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Life History, Distribution, and Impacts of the Chinese mitten crab, *Eriocheir sinensis*.

Tanya C. Veldhuizen, California Department of Water Resources, Environmental Services Office 3251 S Street, Sacramento, CA 95816 USA
Email: tanyav@water.ca.gov

Introduction

The Chinese mitten crab, *Eriocheir sinensis* (H. Milne-Edwards 1854), is native to coastal rivers and estuaries of Korea and China along the Yellow Sea (Panning, 1939; Li *et al.*, 1993), where it is commonly called the river crab or Shanghai crab (Tan *et al.*, 1984). The mitten crab was accidentally introduced to Germany in the early 1900s, proliferated and spread to many northern European rivers and estuaries, where it impacted local fisheries and levee integrity (Panning, 1939). The crab was introduced to the San Francisco Estuary in the late 1980s or early 1990s. The most probable mechanisms of introduction are deliberate release to establish a fishery and accidental release via ballast water (Cohen and Carlton, 1997). It is presently well established throughout the San Francisco Estuary and the lower reaches of the watershed. The establishment of this species in North America is of concern because of its negative impacts in Europe and California.

Biology

The Chinese mitten crab, like other species in the genus *Eriocheir*, is characterized by brown setae densely covering the front claws, producing the appearance of "hairy" claws (Figure 1). Very small juveniles (< 25 mm carapace width) have no or minimal setae on their claws. Overall, the crab is brownish-orange to greenish-brown in color and has white tips on the chelae. There is a small notch between the eyes, two small spines on either side of the notch, and four lateral carapace spines. The carapace width is slightly greater than length, and the legs are nearly twice as long as the carapace width. The carapace width of adult crabs ranges from 34 mm to approximately 100 mm. Crabs mature in 3 to 5 years in Europe (Panning, 1939), 1 to 2 years in China (Cohen and Carlton, 1995), and an estimated 1 to 3 years in California, depending upon environmental conditions.

The mitten crab is catadromous; adults reproduce in brackish or salt water areas of estuaries and offspring

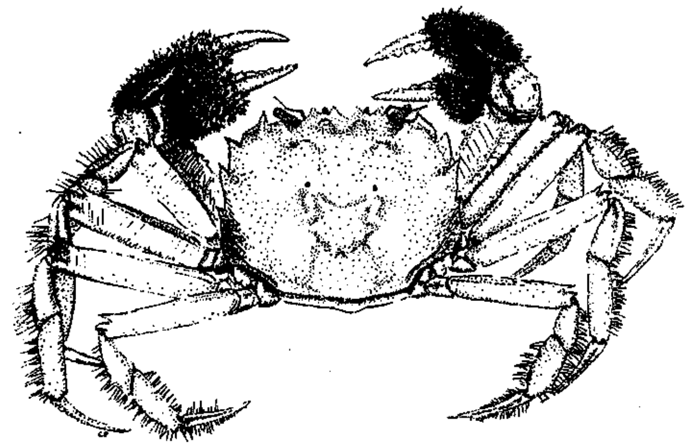

*Figure 1. Ink drawing of the Chinese Mitten Crab (*Eriochier sinensis *H. Milne-Edwards 1854). Drawing by Chris Peregrin*

migrate upstream to rear in fresh or brackish water areas. Spawning occurs in lower estuaries where the average salinity is 20‰ (Anger, 1991). Females produce 100,000 to 1 million eggs per brood, depending upon size (Panning, 1939; Cohen and Carlton, 1995; Zhao *pers. comm.*, 1999). Females probably store sperm and have multiple broods (Culver *pers. comm.*, 2001). The fertilized eggs adhere to pleopods under the abdominal flap until hatching. The larvae hatch from winter through early summer (Anger, 1991; Culver *pers. comm.*, 2001).

The larvae are planktonic for approximately one to two months and pass through a series of development stages: a prezoea stage (a brief, non-feeding stage), five zoeal stages, and a megalopa stage (Anger, 1991; Kim and Hwang, 1995). Optimal water temperatures for all larval stages range from 15 to 18 °C (Anger, 1991). Each larval stage has different salinity requirements. The prezoea and zoea I stages occur in lower estuaries at salinities between 10‰ to 25‰ (Anger, 1991). Larvae in the zoea I stage are very euryhaline, tolerating a wide range of salinities, especially compared to the later zoeal stages (Anger, 1991). This characteristic allows them to survive the variable salinity conditions of lower estuaries (Anger, 1991). Early zoeal stages mainly occur at the surface of the water column and are transported by surface currents toward the mouth of or out of the estuary. The subsequent zoeal stages tend to occur in nearshore marine waters or in lower estuaries and have a reduced tolerance for low salinities. Zoeal stages IV and V are stenohaline with maximum survival at salinities of

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Editor, ***Aquatic Invaders***
National Aquatic Nuisance Species Clearinghouse
New York Sea
Grant Morgan II
SUNY College at Brockport
Brockport, NY, 14420-2978

Telephone:	716/395-2516
	800/285-2285
Fax:	716/395-2466
E-mail:	zmussel@cornell.edu
Web site at:	http://www.aquaticinvaders.org

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FROM THE EDITOR

Welcome to the new and improved look of Aquatic Invaders! As you have doubtless noticed, this is an ongoing process. We have been adding features, such as "Web Watch" in the last several issues, and hope to add more items of interest in the future.

