Chinese Mitten Crab
Early Detection / Rapid Response Plan
for
The Northeast Aquatic Nuisance Species Panel Region
Table of Contents

Introduction 3

Part One - Background
  1.1 Chinese Mitten Crab Life History 4
  1.2 Invasions and Impacts of the Chinese Mitten Crab 5
  1.3 Risk Assessment for the NEANS Panel Region 12

Part Two - Early Detection
  2.1 Background 18
  2.2 Partnership Based Monitoring Networks 19
  2.3 Education, Outreach, and Training Initiatives 23

Part Three - Rapid Response
  3.1 Background 26
  3.2 Quarantine as a First Option 26
  3.3 Some Rapid Response Methods 27
  3.4 Models for Rapid Response 31

Part Four - Post Response
  4.1 Post-Response Assessment Period 37
  4.2 Long-term Monitoring Networks 37
  4.3 Public Outreach 37

References
Appendices
  Chinese Mitten Crab Identification Key
  Chinese Mitten Crab Monitoring and Control Methods: Selected Gear Types
  Links to NEANS Panel Early Detection / Rapid Response Resources

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Introduction

Unwanted biological invasions pose a threat to the native ecosystems and species of the Northeast region of the United States. In addition, these invasions can have adverse effects on the human population in the area, including economic harm. One such invader currently threatening to invade the area is the Chinese Mitten Crab (Genus *Eriocheir*). The threat of invasion by non-native species is a continuing and very complex problem that requires effective partnering and constant stewardship for effective management.

The goal of this Early Detection and Rapid Response plan is to provide a design, framework, and strategy to minimize the establishment and spread of the Chinese Mitten Crab within the northeastern United States for members of the Northeast Aquatic Nuisance Species Panel region. With a plan in place, affected regions might quickly implement rapid response initiatives following the detection of Chinese Mitten Crab populations. It is the time when management must quickly shift from prevention to control or eradication of the species.

Proactive management is an important factor in the both prevention and quick control of invasive species. Prevention includes such things as having laws in place that inhibit the spread, both accidental and intentional of invasive species and public outreach. In some cases, no amount of prevention is enough. If prevention is unsuccessful, and invasion occurs, managers often face one of two scenarios: 1) The first is a situation in which the species can be controlled quickly and in a localized manner thus reducing costs, and 2) The second is a situation in which a slower response results in higher costs once the species has spread. The slower response makes control of an invasive species less feasible because it has given the species time to spread, thus increasing the cost and size of treatment, and diminishing the chance for control.

For response to an invasion to happen rapidly and effectively, the actions to be taken should be anticipated and consensus reached on as many details related to implementation actions as possible prior to the detection of an unwanted introduction. This is especially important when there are so many states and provinces in a region that can potentially be affected by the same
invader. It is important to learn from each other, and be aware of the methods used and resources that are available. Thus, when response is actually required, it can be quick, efficient, and successful.

**Part One – Background and Risk Assessment**

1.1 Chinese Mitten Crab Life History

The Chinese Mitten Crab (*Eriocheir sinensis*) is native to the rivers and estuaries of Central Asia from the west coast of North Korea to the south of Shanghai, China.

This species is distinguished by a dense patch of setae found on the white-tipped claws or chelae of larger juveniles and adults. These “hairy mittens” give the crab its common name. Males and females both have hairy claws, but the setae are usually fuller and cover a wider area on the claws of males. Both front claws are approximately equal in size. The carapace is slightly wider than it is long, and has four spines on the anterior lateral margins. The majority of adult crabs fall within the 40 to 70mm size range. The crabs’ coloration varies from a brownish orange, particularly among juvenile crabs, to a more greenish-brown seen in adult crabs and in newly molted crabs (California Department of Fish and Game, 2008).

The Chinese mitten crab is a catadromous species; reproduction occurs in water of high salinity and rearing occurs in freshwater and brackish habitats. The Chinese Mitten Crab reportedly matures at the age of 1 to 5 years, depending on water temperature. Mating and fertilization occur in late fall and winter, generally at salinities >20‰. The females carry their eggs until hatching, and a single female can carry between 250,000 to 1 million eggs. Both sexes die soon after reproduction. After hatching, larvae are planktonic for approximately 1 to 2 months. The small juvenile crabs settle in salt or brackish water in late spring and migrate to freshwater to rear (California Department of Fish and Game, 2008).

Taxonomy and Genetic Variation within the Genus Eriocheir

The genus is *Eriocheir* is currently assigned to the superfamily Grapsoidea. This superfamily contains several catadromous and semi-terrestrial crabs. *Eriocheir* is generally considered to be a member of the family Grapsidae, subfamily Varuninae.

*Eriocheir sinensis* is a member of a genus that fluctuates in membership as a result of continued genetic and morphological studies. The *Eriocheir* genus also includes *E. japonica*, a species that has been described as closely related to or synonymous with *E. sinensis*, but which many researchers consider a distinct species.

Morphological variations between species in the Genus *Eriocheir* have been described. Whether these differences are a physical expression of population and hybrid differences, or true species-unique characteristics, is debatable. For example, a study which described a mitten crab population with physical traits intermediate to *E. sinensis* and *E. japonicus*, and suggested that the physical characteristics may be caused by variable environmental conditions. Some physical characteristics of mitten crabs are not consistently found on individual crabs. Thus some characteristics, such as the frontal carapace teeth that can change shape with the growth of the carapace, should not be considered to be good identifying characteristics for individual *Eriocheir* species.

