the mean frequency of trips from the United States or from countries with no mitten crab populations, either (WMW test, p > 0.05). The percentage of trips originating from the United States averaged 15.9% (s.d. = 3.2). The percentage of trips of unknown origin was very low, accounting for only 3.9% of all traffic, with two slightly higher frequency values in 1978 and 2002, which coin-

cided with the establishment of the ECAREG database as well as the transition from the ECAREG to the INNAV database (Figure 3a).

The frequency of inbound trips originating from eight out of ten mitten crab countries varied significantly (WMW test, p < 0.05) between the two time periods (Figure 3b). The number of voyages out of France, Germany, Portugal and Finland increased by 23%, 62%, 95% and 97%, respectively, while those sailing from Great Britain, Belgium and the Netherlands fell by 46%, 23% and 19%, respectively. Trips from China/South Korea increased the most (310%), averaging eight per year since 1998. Asian countries remained minor players, however, accounting for only 1.8% of the overall trip frequency of all mitten crab countries (Figure 3b). Inbound trips from Great Britain, Germany and Portugal—which all have abundant crab populations—made up 44%.

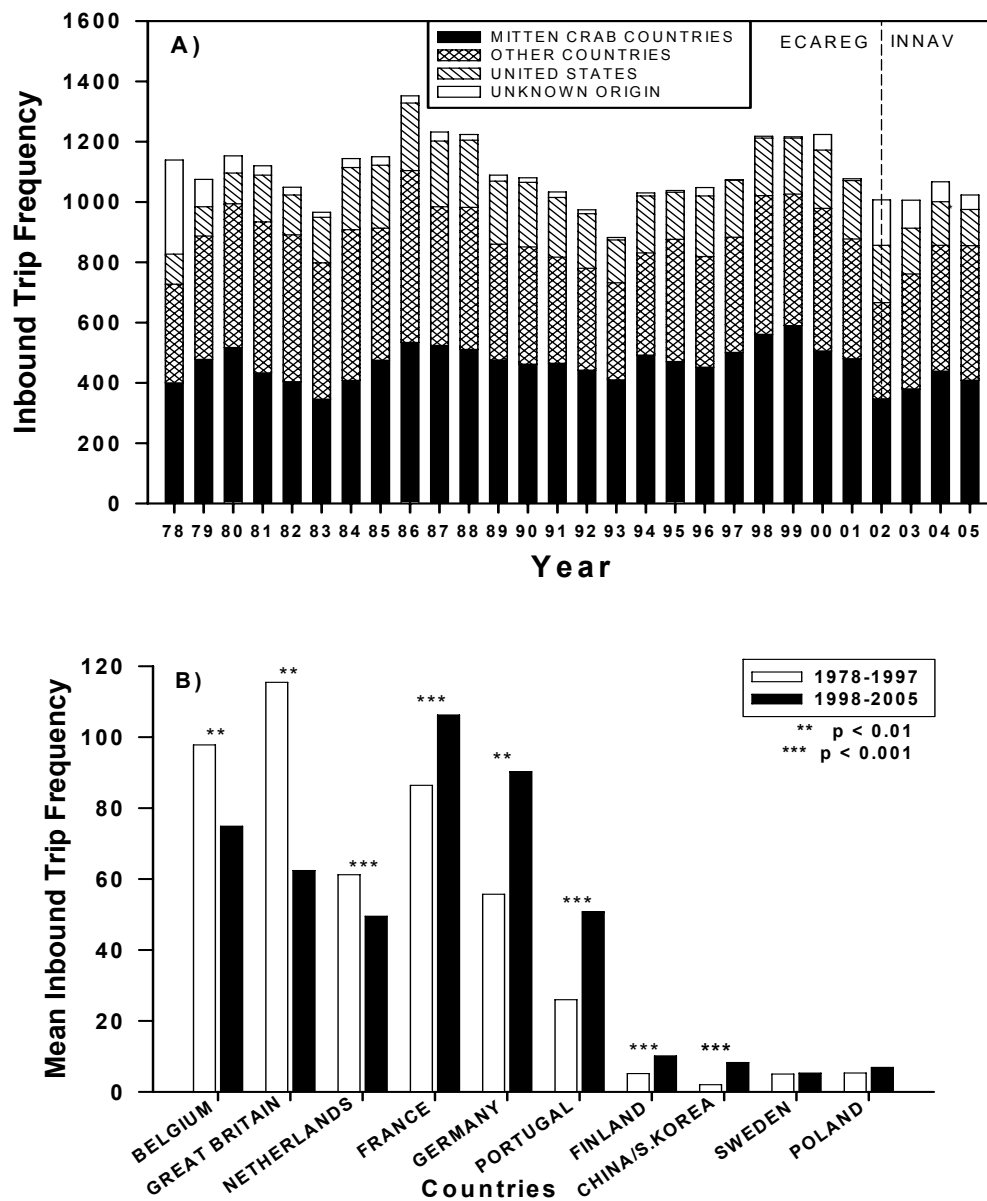


Figure 3. (A) Annual frequency of inbound trips to the St. Lawrence River by vessels from (1) countries with current mitten crab populations, (2) countries with no mitten crab population, (3) the United States and (4) unknown origin as compiled from ECAREG and INNAV databases. (B) Differences in mean inbound ship frequency by country/region of origin over the two time periods

Discussion

The report of nine Chinese mitten crab specimens in the SLRE during the years 2004 to 2007, and of five more in the Great Lakes over the same time period, represents an

unprecedented rate of captures of this invader for this area (Figure 2). The simultaneous discovery of crabs in Lake Superior and in the SLRE, which are more than 1900 km apart, can be interpreted as strong evidence of a new and large-scale wave of introduction across the entire

watershed. Reports of mitten crabs in the SLRE, almost 40 years after the species was first observed in the Great Lakes, may be surprising. However, de Lafontaine and Costan (2002) have previously noted that 83% of nonindigenous species common to the two regions were first reported in the Great Lakes, and that the average delay (or transfer time) in invertebrate species reporting between the lakes and the river was 41 years. Previous records of mitten crabs from Lake Erie were of little concern because these specimens could not get access to seawater and were essentially doomed to die. The establishment of self-maintaining populations within the Great Lakes was therefore virtually impossible and would not have contributed specimens to the SLRE. Chinese mitten crabs were also recently reported for the first time along the Eastern Seaboard of the United States (Ruiz et al. 2006). A total of 13 crab specimens were observed at various locations in Chesapeake Bay, Delaware Bay and the Hudson River estuary between May 2005 and January 2008 (USGS-NAS 2008). This is a total of 27 crab sightings in the eastern waters of Canada and the United States over the last four years and provides strong evidence of an important and large-scale wave of introduction