We also proudly announce our new and greatly enhanced website. The URL was changed to http://www.aquaticinvaders.org or www.cce.cornell.edu/aquaticinvaders/ as of 4 September 2001. Along with the new address came several notable improvements, such as: expanded search capabilities - utilizing an extensive keyword outline or plain English in any of the database fields; a shopping cart to order interlibrary loan copies of papers; an expanded links page, featuring site descriptions; a new announcements page; and improved zebra and quagga mussel distribution map pages. Please visit our website, if you haven't already.

As always, feedback and suggestions are welcome.

Charles R. O'Neill, Managing Editor
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32‰ (Anger, 1991). The megalopae occur lower in the water column and have an increased tolerance to low salinities. Carried by onshore-directed near-bottom currents toward the coast and inner estuaries, the megalopae eventually settle to the floor and develop into juvenile crabs (Anger, 1991). Metamorphosis from megalopa to juvenile crab can occur in salinities as low as 5‰, although 15‰ to 25‰ is optimal (Peters and Panning, 1933; Panning, 1939; Anger, 1991).

After settlement, from late winter through summer, juvenile crabs migrate to upstream rearing areas. The crabs travel in the main river channels and then enter smaller channels with slow moving water. In China, juveniles migrate upstream from February to early May with the onset of migration following an increase in temperature (Tan *et al.*, 1984; Fu *pers. comm.*, 1999). In Europe, they begin migrating in March and continue through July (Peters, 1938). Increasing water temperatures, high population densities, and food competition were hypothesized as migratory cues in Germany (Panning, 1939; Ingle, 1986). In California, preliminary data indicates juvenile crabs migrate upstream year-round, and the migratory cues are not fully understood.

Juvenile mitten crabs rear in warm brackish and fresh water areas. Juvenile crabs prefer temperatures ranging from 20 °C to 30 °C, although lower temperatures are also tolerated (Zhao *pers. comm.*, 1999). Optimal growth rates occur at 24 °C to 28 °C (Zhao *pers. comm.*, 1999). Juveniles utilize a variety of habitats including shallow water with or without aquatic vegetation, deep river channels, shallow creeks and sloughs, and banks (Panning, 1939; Rudnick *et al.*, 2000; Veldhuizen and Messer, 2001). In subtidal freshwater areas of the Sacramento-San Joaquin Delta, juvenile crabs were

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collected more frequently in shallow areas with dense submerged vegetation (especially *Egeria densa*) than in shallow unvegetated areas, shallow rocky areas, or channels (Veldhuizen and Messer, 2001; Grimaldo, unpublished data).

In tidal areas, some crabs construct burrows in the intertidal zone of banks. They retreat into the burrows during low tide (Panning, 1939; Kaestner, 1970; Ingle, 1986; Veldhuizen and Hieb, 1998a). Mitten crab burrows are typically found in vertical river banks but have also been found in firm marsh bottoms in areas that are dewatered during low tide and upstream of tidal areas (Panning, 1939; Halat, 1996; Veldhuizen, 1997; Veldhuizen and Hieb, 1998a; Rudnick *et al.*, 2000). The burrows angle slightly downward and are elliptical in shape (Panning, 1939). However, crabs do not always construct their own burrows. In the San Francisco Estuary (Suisun Marsh), mitten crabs were observed occupying burrows made by the introduced Harris mud crab (*Rhithropanopeus harrisii*) (Veldhuizen and Hieb, 1998a). Mitten crabs may also use dense moist vegetation, root wads, debris, rocks, shallow ponded water, or deep pools as cover during lowtide (Veldhuizen and Hieb, 1998a; Rudnick *et al.*, 2000). They do not burrow as extensively in non-tidal areas or tidal areas with submerged aquatic vegetation.

Mitten crabs remain in these upstream rearing areas until they reach maturity. During late summer through fall, mitten crabs migrate downstream to reproduce in the lower estuary, and the gonads develop during the migration (Panning, 1939; Kaestner, 1970; Anger, 1991). Spawning occurs in lower estuaries where the average salinity is 20‰ (Anger, 1991). In the San Francisco Estuary, ovigerous females have been collected November through May and are found mainly in South Bay, San Pablo Bay, and Suisun Bay (Veldhuizen and Hieb, 1998a; Rudnick *et al.*, 2000). Both sexes die at the end of the spawning season (Panning, 1938; Kaestner, 1970; Wolff and Sandee, 1971).

Distribution and Abundance Trends

The Chinese mitten crab is endemic to coastal rivers and estuaries of Korea and China along the Yellow Sea (Panning, 1939; Li *et al.*, 1993). The native range extends north to the Yalu River in South Korea and south to Hong Kong, China (Hymanson *et al.*, 1999). The mitten crab was introduced to Vietnam in an effort to increase the commercial fishery in the Guangdong Province, thus extending its southern range in Asia (Li *et al.*, 1993). Historically, the mitten crab inhabited the lowland sections of rivers and tributaries near the coast, although it has been reported to migrate 1400 km (800 miles) up the Yangtze River from the Yellow Sea (Panning, 1939; Hymanson *et al.*, 1999). In Korea, the crab is common in rice fields near the coast and inhabits rivers when inland (Panning, 1939).