Given the physical plasticity and genetic homogeneity of *Eriocheir*, it may be difficult to determine the source of mitten crabs in areas in which they are considered invaders (Chinese Mitten Crab Working Group, 2003).
1.2 Invasions and Impacts of the Chinese Mitten Crab

**Known Invasions of the Chinese Mitten Crab**

The Chinese mitten crab likely invades new areas by one or more of three processes: a natural introduction, such as migration or drift of larvae from native habitat; an unintentional introduction associated with such activities as the importation of cargo or ballast water; or intentional introduction of the crab, for purposes including consumption or aquaculture establishment. Given the wide geographical separation of possible source populations such as China and Europe, combined with the preference of the mitten crab for coastal and freshwater habitats, it is unlikely that the mitten crab arrived in North America from natural causes. It is more likely that the crab became established, unintentionally or intentionally, as a result of human activities.

The review of the historic introduction of *Eriocheir spp.* into Europe, and subsequent spread there, demonstrates the potential long-term impacts on U.S. ecosystems. The Chinese mitten crab has become widely established on the European continent and is found, at varying levels of abundance throughout most of western, central, and northern Europe. The first records of the crab's presence in Europe are from the Aller River, Germany in 1912. It was probably introduced by ships' ballast water. By the late 1930s, the crab became a serious pest in Germany. Mitten crabs caused damage to banks and levees through burrowing activities and to fishing operations through entanglement in nets and injury to netted fish (Panov, 2005).

*Eriocheir sinensis* has had a "boom and bust" population cycle in Germany, declining during the 1940s but rebounding in the 1950s, 1970s, and early 1980s. The population has been on the rise again since the mid-1990s. For example, in the spring of 1998, 850kg (750,000 individuals) were caught by hand in the river Elbe in just two hours. Large annual population variations of introduced mitten crabs have been observed in England as well. In the Thames River estuary a large increase in the relative population of mitten crabs, compared to historic levels has been observed since 1992. Prior to 1992, the population had been relatively constant since the 1970s. The recent increase is believed by some to be due to improved mitten crab settlement coinciding with several years of drought. This fluctuation in population has also occurred in populations of *E. sinensis* in other European countries into which it has spread, including the Netherlands and France.

The Chinese mitten crab has also spread into Denmark, Sweden, Finland, Luxembourg, Poland, Austria, Czechoslovakia, and most recently in Portugal and the Seville area of Spain. In the Baltic countries, however, the population densities have remained quite low. This can possibly be attributed to the low salinity and/or low temperature of the Baltic Sea inhibiting successful reproduction of the Chinese mitten crab. In all these countries, the most likely mechanisms of introduction have been cited as accidental importation through ballast water or spread to adjacent countries through connected streams or coastal waterways.
In North America, several Chinese Mitten crab invasions have occurred in Canada and the United States, with one invasion leading to the only known established population on the continent. The first known invasion in the United States occurred on the West Coast in 1992, in the San Francisco Bay estuary. By 2009, a breeding population had been established and spread throughout the bay’s watershed, including the Sacramento-San Joaquin delta and numerous other tributaries that drain into the estuary. The Chinese Mitten Crab subsequently invaded several states along the U.S. East Coast including Connecticut, Delaware, New Jersey, New York, and Maryland where the first specimen was found in the Chesapeake Bay in 2005 (CT DEP/CT Sea Grant press release, 2012). It has also been found in the Gulf of Mexico in the State of Louisiana (Galveston Bay Invasive Species Risk Assessment Final Report, 2004).

Though no known populations have been established in Canada, the first recorded invasion in North America occurred in Ontario in 1965 when a Chinese Mitten crab was found in the Detroit River. In 1973, two specimens were collected from Lake Erie, offshore from Port Stanley and Erieau, Ontario. No other sightings were reported in Lake Erie until 2005 when another specimen was found at Port Alma. Finally, in 2005 and 2006, some specimens were collected in Ontario at a power generating station on Mission Island located in Thunder Bay, Lake Superior.
In the NEANS Panel region, Quebec has experienced several invasions in the St. Lawrence River and Estuary. The other invasions in the region occurred in the states of Connecticut and New York. Each of these cases will be further addressed in Section 1.3 “Risk Assessment for the NEANS Panel Region.”

Figure 1. Global distribution of the Chinese Mitten Crab. ● = introduced/population established • = introduced/population not established, ▲ = native range (Dittel, A. I. and Epifanio, C.E. (2009)

Known Impacts of the Chinese Mitten Crab

The economic and ecological impacts of the Chinese Mitten Crab are well documented for both Germany and California. As of 2009, economic damage in German waters alone has totaled approximately 80 million Euros since 1912. Millions of dollars per year have been spent in California in attempts to control the mitten crab.
Impacts of the Chinese Mitten Crab are well documented in the *National Management Plan For the Genus Eriocheir* (Chinese Mitten Crab Working Group, 2003). The following impacts fall into seven categories, and were documented in California.

(1) Ecological Impacts

An established population of the mitten crab could change the structure of the food web and may reduce the abundance and growth rate of various species through competition and predation.

Throughout the world, the mitten crab has broadly been described as an opportunistic omnivore. It is said that mitten crabs "eat whatever they can get" and this aptly describes the plasticity of this crab's eating habits. Fishermen in the California have reported experiencing substantial bait-stealing by the mitten crab. Crabs will take bait ranging from dead fish and shellfish to worms and even plastic lures. When studies were done to determine what the crab actually eats, a gut content analyses conducted for populations of the crab in Asia, Europe, and the U.S., showed a predominance of vegetative matter and a variety of benthic macroinvertebrates in the stomachs of mitten crabs. Recent analyses of the California population of crabs suggested that macroinvertebrates, algae, and detritus are all likely contributors to the mitten crab’s diet. Researchers have suggested that the crab shifts toward a more carnivorous diet as it ages, incorporating items such as shrimp and other benthic invertebrates into its diet. It is unlikely that mitten crabs prey on healthy, free-swimming fish, but Chinese mitten crabs will readily scavenge dead fish carcasses. In a study of over 3000 crabs from Germany, fish material made up only 2.4% of gut contents analyzed. It is also possible that mitten crabs prey on the eggs of fish and amphibians; for example in San Francisco Bay, the mitten crab preys on the eggs of nest-building fish such as centrarchids and salmonids.