of the species to North America in recent years. Moreover, it is worth noting that, at the international level, Chinese mitten crabs were reported for the first time in the Mediterranean Sea in May 2005 (Venice Lagoon, Mizzan 2005), Waterford Harbour, Ireland in January 2006 (Minchin 2006), Persian Gulf in June 2005 (Clark 2006), Caspian Sea in 2002 (Robbins et al. 2006) and the Volga River, Russia (Shakirova et al. 2007). These recent reports across such a large global scale point strongly to shipping as the principal vector of the introduction and spread of the species, as previously suggested by several authors (Carlton 1985; Clark 2006; Cohen and Carlton 1997; Herborg et al. 2003; 2005; Tepolt et al. 2007).

The results of genetic analyses indicate that crab specimens found in the SLRE exhibit relatively high levels of genetic diversity, with three out of seven haplotypes detected. The haplotype distribution observed in the SLRE more closely resembles that observed in Europe than in China or California (Table 1). In fact, the most frequent haplotype observed in the SLRE (Esin4) is not reported in China, while haplotypes Esin1 and Esin5 are not present in California. However, the three haplotypes

observed in the SLRE are all present in Europe, where they are the ones most frequently observed. Together, the results of genetic analyses appear to indicate that the source of the recent introductions of Chinese mitten crabs to the SLRE system are likely the result of the uptake and transfer of specimens from European countries, as has also been suggested for the Great Lakes (Tepolt et al. 2007).

The upsurge in the frequency of sightings suggested a change in one or more factors responsible for the uptake, transport, survival and release of Chinese mitten crabs into Canadian waters. Our analysis showed that 42% of foreign vessels calling at ports in the SLR came from countries with established and abundant mitten crab populations, the vast majority (> 98%) being European ports. This implies that nearly half of the transoceanic ships entering the SLR may pose a risk of introducing mitten crabs and this percentage has not varied significantly in recent years (Figure 3a). The traffic from individual countries did change significantly, however (Figure 3b), so that, all else being equal, the risk of invasion posed by ships originating in Germany has increased by 20% and it has nearly doubled for those sailing from France and Portugal since 1998. Traffic from Great Britain, Belgium and the Netherlands decreased correspondingly. The four-fold increase in traffic from China and South Korea in recent years can be largely explained by the explosion in commercial trade between North America and China (Normille 2004). Although the risk of invasion of the SLR and the Great Lakes posed by these vessels can be considered minor relative to ships from European countries, if this increasing trend in Asian traffic is maintained, the estimated risk from these sources will be higher in the future. Furthermore, 16% of the overall inbound traffic originated from the United States, which essentially consists of ships from the Eastern Seaboard (Carver and Mallet 2004). While not considered a potential source of crab invasion in the past, recent sightings of mitten crabs in eastern U.S. waters will now undoubtedly increase the risk of species transfer between the two regions.