Population trend data is limited. The Yangtze River probably supported one of the largest mitten crab populations based on the amount of historically available habitat (Hymanson *et al.*, 1999). The Yangtze River population has undergone large fluctuations in abundance. Extreme change in weather patterns (e.g., drought or flood) is reported as one factor contributing to these fluctuations (Hymanson *et al.*, 1999). The population declined beginning in the 1960s due to loss of rearing habitat, water pollution, and over-harvest (Hymanson *et al.*, 1999; Zhao *pers. comm.*, 1999). Only a small wild population persists today in the Yangtze River. Because of this limited wild population, the market demand for the Chinese mitten crab is now met by aquaculture production. In China, the mitten crab supports a fishery with an annual production of over 10,000 tons and annual revenues estimated at $1.25 billion (Li *et al.*, 1993; Hymanson *et al.*, 1999). The reproductive tissue of maturing mitten crabs is considered a delicacy.

The Chinese mitten crab was accidentally introduced into northern Europe, where the population exploded and rapidly expanded in distribution (Panning, 1939). The crab was introduced to Germany in the early 1900s, coinciding with a period of increased maritime traffic between Europe and eastern Asia (Panning, 1939; Ingle, 1986). The first report of a Chinese mitten crab was from the Aller River near Rethem, Germany, in 1912 (Panning, 1939). During the late 1920s-early 1930s, the mitten crab spread throughout Germany and into Denmark, southeastern Sweden, southern Finland, Poland (then East Prussia), Czechoslovakia, the Netherlands, Belgium, northern France, and England (Peters and Panning, 1933; Peters, 1938; Panning, 1939; Wolff and Sandee, 1971; Ingle, 1986). Juvenile crabs were reported as far inland as Prague, Czechoslovakia, which is located 700 km (580 miles) upstream of the North Sea on the Elbe River (Peters and Panning, 1933; Panning, 1939). The mitten crab reached the French Mediterranean through the interconnecting canal system (Hoestlandt, 1959, as cited in Cohen and Carlton 1995).

In Germany, extensive efforts were undertaken by the government in the 1920s and the 1930s to control mitten crab populations in some rivers (Panning, 1939). Control measures often took advantage of the mitten crab's migratory behavior. When the crabs reached a barrier, such as a weir or small dam, their upstream migration slowed and they aggregated in large numbers below the obstruction. The crabs attempted to bypass the obstruction by climbing over the barrier or climbing up the banks. A variety of trapping methods were used to capture the crabs as they attempted to circumvent the structure (Peters and Hoppe, 1938). In some locations, traps were placed on the upstream side of dams and captured juvenile crabs as they migrated upstream, climbed over the dam, and fell into the traps. In other locations, troughs where constructed at the top of the levee and the crabs were funneled toward them. The crabs fell into the troughs and could not escape; the troughs were tiled to prevent the crabs from climbing out. Barrels, wrapped with wire netting or canvas, were also placed below dams amongst the aggregating crabs. The crabs would climb up the barrels and fall inside. At one trapping site, over 113,000 crabs were captured in a single day (Panning, 1939). Electrical screens were also installed on the river bottom. Frequencies of 30 to 40 pulses per minute were found to disable and then kill the crabs (Halsband, 1968, as cited in USFWS, 1989). The total catch of crabs in Germany was estimated at 262,600 kg in 1936 and

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190,400 kg in 1937. In some locations, over 100,000 crabs were trapped per day (Panning, 1939). It is unknown whether these control efforts were successful for controlling the population, as literature is very scarce for this time period. The population did decline in the late 1940s, coinciding with increasing water pollution (Gollasch, 1998). Historical mitten crab catch data for the Elbe, Weser, and Havel rivers in Germany, show that the mitten crab population peaks every 15 years in this region (Gollasch, 1998).

In other parts of Europe, periodic localized population explosions have occurred (Ingle, 1986). From the mid-1930s to the mid-1950s, the mitten crab was very abundant along the Belgian coast and in coastal streams (Strandwerkgroep, 1998). The population declined substantially for unknown reasons and only a few crabs were sighted every year. During the mid- to late 1990s, mitten crab abundance increased in portions of southern Holland, Belgium, England, and Germany, coinciding with an improvement in water quality (Strandwerkgroep, 1998). The population increase in southeast England estuaries from 1989 to 1992 coincided with a decrease in outflow and an increase in salinity (Attrill and Thomas, 1996).

The mitten crab was introduced to the San Francisco Estuary in the late 1980s or early 1990s. The most probable mechanisms of introduction are deliberate release to establish a fishery and accidental release via ballast water (Cohen and Carlton, 1997). Ballast water transport is thought to be the introduction mechanism of the mitten crab to Germany, England, the Mississippi River delta, and Lake Erie (Peters and Panning, 1933; Panning, 1939; Nepszy and Leach, 1973; Ingle, 1986). However, it is more likely the mitten crab was intentionally introduced as it is a delicacy and commands a high market price. Cohen and Carlton (1997) reported that markets in San Francisco and Los Angeles were selling live crabs for US \$27.50 to \$32.00 per kg in 1996. Hymanson *et al.* (1999) reported that mitten crabs exported from China to New York commanded prices of US \$85 per kg for crabs weighing over 200 g and US \$60 per kg for crabs weighing under 150 g. The mitten crab has been found in passengers' carry-on luggage at Seattle, San Francisco and Los Angeles international airports and imported live to markets in California and New York (Cohen and Carlton, 1997; Webb *pers. comm.*, 2000). Recently, a shipment of mitten crabs was intercepted in New York. The shipment was destined for New York, Texas, and California (Webb *pers. comm.*, 2000).