The presence of large numbers of mitten crabs could potentially threaten the existence of some species that reside in the area they are invading. New England is home to a variety of endangered and threatened species, any potential ecosystem wide impacts are of great concern.

Chinese Mitten Crabs may have further effects on the food webs in the areas they invade, because not only are they predators, but they can be prey as well. Anecdotal reports suggest that the Chinese mitten crab has become prey for a wide variety of species in the San Francisco Bay ecosystem, including sturgeon, striped bass, catfish, bullfrogs, loons, raccoons, and egrets. No research has been conducted to verify or quantify these reports; however, given the abundance of the crab and the diversity of potential predators, the introduction of the mitten crab may have food web impacts beyond what it consumes.

(2) Fisheries Impacts
Both recreational and commercial fishing are a large part of New England industry. The most widely reported impact from mitten crabs in California was the interference with recreational sport fishing through bait stealing. Anglers reported having extreme difficulty with crabs when attempting to bait fish, especially during the fall and winter months. Many areas have been reported as “unfishable” during periods of high mitten crab abundance. Fishing interference by mitten crabs resulted in damage to bait, gear and/or the catch. Many fishermen, in California, abandoned traditional fishing areas to avoid such interference. Similar reports have been presented in the German literature after mitten crabs were introduced.

The San Francisco Estuary and its tributaries also support large recreational and commercial fisheries for various crayfish and grass shrimp. Many commercial bay shrimp and crayfish fishers reported large numbers of mitten crabs present in their nets and traps. Most mitten crabs are caught by fishing techniques, such as slow moving trawls, that capture benthic animals on the bottom of the water column. Mitten crabs also feed on the same sources as commercially harvested crayfish, including the red swamp crayfish (Procambarus clarkii) and the signal crayfish (Pacifastacus leniusculus). Experiments have demonstrated that mitten crabs are superior competitors for shelter when compared to locally occurring crayfish. These findings imply that the mitten crab can significantly impact many fisheries.

(3) Fish Salvage Impacts

One of the most noticeable impacts of mitten crabs occurs during their downstream migration. At high populations levels crab migrations cause problems for water diversions, power plants and fisheries. In California, State and Federal facilities pump and divert several million acre-feet of water from the Delta annually. In an effort to protect fisheries and endangered species, the facilities salvage migrating listed and other fish from the system before they reach the facilities turbines and transport them downstream in tanker trucks. Live crabs and their shells can interfere with fish passage, fish salvage and can clog screens, pipes and valves at salvage facilities.

High numbers of migrating adult crabs have caused severe problems for the fish salvage operations at the State and Federal water facilities in Tracy, California. In 1998 the combined daily crab count for the facilities peaked at 51,292 crabs per day in late September. At peak times during the 1998 fall migration period, fish mortality attributed to the crabs at the federal fish salvage facility was 98-99%. Responding to this crab migration required research and development of control methods and increased facility operation costs. The estimated financial impact incurred at the fish salvage facilities that year amounted to over $1 million. The number of migrating crabs in 1998 contrasts sharply with the approximately 40-50 crabs collected in 1996 and approximately 16,000 crabs entrained at the federal facility in 1997.

In years when they are abundant, migrating mitten crabs can overwhelm the fish salvage facilities, resulting in high fish mortality. Several of the anadromous fish species impacted by fish salvage operations are listed as threatened or endangered, under the
Endangered Species Act. Without the ability to predict annual migrating populations of mitten crabs, salvage facilities are forced to choose between inefficiently expending resources or being unprepared for high mitten crab numbers and abundant fish losses.

(4) Power Plant Impacts

During the 1997 mitten crab population increase, natural gas power plants in the Delta in California had intermittent problems with crabs clogging water intakes. Crabs can enter the cooling water intakes during their downstream migration, blocking the plumbing and drastically reducing water flows. Periodic back flushing is then required to prevent overheating of the systems. Similar problems will likely be faced by the extensive fish passages and water diversions in the Pacific Northwest, along the Hudson River and in other locations into which the mitten crab may be introduced.

(5) Burrowing Impacts

For areas that rely heavily on levees for flood protection and water diversion, bank erosion caused by mitten crab burrowing can be very damaging. Maintenance of these structures can be very costly for states. For example in 2001-2002 alone, California budgeted $23.3 million just to maintain levees. Crab burrows in levee banks and other areas have most likely contributed to bank slumping and erosion. However the rate of burrowing and its effects can vary greatly due to densities of the crab in the area. For example, densities of juvenile mitten crabs in the Delta in California are generally far lower than those found in South San Francisco Bay tributaries (less than 1 burrow/m² in most Delta monitoring sites, versus 5 to 30 burrows/m² in South San Francisco Bay streams in the same time period). This difference may arise from two major differences between these areas. A large amount of suitable habitat available to juvenile mitten crabs among the numerous small channels feeding North Bay marshes may lead to juvenile crabs being widely distributed. In addition the greater abundance of aquatic vegetation in shallow, open waters of the North Bay may provide an alternative refuge to burrows.

Burrowing may pose the greatest risk in steep banked creeks. Observations suggest that high rates of burrowing have been associated with areas of increased erosion and bank collapse in San Francisquito Creek, California.

The tidal marsh and the mouth of San Francisquito Creek have experienced accelerated erosion in areas where mitten crabs created burrows in marsh sediments. Wave action during high tides subsequently resulted in the formation of sediment pillars. Over time wave action, combined with burrows, resulted in the vertical collapse of the marsh bank in blocks up to 3 m long. Renewed burrowing of the slumped banks, along with wave action, had been observed to result in the continual removal of marsh bank sediments.

It appears that damage to levees depends on crab densities, levee structure and bank suitability for burrowing. Burrowing by mitten crabs into stream and levee banks has been observed in densities up to 39 burrows per m².

