The Impacts of the Chinese Mitten Crab on the San Francisco Bay

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# Table of Contents

Abstract ................................................................................................................................. 3

Background .......................................................................................................................... 4

Chinese Mitten Crab Biology ............................................................................................... 4

Invasion History .................................................................................................................... 5

Impacts .................................................................................................................................. 7

Ecological Impacts ................................................................................................................ 7

Infectious Agents .................................................................................................................. 8

Economic Impacts .................................................................................................................. 9

Management ........................................................................................................................ 11

Consumption as Control ....................................................................................................... 12

Current Legislation ............................................................................................................... 13

A Global Effort ...................................................................................................................... 13

Sources Cited ......................................................................................................................... 15
Abstract

The San Francisco Bay is a major port for international trade, which produces significant economic benefit, although it also introduces invasive species. With over 230 invasive species, the San Francisco Bay is one of the most invaded estuaries in the world (NOAA, 2008). The Chinese mitten crab (*Eriocheir sinensis*) is one of the species introduced and spreading throughout the San Francisco Bay and up into its tributaries. This species is native to the pacific coasts of China and Korea and can now be found throughout Northern Europe, Western Asia, and North America (CDFW, 1998). The spread of the Chinese mitten crab has caused significant ecologic and economic impacts. Currently there is no effective management plan for eradicating this species from its non-native habitats.
Background

The San Francisco Bay is one of the largest hubs for the national and international shipping industries (Rudnick et al. 2000). This large volume of traffic produces significant economic benefit, although it also opens the area up to the introduction of invasive species (Rudnick et al. 2000). With over 230 invasive species, the San Francisco Bay is one of the most invaded estuaries in the world (NOAA, 2008). One species that has established itself throughout the Bay-Delta region is the Chinese Mitten Crab (Eriocheir sinensis).

As defined by Executive Order 13112, invasive species are “an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health” (ISAC 2006). This definition is further clarified in the Executive Summary of the National Invasive Species Management Plan (NISMP) as “a species that is non-native to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health” (ISAC 2006). Invasive species are a kind of biological pollution, but unlike many other types of pollution, they do not dissipate over time. Once a population of invasive species is established, their numbers tend to increase rapidly, making removal from the area difficult.

Chinese Mitten Crab Biology

The Chinese mitten crab is a large, decapod crustacean that got its name from the light brown hairs, or setae, found on their claws that give it the appearance of wearing furry mittens (Veilleux and de Lafontaine 2007). Chinese mitten crabs are catadromous, as they are born in saltwater and migrate to fresh water to grow and mature until they
migrate back downstream to spawn and eventually die (Veilleux and de Lafontaine 2007, Dittel and Epifanio 2009). During their reproductive season, female crabs can produce between 100,000 and 1 million eggs (Dittel and Epifanio 2009).

Chinese mitten crabs can survive and even thrive in a wide variety of habitat conditions. While the range of the Chinese mitten crab is mostly restricted to the temperate zone, this species is very tolerant of temperature and has been found in waters ranging from 4 °C and 32 °C (Jakubowska and Normant 2011). These crabs can even survive 10 days outside of the water in drier conditions if they remain in their burrows or 38 days in wet meadows (Nepszy and Leach 1973, Veilleux and de Lafontaine 2007). Mitten crabs can also tolerate living in highly disturbed areas and even take advantage of the decrease in predators that prey on this species in polluted waters (Veilleux and de Lafontaine 2007).

*Invasion History*

The Chinese mitten crab is native to the coastal rivers and estuaries of the Yellow Sea in China and Korea and has dispersed globally within the past century (Veilleux and de Lafontaine 2007). The mitten crab is first recorded to have invaded the Weser River in Germany in 1912, and then quickly migrated throughout the coast and waterways of Northern Europe (Nepszy and Leach 1973, Dittel and Epifanio 2009). It was not until the winter of 1992 that the Chinese mitten crab was found in the southern portion of the San Francisco Bay and quickly established a breeding population (Dittel and Epifanio 2009). The crabs have since spread throughout the rest of the bay as well as the Sacramento-San
Joaquin delta and many of the tributaries that feed into the estuary system (Rudnick et al. 2000, Dittel and Epifanio 2009).