The Chinese mitten crab was first collected in South San Francisco Bay by commercial shrimp trawlers in 1992 and was collected in San Pablo Bay in fall 1994 (Figure 2) (Hieb, 1997). By 1996, the mitten crab had spread throughout the lower tributaries to San Pablo and South San Francisco bays, Suisun Bay, Suisun Marsh,

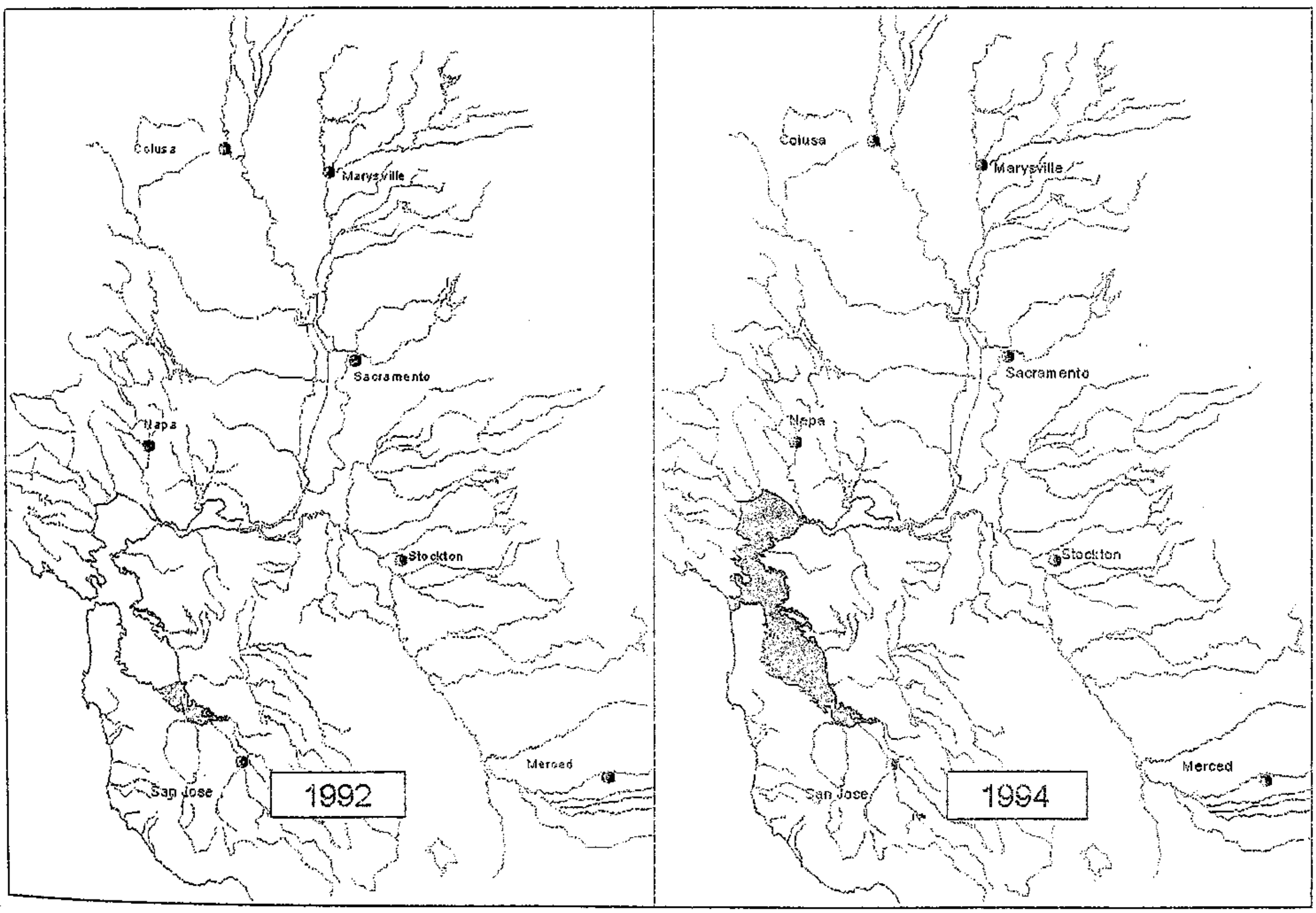


*Figure 2. Range expansion of the Chinese Mitten Crab (*Eriochier sinensis*) in California 1992 - 1998.*

and the Sacramento-San Joaquin Delta (Hieb, 1997; Veldhuizen, 1997). The maximum reported distribution of the Chinese mitten crab in California extends north in the Sacramento River drainage beyond the cities of Marysville and Colusa and south in the San Joaquin River drainage near the city of Gustine (see figure 2) (Veldhuizen and Hieb, 1998b). The mitten crab's potential distribution in the San Francisco Estuary watershed extends throughout all waterways up to any migration barrier, such as large dams.