(6) Potential Agricultural Impacts

Chinese Mitten Crabs are known to feed on agricultural crops in other regions of the world. In China and Korea the crab was reported to damage rice crops by feeding on young rice shoots. As compared to some of the other impacts this one might be of lesser concern for the New England area.

(7) Potential Human Health Threats

The Asian Lung Fluke (*Paragonimus westermani*)

The Chinese Mitten Crab can serve as the secondary host for the Asian lung fluke, *Paragonimus westermani*. Symptoms of Asian lung fluke infection are typically tuberculosis-like. Mammals, including humans, are the final host of the lung fluke, with infection likely through the ingestion of raw or undercooked infected crab or transfer of the fluke by utensils contaminated by touching such crabs.

Although evidence suggests that the Chinese mitten crab can serve as a secondary host for the Asian lung fluke, no mitten crabs infected with this parasite have been found in U.S. waters. A study confirmed that the primary host for the Asian lung fluke has been found in U.S. waters. One species that acts as a primary host is a snail (*Melanoides tuberculata*).
1.3 Risk Assessment for the NEANS Panel Region

The NEANS Panel region is clearly at risk for the introduction of the Chinese Mitten crab, as it has already been documented in nearby areas such as the province of Quebec and the states of New York and Connecticut. The first record of a Chinese Mitten crab in the region came from Quebec in 2004, when a specimen was discovered along the southern side of Lake St. Pierre, a fluvial lake of the St. Lawrence River, at Notre-Dame-de-Pierreville. Including this specimen, a total of nine Chinese Mitten crabs have been collected from the St. Lawrence River or Estuary during the period September 2004 – December 2007 (Figure 3).

All of these individuals were found in various fishing gear including fyke nets, gill nets, and eel weirs. Five were identified as males, three were females, and one was released without its gender having been determined. The earlier introductions occurred in freshwater and the more recent specimens were generally found in the estuary where conditions for reproduction and establishment are more favorable (Table 1).
Table 1. Chinese Mitten crabs sighted in the St. Lawrence River and Estuary, 2004 - 2007

<table>
<thead>
<tr>
<th>Specimen ID</th>
<th>Date of capture</th>
<th>Location of capture</th>
<th>Coordinates, Lat/Long N/W</th>
<th>Method of capture</th>
<th>Sex</th>
<th>Carapace width (mm)</th>
<th>Wet weight (g)</th>
<th>Genetic haplotype</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sept. 2, 2004</td>
<td>Lévis, Québec</td>
<td>46°46.3’ 71°13.2’</td>
<td>Eel fishing weir</td>
<td>Female</td>
<td>43.7</td>
<td>39.6</td>
<td>Esin5</td>
</tr>
<tr>
<td>2</td>
<td>Fall 2004</td>
<td>Sainte-Angèle-de-Laval, Québec</td>
<td>46°20.3’ 72°30.3’</td>
<td>Fyke net</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>3</td>
<td>Sept. 2, 2005</td>
<td>South shore Lake Saint-Pierre, near Saint-François River, mouth Québec</td>
<td>46°08.9’ 72°52.7’</td>
<td>Fyke net 1.5-2 m deep</td>
<td>Male</td>
<td>37.8</td>
<td>25.5</td>
<td>Esin4</td>
</tr>
<tr>
<td>4</td>
<td>July 11, 2006</td>
<td>La Pocatière, St. Lawrence Estuary, Québec</td>
<td>47°22.6’ 70°09.92’</td>
<td>Gill net (sturgeon)</td>
<td>Male</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>5</td>
<td>July 11, 2006</td>
<td>La Pocatière, St. Lawrence Estuary, Québec</td>
<td>47°22.6’ 70°09.92’</td>
<td>Gill net (sturgeon)</td>
<td>Male</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>6</td>
<td>Sept. 30, 2006</td>
<td>La Pocatière, St. Lawrence Estuary, Québec</td>
<td>47°24.22’ 70°03.03’</td>
<td>Eel fishing weir</td>
<td>Female</td>
<td>65</td>
<td>–</td>
<td>Esin5</td>
</tr>
<tr>
<td>7</td>
<td>Oct. 9, 2006</td>
<td>South shore Lake Saint-Pierre, near Nicolet River mouth, Québec</td>
<td>46°13.1’ 72°40.6’</td>
<td>Fyke net</td>
<td>Male</td>
<td>72.2</td>
<td>–</td>
<td>Esin1</td>
</tr>
<tr>
<td>8</td>
<td>July 1, 2007</td>
<td>Kamouraska, St. Lawrence Estuary, Québec</td>
<td>47°34.28’ 69°52.03’</td>
<td>Eel fishing weir</td>
<td>Male</td>
<td>65</td>
<td>–</td>
<td>Esin4</td>
</tr>
<tr>
<td>9</td>
<td>Oct. 3, 2007</td>
<td>Rivière-Ouelle, St. Lawrence Estuary, Québec</td>
<td>47°38.21’ 70°01.94’</td>
<td>Eel fishing weir</td>
<td>Female</td>
<td>74.1</td>
<td>171.6</td>
<td>Esin5</td>
</tr>
</tbody>
</table>

The first Chinese Mitten crab in New York was caught in June 2007, in the Tappan Zee section of the Hudson River, 27 miles upstream of the river’s mouth. A juvenile specimen was found the following year in Cold Spring, Putnam. When two more were found in Tivoli Bays, Dutchess County, it perhaps suggested that reproduction is occurring and Chinese Mitten crabs are moving rapidly upriver (NY Department of Environmental Conservation, 2014).
In 2012, the Connecticut Department of Energy and Environmental Protection (DEEP), and Connecticut Sea Grant confirmed that a juvenile Chinese mitten crab had been collected from the Mianus Pond fishway on the Mianus River in Greenwich. The crab was first delivered to DEEP’s Marine Headquarters in Old Lyme, and following examination by DEEP and CT Sea Grant biologists, sent to the Marine Invasion Research Lab of the Smithsonian Environmental Research Center where the initial identification was confirmed.