The worldwide distribution and spread of the Chinese mitten crab is primarily attributed to human activity. There are numerous routes for this species to invade new locations. The most likely method of introduction is through the transport and discharge of ballast water from ships (Veilleux and de Lafontaine 2007). Although the larval stages of the Chinese mitten crab have never been identified in ballast water inspections, crab larvae have been identified but not identified to the species, in many US ports (Dittel and Epifanio 2009). These findings confirm that despite the harsh conditions found in ballast water tanks, crab larvae and likely mitten crab larvae can survive during transport over long international voyages (Dittel and Epifanio 2009). Another likely source of mitten crabs is the intentional introduction by individuals to start a population to use as a food source or escaped crabs that were smuggled in for live food markets (Veilleux and de Lafontaine 2007). Other potential sources of dispersal include larvae carried by ocean currents, crabs carried on floating material or slow-moving vessels, the transport of crabs on the settlement and growth of marine plants and animals on submerged parts of ship hulls (ship fouling), crabs transported in cargo or fisheries products, the transport of larvae in water with shipments of live fish, or the escape or release of crabs from aquariums or research facilities (Veilleux and de Lafontaine 2007).

Established Chinese mitten crab populations will often have individuals migrate to other nearby aquatic systems and invade these areas (Veilleux and de Lafontaine 2007). Chinese mitten crab larvae can drift further away from where they originally hatched along
coastal areas and settle into new habitats (Veilleux and de Lafontaine 2007). Juvenile crabs are capable of long upstream migration, and in their native range, some crabs have been found as far as 1,400 km upstream from the sea (Nepszy and Leach 1973, Veilleux and de Lafontaine 2007). These natural dispersal processes can lead to mitten crabs colonizing new areas and are likely responsible for extensive spread of the Chinese mitten crab in northern Europe (Veilleux and de Lafontaine 2007).

**Impacts**

*Ecologic Impacts*

The presence and proliferation of the Chinese mitten crab in new habitats can potentially alter the food web of the ecosystem. Crabs impact native species populations through competition for resources such as food and habitat or by predation (Veilleux and de Lafontaine 2007). The Chinese mitten crab is an opportunistic omnivore with a diet limited only by the life cycle stage the crab is in (Veilleux and de Lafontaine 2007). Mitten crab larvae feed on phytoplankton and zooplankton, while juvenile crabs feed mostly of aquatic plants such as filamentous algae, Potomogeton, Elodea, and Lemna (Veilleux and de Lafontaine 2007). As they age, mitten crabs shift to a more carnivorous diet as invertebrate prey, algae, and detritus make up most of the crab’s diet (Veilleux and de Lafontaine 2007, Dittel and Epifanio 2009). Increasing Chinese mitten crab populations can have a detrimental effect on Crayfish species, such as the red swamp crayfish (*Procambarus clarkii*) and the signal crayfish (*Pacifastacus leniusculus*), because of the crabs aggressive behavior, shared diet, and freshwater habitat (Veilleux and de Lafontaine 2007, Dittel and Epifanio 2009). Chinese mitten crabs have been known to prey on freshwater shrimp,
which raises concerns that they will feed on California Freshwater Shrimp (*Syncaris pacifica*), an endangered species. Some studies in the San Francisco Bay also indicate that the crabs will consume centrarchids and salmonid eggs as well as those from other nest-building fish, which in addition to current pressures on an already threatened population, could lead to further declines in these populations and hurt the salmon fishery (Dittel and Epifanio 2009).