Population trend data indicates the mitten crab population size rapidly increased during the first years of establishment. The population in the North Bay and Delta appears to have peaked in 1998, then declined in subsequent years (Hieb, unpublished data). The population in South San Francisco Bay continues to steadily increase (Rudnick, unpublished data).

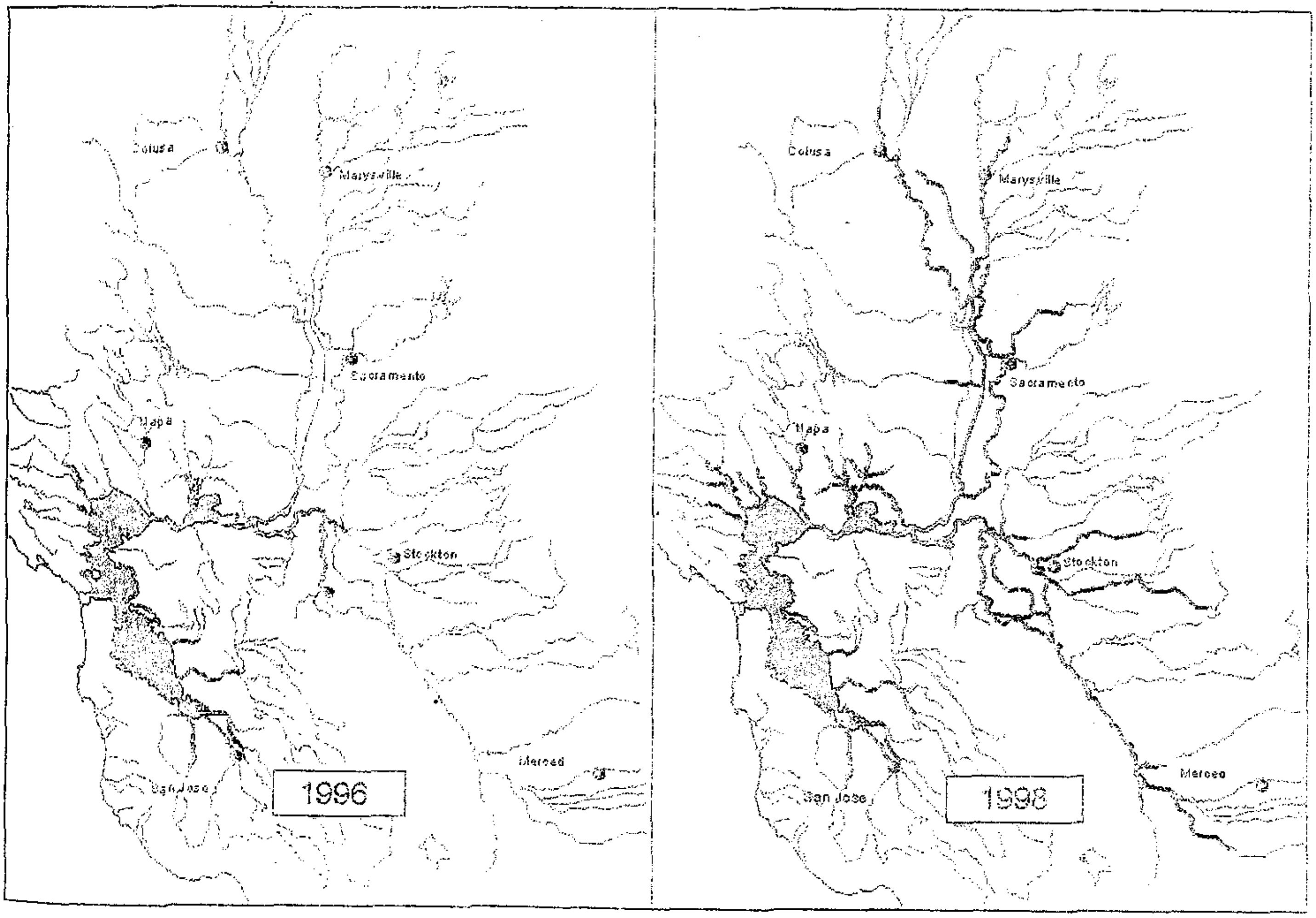
Although only established in California, the mitten crab has been collected in other parts of North America. An adult male was collected in the Detroit River at Windsor, Ontario, in October 1965, and a female and two male adults were collected in Lake Erie in April and May of 1973 (Nepszy and Leach, 1973). Another six or seven crabs were collected in the Great Lakes region between 1973 and 1994 (Cohen and Carlton, 1997). In Louisiana in 1987, an adult was collected in the Mississippi River Delta (USFWS, 1989). A male Japanese mitten crab, *Eriocheir japonicus*, was collected in the Columbia River near Astoria, Oregon, in August 1997 (Sytsma *pers. comm.*, 2001). An unverified report of a mitten crab captured near Portland, Oregon, was made in 1999 (Sytsma *pers. comm.*, 2001). This crab lacked the "hairy" claws and was probably not a mitten crab.