The Chinese Mitten crab is obviously present some parts of the NEANS Panel region, and its occurrence at the geographic extremes appears to put the entire region at risk of invasion. Nonetheless, the risk of introduction is uncertain for unaffected areas and the question of establishment is unanswered for the entire region. Risk assessment is a useful tool for reducing this uncertainty. It can assign risk probabilities and help develop thresholds for triggering various management responses.

The following risk assessment discussion is taken from two primary sources, Dittel and Epifano (2009) and Therriault et. al. (2008). The former discusses two approaches for predicting risk, one
that compares ecological characteristics of areas with and without established populations, and a modeling technique, the Genetic Algorithm for Rule-set Prediction or “GARP”, that describes environmental conditions that support Chinese Mitten crab populations and assigns risk factors to areas of potential invasion (Dittel and Epifiano, 2009). Therriault et. al. (2008) then applies the GARP Model to a risk assessment for the introduction of the Chinese Mitten crab in Canadian waters that include parts of the NEANS Panel region. As will be shown, Therriault’s work includes the entire NEANS Panel region when it analyzes the potential for Mitten crab distribution on the Atlantic coast. This discussion provides an overview of risk assessment and makes recommendations for monitoring the Chinese Mitten crab.

Dittel and Epifiano’s examination of the ecological characteristics approach included a habitat comparison method which analyzed the vulnerability of some estuarine systems in the Pacific Northwest. Ecological characteristics of estuaries with established populations were compared to several estuaries in Oregon, Washington, and Alaska. Variables included the area of a watershed and its associated estuary to provide a measure of potential habitat. Horizontal salinity profiles and residence time of estuarine waters were determined to identify areas conducive for larval development and dispersal (Hanson and Sytsma, 2008 in Dittel and Epifiano, 2009). A temperature-driven regression model of larval development to estimate larval duration in the various estuaries was also examined. Results indicated that large estuaries in Oregon and Washington could support crab populations, but that the majority of Pacific Northwest and Alaskan estuaries are not at risk for invasion (Anger, 1991 in Dittel and Epifiano, 2009).

Regarding the GARP modeling approach, Dittel and Epifiano cited Stockwell (1999) and Stockwell and Peters (1999) who described this technique as creating an ecological niche model for a species of interest. The model is based on a set of mathematical rules that represent the limiting environmental conditions, and describes those under which a species should be able to maintain a population. Further, Heborg et al. (2007b) used GARP modeling to generate a predictive model of mitten crab distribution in Europe; the results showed a strong correlation between predicted and observed invasions. In addition, Heborg applied a similar approach to predict the potential distribution of the Chinese Mitten crab on the Atlantic coast of North America. In this case, GARP, when combined with ballast-water discharge patterns, showed that the Chinese Mitten crab was likely to be introduced to the ports of Norfolk and Baltimore. As such, it was concluded that large estuaries in the region, including the Chesapeake, Delaware, and the Hudson were at a high risk for invasion (Heborg et al. 2007a, in Dittel and Epifiano, 2009).

Based on GARP model predictions using the Asian distribution of Chinese mitten crab the highest environmental suitability exists around southwestern Nova Scotia on the Atlantic coast. Moderate suitability exists around much of the rest of Nova Scotia and lower suitability around Prince Edward Island, the mouth of the St. Lawrence River and the Avalon Peninsula of Newfoundland (Figure 5). Using the European GARP model predictions the highest environmental suitability includes much of Nova Scotia and Prince Edward Island. Lower suitability occurs around New Brunswick and parts of Quebec and Newfoundland (Figure 5).
Figure 5: Potential distribution of Chinese mitten crab in NEANS Panel region per GARP model predictions using the native Asian distribution (top) and the invasive European distribution (bottom).
For the NEANS Panel region as a whole, both the Asian and European distribution of the Chinese Mitten crab show the highest environmental suitability in U.S. states, including those with and without known introductions (Figure 5). Even given the relatively lower environmental suitability for establishment in the Canadian provinces, the recent increase in sightings in the St’ Lawrence River, and in particular, the St. Lawrence Estuary argues at least in favor of monitoring Canadian coastal waters for the presence and spread of the Chinese Mitten crab. For the United States portion of the NEANS Panel region, implementing early detection and rapid response strategies appears to be a prudent management decision.
Part Two -- Early Detection

2.1 Background

An early detection (e.g. monitoring) program for the Chinese Mitten crab might include standardized field surveys conducted by a government agency that examines every habitat critical to this species’ life history. Marine and estuarine waters at the mouth of a coastal river where reproduction occurs might be surveyed for planktonic zoeae in the water column from late winter through spring. Suspended plankton nets towed by small craft could be a survey method designed to capture them at the surface and in mid-water. For juveniles that have settled from the water column to adopt a benthic lifestyle, monitoring might be conducted during spring and summer; fine mesh nets or other gear designed for bottom sampling could be used. Seine nets, passive habitat traps, along with, crab, eel, or crayfish pots might be used to capture adult stage crabs during the summer and fall. The monitoring cycle could be completed as adult crabs are similarly detected when their downstream migration during the fall and winter returns them to the river’s mouth to spawn.

The gear types mentioned above have been used successfully to monitor for mitten crabs, but different circumstances can affect their reliability. Passive habitat traps for example work well to capture age 0+ specimens rearing in rivers, but only when crabs occur at a high density (Thompson, 2013). Monitoring strategy itself can be affected by its intended purpose. Searching for crabs that have already been introduced or established may call for surveys that are conducted according to specific temporal, geographic, and gear type criteria. Attempting to discover new introductions at the earliest opportunity may best be served by employing as broad a range as possible of gear types and monitoring strategies. Whether a particular area is at high or low risk for a new introduction can also influence the scope and intensity of monitoring effort. Though nets, traps, and other types of sampling gear are essential to successful monitoring efforts, they will not be discussed in any great detail in this section. Descriptions of gear types that have been or may be useful for monitoring the mitten crab can be found in Appendix II.