*Infectious Agents*

Chinese mitten crabs are host to a number of parasites and pathogens within its native ecosystem including the microsporidian parasite, *Endoreticulatus eriocheir* (Stentiford et al. 2011) and the oriental lung fluke (*Paragonimus westermani*) (Clark et al. 2009). There is reasonable concern that these infectious agents will be introduced to new areas and passed to other species in the environment, including humans. The oriental lung fluke requires three different host species to complete its lifecycle: snails from the family Thiaridae, crabs of the genus *Eriocheir*, and mammals (CMCCC 2002, Veilleux and de Lafontaine 2007). Humans are infected by the fluke by eating raw or insufficiently cooked crab meat or spread through the crab’s bodily fluids contaminating other foods by the use of non sterile cooking practices (CMCCC 2002, Veilleux and de Lafontaine 2007). The symptoms of infection by the oriental lung fluke are often similar to that of the flu or tuberculosis (CMCCC 2002, Veilleux and de Lafontaine 2007). In the San Francisco Bay, over 13,000 mitten crabs have been tested for the fluke, but so far none have been found (Veilleux and de Lafontaine 2007). Currently no Thiaridae species reside in the bay, as they prefer warmer, circumtropical waters, but there are other species of snail that could
potentially host the fluke (CMCCC 2002, Veilleux and de Lafontaine 2007). Although there is currently very little risk of contracting the fluke from the San Francisco Bay population of mitten crabs, there is still a risk of future parasite infection and, therefore, we should continue to monitor for it. Some Chinese mitten crabs have also been found to contain the human pathogenic bacterium Vibrio parahaemolyticus, which is frequently associated with seafood-borne gastroenteritis and, therefore, this species should not be eaten unless properly cooked (Wagley et al. 2009).

Chinese mitten crabs sometimes reside in areas such as agricultural ditches containing higher concentrations of contaminants including pesticides and heavy metals (Dittel and Epifanio 2009, Veilleux and de Lafontaine 2007). This increases the risk of these contaminants becoming biomagnified in the food chain. If the concentration of these contaminants get too high they can harm the organisms that prey upon the crabs. So far, the crabs that have been tested for contaminants including arsenic, selenium, DDE and other organochlorine pesticides, and heavy metals have had levels typically below detection levels and always below the FDA threshold values for unsafe human consumption (Dittel and Epifanio 2009, Veilleux and de Lafontaine 2007).

**Economic Impacts**

The most noteworthy and damaging behavior of the Chinese mitten crab is burrowing along the banks in channels and creeks. Burrows are usually created in softer banks and levees composed mainly of sand and silt, on a downward-sloping angle so that it retains water during low tide (Dittel and Epifanio 2009, Veilleux and de Lafontaine 2007). These tunnels are a refuge from predators and protection from dry conditions during low
tide (Veilleux and de Lafontaine 2007). Depending on the abundance of crabs in the area, the burrows can be as simple as a single tunnel or a complex network of interconnected tunnels (Dittel and Epifanio 2009). This complexity suggests that these burrows are possibly maintained and reused by successive generations of crabs (Veilleux and de Lafontaine 2007). The number of mitten crabs found in the San Francisco bay has been on a continuous increase since their introduction, and as a consequence, so has the abundance of their burrows (Rudnick et al. 2000). The density of these burrows has already exceeded damage causing levels, especially along the intertidal banks and levees (Rudnick et al. 2000). Areas with steeper banks and along intertidal shorelines experience significant and accelerated bank erosion because of the weakening of the banks by the crab burrows and destruction of bank vegetation in addition to the tidal fluctuations and wave action (Dittel and Epifanio 2009, Veilleux and de Lafontaine 2007). Bank erosion also means that there is sediment loss to the adjacent open water and an increase in the water turbidity, which leads to a decrease in the water quality if runoff is significant enough (Veilleux and de Lafontaine 2007).

Other economic impacts of the spread of the Chinese mitten crab are primarily due to their massive spawning season migration, which negatively affects both the local fishery and agriculture industry (Dittel and Epifanio 2009). During their migration, mitten crabs often enter traps and nets intended for other species and consume the bait and get trapped instead (Dittel and Epifanio 2009, Veilleux and de Lafontaine 2007). This leads to a reduced amount of the target species caught and what are caught risk damage from the mitten crabs, and the time it takes to remove both from the net increases, thus further reducing the overall daily catch of the targeted species (Dittel and Epifanio 2009, Veilleux and de
The downstream migration of adult mitten crabs lead to the clogging of screens, pipes, and valves integral in diverting water from the Sacramento–San Joaquin Delta to the rest of California’s Central Valley (Dittel and Epifanio 2009, Veilleux and de Lafontaine 2007). Systems that divert water also prevent fish from entering these diversion canals by incorporating fish collection facilities (Dittel and Epifanio 2009); however, mitten crabs clog these facilities along with the fish they are supposed to collect and trap them in the salvage tanks (Dittel and Epifanio 2009). In the fall of 1998, an estimated 50,000 migrating mitten crabs were collected daily at the Tracy Fish Collection Facility near Stockton, California (Dittel and Epifanio 2009, Veilleux and de Lafontaine 2007).