Realized and Potential Negative Impacts

When mitten crabs become very abundant, negative impacts become apparent. In Germany when the population exploded in the 1930s, mitten crabs impacted levee integrity and commercial fishing operations (Peters and Panning, 1933; Panning, 1939). In California, the mitten crab has impacted commercial fisheries, recreational fishing, and infrastructure (Table 1). Although yet undocumented, the mitten crab is probably causing ecological changes in the San Francisco Estuary. There is also concern that the mitten crab may carry parasites harmful to mammals, bioaccumulate toxins, and consume rice crops.

Infrastructure

In Germany, the numerous burrows constructed by mitten crabs accelerated bank erosion rates and caused reduced levee stability (Peters and Panning, 1933; Panning, 1939). In some locations, burrows were reported to be up to 50 cm deep and at densities of up to 30



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burrows/m² (Peters and Panning, 1933). Surveys of levees and banks in the Sacramento-San Joaquin Delta and Suisun Marsh found crab densities up to 5 crabs/m² (Veldhuizen, 1997; Holmes and Osmondson, 1998). In tributaries to South San Francisco Bay, mitten crab burrow surveys conducted in 1995-1996 found densities of 2 to 18 burrows/m² with an average depth of 20 cm (Halat, 1996; Rudnick *et al.*, 2000). By 1999, densities ranged from 18 to 39 burrows/m² with burrows forming a complex network of interconnecting tunnels (Rudnick *et al.*, 2000). Burrow densities were highest in tidally influenced areas with steep banks containing a high clay or silt content (Rudnick *et al.*, 2000). Based on available data, any damage to banks or levees in the estuary will most likely be confined to tidally influenced areas and will be dependent on crab density, levee structure, and suitability of the bank for burrowing.

To date, the most conspicuous impact of the crab in California is on the fish salvage operations at the Federal and State water pumping plants and fish collection facilities located in the south delta. These facilities pump and divert several million acre-feet of water from the Sacramento-San Joaquin Delta annually to water users in other parts of the state. The fish collection facilities screen all water heading toward the pumping plants and salvage millions of fish. The fish salvage operations at both fish collection facilities were severely hindered in 1998 when nearly 750,000 crabs (5,000 to 40,000 crabs captured per day during the peak fall migratory period) were entrained into the facilities, clogging the holding tanks and fish transport trucks (Siegfried, 1999; Wynn *et al.*, 1999; White *et al.*, 2000). The Federal and State fish facilities have developed mitten crab exclusion devices to prevent crabs from entering the facilities (White *et al.*, 2000).

In Europe, reports were made of crabs entering water intake pipes or becoming trapped on the screens (Ingle, 1986; Attrill and Thomas, 1996; Vincent, 1996; Clark *et al.*, 1998). In California, Pacific Gas and Electric Company (PG&E) reported that the Pittsburg Power Plant, located on the southern shore of Suisun Bay, was affected by high numbers of adult crabs in fall 1997 and 1998, and the Contra Costa Plant, located near Antioch, was affected in fall 1998 (Hieb *pers. comm.*, 1998). Hundreds of crabs entered the cooling water system each fall when migrating downstream, partially blocking the plumbing system and reducing flows. Workers periodically back-flush with hot water to remove the crabs.

Fisheries

The most widely reported economic impact of mitten crabs in Europe was physical damage to commercial fishing nets and the catch when high numbers of crabs were caught (Panning, 1939). The crabs ate the abdomens of the fish and caused increased wear on the nets. Crabs also filled eel-basket pots and hoop nets, preventing eels from entering the traps, thus reducing catch (Panning, 1939). In 1981, the mitten crab population in the Netherlands increased substantially, resulting in serious damage to fishing nets (Ingle, 1986). However, mitten crabs are no longer a problematic by-catch, because of the currently low population level in most areas of Europe, a demand for crabs by Chinese restaurants, and exportation of crabs to Asian countries (Schubart, 1997; Jung *pers. comm.*, 2001).

In the San Francisco Estuary, the large mitten crab population has been a nuisance to commercial and recreational fisheries for several years. In South San Francisco Bay, commercial shrimp trawlers find it time consuming to remove crabs from their nets (one fisherman twice caught over 200 crabs in a single tow during fall 1996). They are also concerned that a large catch of mitten crabs will damage their nets and the shrimp.

Factor	Realized Impact	Potential Impact
Infrastructure	1. Large influx of crabs during fall spawning migration adversely impacts water diversion facilities and fish protection operations	1. Burrowing into levees and banks may weaken these structures increasing the likelihood of failure
Fisheries	1. High crab abundance in commercial Bay shrimp catch damages catch and nets	1. Crabs may compete with the signal crayfish reducing catch over time
	2. Theft of bait from recreational anglers especially severe during the fall spawning migration	
Ecology		1. Crabs may adversely affect other native species through competition or predation
		2. Consumption of crabs may transfer elevated concentrations of some compounds through the food chain
Public Health		1. Crabs may be an intermediate host to North American or Oriental lung flukes
		2. Crabs may bioaccumulate some compounds to harmful levels
Agriculture		1. Crabs may consume rice shoots
		2. Crabs may burrow in the levees of rice fields affecting successful cultivation

Table 1. List of realized and potential impacts associated with the establishment of the Chinese mitten crab in California.