Beyond the variables of gear types and monitoring strategies, the traditional monitoring scenario where a sole government agency provides resources and leadership has been in flux for some time. In describing an EDRR system for invasive plants, the USGS compared traditional roles and responsibilities (single agency-led programs) with emerging EDRR partnerships. Regarding early detection and reporting, surveys traditionally led by agencies (e.g., APHIS CAPS Program) are being complemented by volunteer based EDRR networks and public or private land managers (Federal Interagency Committee for the Management of Noxious and Exotic Weeds, 2003). Elements of such networks are already in place in some of the states and provinces represented on the NEANS Panel. AIS monitoring in Connecticut occurs opportunistically as
state agencies conduct other environmental assessments. Massachusetts and Rhode Island rely on citizen based volunteer monitoring networks to conduct AIS field surveys where oversight is provided by a state agency or quasi-state agency. In some cases volunteers may be recruited and trained by a government agency, university, NGO, or other organization to participate in structured field surveys that follow established monitoring protocols. In other cases, outreach/education initiatives are established and stakeholders – commercial and recreational fishers, aquaculturists, SCUBA divers, and boaters among others – are trained to identify AIS and report sightings to a designated government agency or other organization. Though these stakeholders don’t participate in the field surveys that trained volunteers do, their frequent contact with water bodies where mitten crabs may occur makes them good candidates for early detection initiatives. The remainder of this section on Early Detection will focus on two of the primary objectives of the National Management plan as foreshadowed in this paragraph: 1) building partnership based monitoring networks whose members participate in structured field surveys; and, 2) implementing outreach, education, and training initiatives for stakeholders that may have opportunistic sightings.

2.2 Partnership Based Monitoring Networks

Prior to establishing a Chinese Mitten crab monitoring network, it is necessary to determine who might be involved in leading and coordinating its establishment. It is anticipated that the leadership necessary to coordinate the establishment and functions of a Chinese Mitten crab monitoring network – at both the state/province and regional level – should be identified among the NEANS Panel membership. The NEANS Panel has already taken some steps toward this through a Chinese Mitten Crab ALERT.

In partnership with Salem Sound Coastwatch and Northeast Sea Grant programs, the NEANS Panel produced a series of Chinese Mitten Crab ALERT posters, and in so doing asked member states to identify lead agencies and other organizations that would serve as points of contact for Chinese Mitten crab sightings. For each of the five states that did so the NEANS Panel produced a custom made Chinese Mitten Crab ALERT poster which included lead agency contact information. The following list provides links to these posters:

(Connecticut) [http://www.northeastans.org/docs/ctcrab.pdf](http://www.northeastans.org/docs/ctcrab.pdf)
(Maine) [http://www.northeastans.org/docs/mecrab.pdf](http://www.northeastans.org/docs/mecrab.pdf)
(Massachusetts) [http://www.northeastans.org/docs/macrab.pdf](http://www.northeastans.org/docs/macrab.pdf)
(New York) [http://www.northeastans.org/docs/nycrab.pdf](http://www.northeastans.org/docs/nycrab.pdf)
(Rhode Island) [http://www.northeastans.org/docs/ricrab.pdf](http://www.northeastans.org/docs/ricrab.pdf)

In addition to the agencies and individuals identified on the posters, other NEANS Panel members might assist toward establishing a Chinese Mitten crab monitoring network in the state or province they represent on the Panel. The NEANS Panel Membership List provides contact
information for organizations with a demonstrated interest in the problem of AIS. If these organizations possess the interest, expertise, or responsibility to respond to the problem of the Chinese Mitten crab, they may be good candidates to help lead the establishment of a monitoring network. The following link leads to the NEANS Panel Membership List: 

Once the issue of who will lead and coordinate the monitoring network is settled, the next step is to identify other organizations and individuals that might participate in field surveys. The NEANS Panel has held several meetings and workshops that focused on early detection/rapid response and citizen monitoring for AIS. The attendees at a 2006 citizen monitoring workshop sponsored by the NEANS Panel represent a broad range of organizations that might all have an interest in monitoring for the Chinese Mitten crab. Motivations for monitoring could include an interest in protecting commercial or recreational fisheries resources, academic research, water quality protection, environmental education, and a host of other drivers. Regardless of motivation, any of these groups could be important contributors to a coordinated, partnership-based Chinese Mitten crab monitoring network. The different types of organizations as shown on the Workshop Proceedings attendance list include:

- Universities and Research Labs
- Federal Agencies
- State Agencies
- Non-Governmental Organizations
- Schools
- Watershed Groups
- Public Aquaria

A look at the attendance list indicates some potential for recruiting monitoring partners: 

Based on its mandate and expertise, a government agency may be a natural choice to lead the design and implementation of a Chinese Mitten crab monitoring project under accepted scientific protocols. An NGO, university, or other organization with a similar mission and expertise may also be a candidate to do the same. But in partnership with varied other interest groups, the lead agency or organization can enhance its monitoring capacity by helping to develop a volunteer monitoring network whose members are trained to participate in field surveys. The value to an agency, NGO, or other organization with environmental monitoring responsibilities is that the greater number of personnel involved in monitoring means more eyes on the water to provide more comprehensive geographic coverage. But the tasks of recruiting, training, and overseeing
volunteers, and managing the increased flow of field survey data generated by them are not easy. In Rhode Island, newspaper advertisements were used to announce an AIS volunteer monitoring project sponsored by a state coastal zone management agency. About thirty individuals, including retirees, university students, and various professionals, attended the training sessions and proved to be reliable members of the volunteer monitoring network that resulted. However, it is important to keep in mind that early success doesn’t necessarily translate to continued success; retaining volunteers and recruiting new ones is a continual and necessary task if you hope to maintain long-term monitoring results based solely on volunteer networks.