**Management**

Like many invasive species Chinese mitten crabs are incredibly difficult to get rid of once a population is established. There have been many attempts to curtail and eradicate the invasive crabs; however, all efforts have shown limited efficacy and no effective management program has yet been developed (Gollasch 2006). Lifting catch limits and allowing people to trap and catch as many as they can is not enough to control a self-sustaining population (Gollasch 2006). Erecting barriers to block and prevent migration up river has also been unsuccessful (Gollasch 2006). During the 1930s and 1940s, Germany installed electrical screens on the river bottom that would stop or kill crabs using electrical pulses, but they were ineffective (Gollasch 2006). For a more successful effort to control the mitten crab population there needs to be more accessible informative material on this species and the hazards they present (Gollasch, 2006). There is still stages in the life cycle of these crabs that are not fully understood, particularly the larval stages (Dittel and
Most crab species spread during larval stages, so a better understanding of their invasive biology could lead to better prevention of the crab dispersal (Dittel and Epifanio 2009). The most effective strategy would be to prevent the crabs from being established by targeting the source of that introduction; however, the options for treating ballast water and hull fouling on the majority of international vessels remain only marginally effective or prohibitively expensive (Bax et al. 2003).

Consumption as Control

One controversial but potentially cost effective method of controlling the population growth of the Chinese mitten crab is to market and consume them. The brown meat or gonads of a sexually mature crab is considered a delicacy in their native home of China and the muscle tissue is consumed as well (Clark et al. 2009). There is already a $1.25 billion per year aquaculture industry in the Yangtze Basin established to satisfy the demand from local and international markets for live mitten crabs (Dittel and Epifanio 2009). These crabs are also used for bait and in the production of agricultural fertilizer, fish meal, and cosmetic products (Dittel and Epifanio 2009).

There is concern that the crabs, especially the brown meat, contain unsafe levels of contaminants such as dioxins (polychlorinated dioxins and polychlorinated dibenzofurans), PCBs (polychlorinated biphenyls), organochlorines, arsenic, and heavy metals if the waters they come from are highly polluted (Clark et al. 2009, Hoogenboom et al. 2015). Some of these compounds can also alter flavor and quality of the crab meat (Veilleux and de Lafontaine 2007). Although, so far, not enough of these toxins have been found in the crabs from Europe or North America to exceed the suggested European Tolerable Daily Intakes
(TDI) or the FDA guidelines (Dittel and Epifanio 2009). However, the average meal sized portion of this crab is typically 2-3 per person and frequent consumption could still put the consumer at risk (Hoogenboom et al. 2015). The most sensitive groups, children and pregnant women, should limit their intake (Clark et al. 2009).

Current Legislation

Currently, there are both federal and state laws to curtail the introduction and spread of invasive species. Title 14, Section 671 of the California Code of Regulations states that "It is illegal to import, transport, or possess live Chinese mitten crabs" (CDFW). Since there is a potential risk of escaped or released crabs to colonize new locations, any caught and retained mitten crab must be dead (CDFW). To fish for Chinese mitten crabs in California,

“You must possess a valid California Sport Fishing License to fish for Mitten Crabs. Upstream of the Carquinez Bridge, you can only fish by hook and line and there are no bag or size limits. Downstream of the Carquinez bridge, you can fish with traps and hook and line, but the limit is 35 per day.” (CDFW)

Also, under the 1989 federal Lacey Act, it is illegal to import mitten crabs into the United States (Veilleux and de Lafontaine 2007).

A Global Effort

To successfully manage the spread and threat of Chinese mitten crab, as well as other marine invasive species, there needs to be a greater global effort and cooperation (Bax et al. 2003). Action at the regional and national level can temporarily reduce the population of the invasives, however, without a global effort; there is always the risk of re-
introductions especially as more invasive species become established in neighboring regions or in the ports of trading partners (Bax et al. 2003).
Sources Cited