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Damaged shrimp are unsuitable for the bait market.

A commercial fishery for the introduced signal crayfish (*Pacifastacus leniusculus*) is located in the Sacramento-San Joaquin Delta. During fall 1998, when large numbers of adult mitten crabs migrated downstream, mitten crabs were occasionally caught in crayfish traps reducing the crayfish catch. The mitten crab overlaps in dietary and habitat preferences with the signal crayfish, which may impact crayfish population size.

The mitten crab has impacted the recreational fishing community and associated commerce. The impact is greatest during the fall spawning migration. Maturing and adult mitten crabs steal bait, forcing anglers to move to areas with fewer crabs. Marinas near large seasonal mitten crab aggregations are also impacted, because anglers avoid the area and do not use their boat launching facilities.

Ecology

The ecological impact of a large mitten crab population is the least understood of all the potential impacts. Mitten crabs are omnivores. Young crabs consume mainly vegetation and detritus, and, as they mature, increase their consumption of benthic organisms, especially small invertebrates, such as mollusks, aquatic insects, shrimp, and polychaetes (Thiel, 1938; Hoestlandt, 1948; Tan *et al.*, 1984; Rudnick *pers. comm.*, 2001). A large mitten crab population could change the structure of the estuary's fresh and brackish water benthic invertebrate communities (which is dominated by introduced species) through direct predation and effect the abundance and growth rates of other species through competition.

German fishermen in the 1930s claimed the crabs caught and consumed fish and reduced fish population levels (Panning, 1939). However, the mitten crab is too slow to harm or capture most adult fish, as evidenced by crabs and fish occupying the same aquarium for many months (Panning, 1939). But, fish species that produce demersal or adhesive eggs may be affected. Chinese mitten crabs may prey on the eggs of nest building species, such as centrarchids. Some fish species spawn in submerged aquatic vegetation, a known habitat of mitten crabs, and thus expose their eggs to mitten crab predation. Mitten crabs have the ability to reach salmonid spawning grounds, especially in the smaller tributary streams in the Bay Area. Because mitten crabs prefer vegetated areas and warm waters (20 to 30 °C), they will probably not occur in high numbers in the cool, fast-flowing portion of rivers and streams characteristic of salmon and steelhead spawning areas (Hymanson *et al.*, 1999).

In freshwater portions of the estuary, the mitten crab and the introduced red swamp crayfish (*Procambarus clarkii*) and signal crayfish (*Pacifasticus leniusculus*) co-occur, overlapping in dietary and habitat preferences. A 1996 survey in tributaries to South San Francisco Bay found no negative correlation between the presence of the mitten crab and presence of the red swamp crayfish; the crayfish was always present in areas with the mitten crab (Halat, 1996). However, at almost all sites mitten crabs were visually more abundant, active, and aggressive than crayfish (Halat, 1996). If competition does occur, the mitten crab may reduce abundance and growth rates of the red swamp crayfish and the introduced signal crayfish (*Pacifasticus leniusculus*), which supports a commercial fishery in the Sacramento-San Joaquin Delta.

Conversely, some species may benefit from mitten crabs as a new prey source. Predatory fishes, waterfowl, and aquatic birds were noted as predators of the mitten crab in Germany (Panning, 1939). White sturgeon, striped bass, black bass, catfish, bullfrogs, loons, and egrets have been reported to prey upon the crabs in the San Francisco Estuary (Veldhuizen and Hieb, 1998a). Other predatory fishes, river otters, raccoons, and other wading birds may also consume mitten crabs.

Public Health

The presence of the mitten crab is also a human health concern, as it may carry parasitic lung flukes and bioaccumulate compounds harmful to humans. It may be a secondary intermediate host to the North American lung fluke (*Paragonimus kellicotti*) or the Asian lung fluke (*P. westermani*). Snails are the primary intermediate host, crustaceans are the second intermediate host, and mammals are the final host of *Paragonimus* species. *Paragonimus* species can use a variety of snail species as host, and potential host snail species occur in the San Francisco Estuary watershed (Walter and Culver, 2000). [Note: The accuracy of the reports stating the Chinese mitten crab is a host for *Paragonimus* species is under question by some researchers (Hymanson *et al.*, 1999; Zhao *pers. comm.*, 1999)]. Humans risk infestation through the consumption of raw or partially cooked infected mitten crabs or the transfer of the crab's bodily fluids through unsterile cooking practices (USFWS, 1989; Halat, 1996).

To determine if North American or Asian lung flukes are present or could become established in California's mitten crab population, researchers are in the midst of examining Chinese mitten crabs, signal crayfish (*Pacifasticus leniusculus*), red swamp crayfish (*Procambarus clarkii*), and various snail species for flukes. They have dissected approximately 725 mitten crabs and 400 crayfish, collected from various locations in the San Francisco Estuary, and found none of the specimens were infected with *Paragonimus* species. (Culver pers. comm., 2001; Walter *et al.*, in prep).