The authors of the National Management Plan recognized this when taking on the task of developing the plan itself. They noted that a strategy essential to the successful implementation of the plan was that its development and implementation will proceed as a cooperative intergovernmental initiative with participation from academia, commercial industries, stakeholders, agencies and other interested parties.

The NEANS Panel recognizes that the same applies to this present EDRR plan. It is recommended that partnership based monitoring networks within the NEANS Panel region proceed as a cooperative initiative. While all successful projects require clear leadership, the task of coordinating and implementing a Chinese Mitten crab monitoring network that relies upon multiple partners should be a shared responsibility. It is therefore recommended that once a lead agency or organization is identified and committed partners agree to form a monitoring network, that a coordination committee be formed to organize its creation and implementation.

The coordination committee will be faced with numerous tasks in creating a successful monitoring network. Few will be as important as recruiting individuals to conduct field surveys. The following outline illustrates how certain partners can potentially contribute to this critical resource need:

1) Universities
   a) Faculty research
   b) Graduate student research
   c) Undergraduate coursework
   d) Independent studies
   e) Student volunteer monitors

2) Non Governmental Organizations
   a) Mission based mitten crab monitoring
   b) Opportunistic sightings via other field work
c) NGO based volunteer monitors

3) Government Agencies
   a) Mission based mitten crab monitoring
   b) Opportunistic sightings via other field work

4) Watershed groups
   a) Mission based mitten crab monitoring
   b) Watershed group based volunteer monitors

Two distinct monitoring scenarios emerge from this outline. In some cases monitoring activities may already be in place under an agency mandate or organizational interest. Federal and state government agencies, universities, NGOs, and watershed groups may have an interest in the mitten crab and already be conducting a field survey. In this case, the mitten crab monitoring network’s coordination committee has the task of communicating with these groups to try and gain access to existing and emerging data relevant to early detection and tracking the spread of mitten crabs.

The other scenario is where monitoring activities are not occurring, agencies, organizations, and individuals may be interested in establishing or participating in a field survey. In this case, the coordination committee is tasked with communicating the importance of early detection and continued monitoring of the mitten crab. The committee should organize or if necessary, produce outreach and education materials and make presentations to try and recruit partners to form a monitoring network that is overseen by the coordination committee. If a monitoring network is formed, the coordination committee would be expected to take responsibility for all aspects of its operation, from field survey design, training volunteer and other field survey participants, providing sampling equipment, scheduling field survey events, data management, and any other tasks required to ensure continued success.

It may be that both scenarios are possible. In this case, the coordination committee’s responsibilities will include continued communication with groups that have established field surveys, and overall project management where monitoring networks are established through the efforts of the committee. In all cases it is important that a coordination committee address at least address the following: 1) develop model monitoring protocols, data collection, and documentation procedures; 2) provide current information about the mitten crab, management issues, and ongoing concerns; 3) develop cooperative working relationships; 4) identify and respond to specific initial and ongoing needs; 5) make recommendations for actions and tasks; 6) cross-train appropriate government personnel and others involved in field surveys; 7) clarification of agency jurisdiction roles and responsibilities; 8) enhanced communication and
coordination; 9) enlisting technical support for taxonomic identifications; and, 10) identification of critically important research questions relevant (National Management Plan, 2003)

The following recommendations are intended to provide guidance for individuals and organizations interested in establishing or enhancing a mitten crab monitoring network in a state or province in the NEANS Panel region. These steps are necessary to determine: 1) the geographic scope that a monitoring network would have to cover; 2) the existing monitoring capacity in a given state or province; and, 3) additional human resources and equipment needed to adequately monitor areas at risk for the introduction or spread of mitten crabs:

1) Conduct risk assessments for all estuarine water bodies to determine their capacity to support the introduction, establishment, and spread of the Chinese Mitten crab

2) Characterize estuarine water bodies to assess the suitability of various monitoring and control methods

3) Identify agencies, organizations and others currently engaged in monitoring for the Chinese Mitten crab to determine their interest in and capacity for increasing current efforts

4) Identify agencies, organizations and others that might potentially engage in monitoring for the Chinese Mitten crab and determine their interest and capacity to do so

5) Determine whether other states/provinces are able to and interested in contributing to a neighboring jurisdiction’s Chinese Mitten crab monitoring network

Determining the level of risk for introductions and the capacity for monitoring of each member state and province is an important first step toward preparing to respond to the threats posed by the Chinese Mitten crab in the NEANS Panel region,

2.3 Outreach, Education, and Training Initiatives

The National Management Plan ranks early detection as a high priority as it affords decision makers the maximum time to address a new introduction. Though it goes on to state that successful implementation of early detection networks, like those described in the previous section, will be enhanced by developing efficient sampling and detection protocols, it emphasizes that early detection efforts will also hinge upon the dissemination of current information, ongoing educational outreach and coordination between affected organizations.

Given that most mitten crab records are random encounters, stakeholders who frequent waterbodies where Chinese Mitten crabs are likely to be found can make significant contributions toward finding new introductions and tracking their spread (R. Schmidt, pers. comm. who has been studying mitten crabs in NY for several years). As such, outreach, education, and training initiatives can be an important part of early detection.
Chinese mitten crab outreach and education efforts have already been employed in the eastern U.S. In the Chesapeake Bay area where the crab was first found in 2005, the Maryland Department of Natural Resources and its partner agencies circulated a mitten crab watch statement to federal, state, county, municipal and private agencies and/or organizations that conduct various sampling programs in the Chesapeake Bay watershed and potential mitten crab habitat. The Maryland DNR also networked with commercial watermen, fish passage monitoring programs, and with power companies that monitor species captured on cooling water intake screens. This broad-based monitoring is the first step to assessing if additional mitten crabs are present in a water body where crabs have already been found.