This analysis does not account for the effect of ships' ballast-water exchange (BWE) regulations implemented in Canada and the United States in the early 1990s (Wiley and Claudi 2002). Presumably, the regulations could have contributed to reducing the estimated risk of invasion in recent years. While the open-

ocean BWE procedure can be effective in reducing the risk of invasion of freshwater invertebrates (Gray et al. 2007), its efficacy against estuarine or brackish water organisms is expected to be lower (Ricciardi 2006). The results of a ballast-exchange model developed by Wonham et al. (2005) predicted very low mortality rates for Chinese mitten crab larval stages in exchanged waters, suggesting that BWE would not be very effective against this catadromous species. Under this scenario and given the relatively minor changes in inbound traffic to the SLR, the estimated risk of crab invasion based on shipping traffic has probably not decreased much in recent years. On the contrary, the recurrence of crabs would be indicative of an increased risk of invasion and points to the need for ballast water management and enforced treatment to prevent further introductions (Hunt et al. 2005; Matheickal and Raaymakers 2004). Furthermore, open water exchange or freshwater flushing may not be effective to control bioinvasions (Hülsmann and Galil 2001) and treatment of ballast water might be more appropriate to reduce the risk of invasion. Data on ballast water discharges were not available and were not considered in our analysis which thus included NoBOB ships as well. If crabs are transported in NoBOB ships, they could be released if ships take up and discharge freshwater in the SLR or the Great Lakes.

Changes in the frequency of ship traffic from mitten crab countries are therefore not sufficient to explain the recent wave of introductions. Rather than looking at a recipient-based explanation (e.g. in inbound ship frequencies), changes in donor-based factors such as mitten crab abundance in source populations are worth investigating. In the context of the propagule theory, the probability of loading organisms into ships' ballast tanks will be a function of the species' abundance at the source port and will necessarily affect the number of individuals released at destination (MacIsaac et al. 2002). Mitten crab populations are typically characterized by high variability in densities over time (Gollasch 1999; Fladung 2000). Since the late 1990s, population abundance has increased by a factor of 10 and more in many European countries, including Germany (Fladung 2000) and the Baltic Sea basin (Ojaveer et al. 2007), Portugal (Cabral and Costa 1999) and Great Britain (Gilbey et al. 2007; Herborg et al. 2005; Rainbow et al. 2003). Given the level of

variation in propagule abundance at these most probable donor areas (based on analysis of shipping traffic and genetic evidence), the risk of crab invasion into the St. Lawrence system has probably increased despite the constant inbound ship traffic. We therefore suggest that the recent wave of introduction of mitten crabs to Eastern North America was related more to changes in the abundance of European populations than to changes in shipping vector activity (Ricciardi 2006).

The discovery of crabs in the SLRE as well as along coastal U.S. waters raises a major concern of the elevated risk of species establishment, due to the access of seawater. While a single introduction does not make a successful invasion, repeated introductions definitely increase the probability of success. The small size range (38–44 mm CW) of the specimens captured in the river over two successive years (Annex 1, Figure 2) suggests that these immature crabs belonged to two distinct cohorts, given that juvenile growth does not vary between male and female (Rudnick et al. 2000). The larger (65–74 mm CW) crabs caught in the estuary would appear to correspond to mature individuals (Herborg et al. 2003) but were not egg-carrying females. The presence of smaller crabs in the river is consistent with other observations, which typically found younger and smaller juveniles at the downstream end of river systems (Gilbey et al. 2007; Herborg et al. 2003). Juvenile crabs < 35 mm CW in freshwater environments are often found inhabiting burrows and are less easily captured in fixed fishing gears (Rudnick et al. 2000).