Mitten crabs are known to inhabit agricultural ditches and other areas that may contain high levels of contaminants, prompting concern that the crabs may bioaccumulate harmful compounds. The California Department of Health Services, Food and Drug laboratory conducted a preliminary study of concentrations of arsenic, selenium, DDT/DDE and mercury in the soft tissue of adult mitten crabs (Loscutoff *pers. comm.*, 2001). Average arsenic concentrations ranged from 0.55 to 0.81 parts per million (ppm). This is well below the U.S. Food and Drug Administration's (FDA) arsenic level of concern of 68 ppm for crustaceans. Average selenium concentrations ranged from 0.66 to 0.73 ppm, approximately one-fifth of the daily selenium requirement. Average DDT/DDE concentrations ranged from 1.61 to 2.12 ppm. The FDA level of concern is 5 ppm. Average mercury concentrations were below the 5 ppm detection limit. The crabs were collected from the USBR Tracy Fish

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Collection Facility, located in the South Delta, from October to November 1999. The crabs entering the facility either reared in the delta or upstream of the delta in the San Joaquin River.

Agriculture

In its native range in China and Korea, juvenile mitten crabs were reported to damage rice crops by consuming the young rice shoots and burrowing in the rice field levees (Ng, 1988, as cited in Halat, 1996). However, no control measures have been reported. Conversely, the crabs are routinely cultured in rice fields and are considered a benefit as they eat aquatic weeds and harmful insects and their waste products fertilize the rice (Hymanson *et al.*, 1999; Zhao *pers. comm.*, 1999). Crabs are stocked after the rice shoots are several centimeters high and at a controlled density to minimize damage. In California, rice farmers have not reported any damage related to mitten crabs.

Conclusion

The Chinese mitten crab can cause significant negative impacts when populations explode or reach high densities. This has occurred in Europe and in California where infrastructure, fisheries, and possibly ecosystems have been adversely impacted. With the market demand for and continuous importation of mitten crabs, there is a high probability that the mitten crab will be intentionally introduced to and subsequently established in other North American estuaries. In addition, the mitten crab may spread from the San Francisco Estuary to other West Coast estuaries via domestic ballast water transport and ocean currents.

The threat of the Chinese mitten crab becoming established in other estuaries has prompted the establishment of monitoring programs and an assessment of its potential distribution in the western United States. The San Francisco Estuary Institute, funded by the United States Bureau of Reclamation, is conducting the assessment of Chinese mitten crab establishment and distribution in the Columbia River system, Rogue River, Klamath River, Sacramento River and San Joaquin River system, and Lavaca and Nueces watersheds. USBR facilities are located in all of these systems. This report is will be released later this year.

To track the spread of the California mitten crab population, the United States Fish and Wildlife Service and the California Department of Fish and Game in cooperation with the Interagency Ecological Program (IEP) implemented a monitoring program. To report mitten crab sightings in California or to become a monitoring volunteer, contact Ray von Flue at mcrabman@delta.dfg.ca.gov, call 1-888-321-8913, or logon to <http://www.delta.dfg.ca.gov/mittencrab/sighting.asp>.

Biologists in Oregon recently implemented a volunteer-based mitten crab monitoring program. They are currently monitoring in the Columbia River, Grays Harbor, and Willapa Bay. Eventually, they would like to expand the program to other estuaries in Oregon and Washington. If you would like to volunteer, please contact Erik Hanson at the Center for Lakes and Reservoirs at 503-725-3834. To report a mitten crab or other nonnative species in Oregon, call the toll-free Oregon Invasive Species hotline at 1-866-INVADER (1-866-468-2337).

To obtain more information on the Chinese mitten crab and to view photos, diagnostic characteristics, and distribution maps, visit <http://www.delta.dfg.ca.gov/mittencrab/>. For information on Chinese mitten crab research projects occurring in the San Francisco Estuary, browse through the latest issues of the IEP Newsletter available online at <http://www.iep.ca.gov/report/newsletter/>.

About the Author

Tanya Veldhuizen is an Environmental Specialist for the California Department of Water Resources and a graduate student at California State University, Sacramento. She has been involved in mitten crab research since 1995. Currently, she is researching the habitat use of juvenile Chinese mitten crabs in the Sacramento-San Joaquin Delta.

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Personal Communications

Culver, Carrie. University of California, Marine Science Institute, Santa Barbara, California.

Fu, Xiao Ming. IEC (America) Inc., South San Francisco, California.

Grimaldo, Lenny. California Department of Water Resources, Environmental Services Office, Sacramento, California.

Hieb, Kathryn. California Department of Fish and Game, Central Valley Bay-Delta Branch, Stockton, California.

Jung, David. Law Offices of Jung and Jung, California.

Loscutoff, Susan. California Department of Health Services, Sacramento, California.

Rudnick, Deborah. University of California, Department of Environmental Science, Policy, and Management, Berkeley, California.

Schubart, Christoph. University of Southwestern Louisiana, Department of Biology, Lafayette, Louisianna.

Sytsma, Mark. Portland State University, Center for Lakes and Reservoirs, Environmental Sciences and Resources, Portland, Oregon.

Webb, Kim. United States Fish and Wildlife Service, Stockton, California.

Zhao, Nia-Gang. Anhui Weiqing Aquatic Products Co., Ltd., Hefei, Anhui, China.

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