Based on the results of niche models of established mitten crab populations in China and Europe, and taking into account the environmental requirements for crab reproduction and survival (mainly physico-chemical water properties) and the propagule pressure linked to ships' ballast-water discharge, Herborg et al. (2007) were able to identify the SLR as environmentally suitable for the establishment of Chinese mitten crab populations. Even after considering a restricted dispersal distance for upstream migration (354 km), the SLR up to Montreal remained at high risk for establishment. Summer water temperatures in the SLR and Estuary vary greatly among locations. In the freshwater section, it can reach 30°C in the nearshore zone (de Lafontaine et al. 2006). Along the south shore of the lower estuary (near Rimouski), the maximum water temperature in

mid-July rarely reaches 14°C and exceeds 11°C for no more than one month (de Lafontaine et al. 1984; Sinclair 1978). While the risk model developed by Herborg et al. (2007) can predict the establishment of the mitten crab in the SLRE system, the survival and the development of crab larvae in the estuary and along the Gaspé coast remains uncertain, due to the cold water temperatures prevailing year-round there. The possible spread of the species from the SLRE toward the Gulf of St. Lawrence and the Eastern Canadian Maritime provinces is questionable.

Overall, it is too premature to conclude that the species has established itself in the St. Lawrence ecosystem. During the very early phase of establishment of the species in northern Europe, crab populations were usually characterized by low numbers and small spatial extent prior to the rapid exponential phase of invasion (Herborg et al. 2003). This establishment phase lasted 15 years in Germany (Herborg et al. 2003) and 22 years in the United Kingdom (Herborg et al. 2005). Assuming a similar pattern of colonization and spread in the St. Lawrence system, it seems imperative that a long-term monitoring program for mitten crab sightings be set up and operated for a sufficient period of time (i.e. 15 years) to efficiently track the invasion of the Chinese mitten crab in the SLR and its numerous tributaries. The development of a mitigation/eradication plan should be also prioritized and applied whenever the establishment of the crab is confirmed.

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Eriocheir sinensis in the St. Lawrence River and Estuary

Annex 1

Crab sightings in the St. Lawrence River and Estuary and the Great Lakes from 2004 to 2007

Specimen ID	Date of capture	Location of capture	Coordinates, Lat.N/ Long.W	Method of capture	Sex	Carapace width (mm)	Wet weight (g)	Genetic haplotype
1	Sept. 2, 2004	Lévis, Quebec	46°46.3' 71°13.2'	Eel fishing weir	Female	43.7	39.6	Esin5
2	Fall 2004	Sainte-Angèle-de-Laval, Quebec	46°20.3' 72°30.3'	Fyke net	–	–	–	
3	Sept. 2, 2005	South shore Lake Saint-Pierre, near Saint-François River, mouth Quebec	46°08.9' 72°52.7'	Fyke net 1.5-2 m deep	Male	37.8	25.5	Esin4
4	July 11, 2006	La Pocatière, St. Lawrence Estuary, Quebec	47°22.08' 70°09.92'	Gill net (sturgeon)	Male	–	–	
5	July 11, 2006	La Pocatière, St. Lawrence Estuary, Quebec	47°22.08' 70°09.92'	Gill net (sturgeon)	Male	–	–	
6	Sept. 30, 2006	La Pocatière, St. Lawrence Estuary, Quebec	47°24.22' 70°03.03'	Eel fishing weir	Female	65		Esin5
7	Oct. 9, 2006	South shore Lake Saint-Pierre, near Nicolet River mouth, Quebec	46°13.1' 72°40.6'	Fyke net	Male	72.2		Esin1
8	July 1, 2007	Kamouraska, St. Lawrence Estuary, Quebec	47°34.28' 69°52.03'	Eel fishing weir	Male	65		Esin4
9	Oct. 3, 2007	Rivière-Ouelle, St. Lawrence Estuary, Quebec	47°28.21' 70°01.94'	Eel fishing weir	Female	74.1	171.6	Esin5
Great Lakes								
10	March 18, 2004	Lake Erie, near Wheatley, Ontario	41°55.0' 82°19.8'	Fishing net	Male	70	–	
11	March 7, 2005	Lake Erie, Port Alma, Ontario	42°05' 82°14'	Fishing net	Female	74	–	
12	Dec. 8, 2005	Lake Superior, Thunder Bay Harbour, Mission Island, Ontario	48°24.07' 89°16.05'	Power generating station	Male	65	110	Esin4
13	Oct. 21, 2006	Lake Superior, Thunder Bay Harbour, Mission Island, Ontario	48°24.07' 89°16.05'	Power generating station	Female	62	83	Esin4
14	May 11, 2007	Lake Erie, Lorain Harbour, Ohio	41°28' 82°11'	Baited fishing rod	Male	50	–	