The National Management Plan also identifies hydropower facilities, watershed groups, volunteers, residents, commercial fishers, recreational anglers, farmers, and civil servants, as potential contributors to early detection if properly trained through outreach and education efforts. Such efforts may be best directed at high risk areas.

For example, education and outreach initiatives directed at organizations and individuals working, living and/or recreating in the Lower Columbia River in Oregon provided materials that enabled people to identify and report the sighting of mitten crabs. An educational video “You Ought to Tell Somebody – Dealing With Aquatic Invasive Species”, was developed specifically for this purpose by the Pacific Northwest Marine Invasive Species Team. In addition, a wallet-sized identification card developed by the US Fish and Wildlife Service with support from Pacific States Marine Fisheries Council and the Bonneville Power Administration served as another valuable outreach tool. After learning about the problems posed by the introduction of the Chinese Mitten crab, some residents undertook a limited trapping program by deploying artificial substrates and baited crayfish traps. This outcome represents a nexus between an outreach, education, and training initiative and a partnership based monitoring network: individuals exposed to outreach, education, and training became active participants in a monitoring efforts. While this is an “value added” outcome, it is nonetheless of great value to simply train stakeholders to know how to identify and report mitten crab sightings.

The coordination committee described in the preceding section on Partnership Based Monitoring Networks should also take on the responsibility of managing a state or provincial Outreach, Education, and Training initiatives. The following recommendations represent some tasks that the coordination committee should ensure are successfully addressed:

1) identify and develop outreach/education/training partnerships
2) appoint media contact person to handle media requests
3) develop and/or distribute existing mitten crab fact sheets.
4) sponsor workshops to educate/train various stakeholders
5) cross-train government agency staff that conduct other field surveys
6) train state/federal conservation and law enforcement officers
7) include mitten crab educational materials on existing websites
Part Three -- Rapid Response

3.1 Background

Just as monitoring is a fundamental element of early detection, control is likewise common to rapid response. Where early detection methods differ according to species, life stage, habitat, and other variables, so too does rapid response, where control options can range from no response to attempted eradication. However, it should be noted no confirmed eradications of an invasive Chinese Mitten crab population have been reported to date. Accordingly, the suite of available control methods includes a wide range of equipment, techniques, and expertise. And just as early detection is well served by partnerships so is rapid response. In fact, similarities between partnership based early detection networks and rapid response networks are so apparent that a detailed discussion of the latter in this section is redundant to that on early detection in Section Two.

In practice, early detection and rapid response networks should be combined to ensure that the resources and commitments required to successfully address the problem of a Chinese Mitten crab invasion in the NEANS Panel region are available under pre-invasion scenarios. As such, any interest in rapid response networks and their related outreach, education, and training initiatives is well served by referring to the two sections in Part Two of this document (Early Detection) that address them. The remainder of this section will instead outline some rapid response methods and two models by which rapid response networks can be organized and implemented.

3.2 Quarantine as a First Option

The first action a state or province should consider when an introduction is confirmed is to quarantine an affected waterbody. Government agencies are typically authorized to enforce quarantines through its police powers. In the United States police power is conferred by the Tenth Amendment of the U.S. Constitution, upon the individual states, and in turn delegated to local governments. The police power allows a state to place restraints on personal freedom and property rights of persons to protect public safety and health among other purposes (Black’s Law Dictionary, 1991). For example, the Rhode Island General Assembly authorizes its agencies to adopt emergency rules when:

“an agency finds that an imminent peril to the public health, safety, or welfare requires adoption of a rule upon less than thirty (30) days' notice, and states in writing its reasons for that finding, it may proceed without prior notice or hearing or upon any abbreviated notice and hearing that it finds practicable, to adopt an emergency rule.” [RIGL 42-35-3 (5) (b)]

In Rhode Island, an emergency regulation to prevent the introduction of an invasive baitfish called the “black salty” was enacted under this statute. As such, the state’s coastal waters were effectively quarantined against the introduction of a potentially invasive finfish.
When used in response to an actual invasion, a quarantine can give a state’s resource agencies a head start on controlling the spread of an introduced species by restricting activities in a waterbody including denying otherwise legal public access. In this way the unintended spread of an invasive species by recreational and commercial fishers, boaters, and other user groups is minimized if not eliminated. Under this scenario, only individuals trained in rapid response would be allowed access to a quarantined waterbody to implement control methods. Whether quarantine is or can be enacted in a given jurisdiction or not, the following rapid response methods provide guidance for agencies and others faced with minimizing the impacts of invasive species. Some of these methods were successfully implemented in California where extensive agricultural water infrastructure exists. While some of these methods may not appear to be applicable to the rivers and coasts of the northeastern U.S. and Canada, they are intended as guidance toward the development and application of rapid response methods that prove successful in the NEANS Panel region.

3.3 Some Rapid Response Methods

Rapid response methods should be evaluated for their applicability to specific scenarios. If an invasion has not yet occurred but seems imminent it is important to consider control strategies based on the different life stages of the Chinese Mitten crab.

Plankton net tows can provide the earliest evidence that Chinese Mitten crabs have arrived due to the large numbers of zoeae that can inhabit the estuarine mouths of coastal rivers following spawning events. But this early detection method has virtually no value for rapid response.

Many attempts to control Chinese Mitten crabs have focused on capturing adult specimens as they migrate down river to spawn. Deploying fyke nets, gill nets, and/or seine nets may be the best methods to capture adults in rivers without dams. Where dams are present placing barrels or other collection devices at the downriver base of a dam, a popular method deployed in Germany during the 1930s, may be the most effective option. In all cases, it is important to follow criteria for choosing the best rapid response approach, some of which include:

1) Financial costs and funding sources
2) Human resources required
3) Environmental, economic, and human health impacts
4) Timeframes for planning, implementation, and post-treatment monitoring
5) Scale of the invasion and the efficacy of rapid response options
6) Public relations value of different rapid response methods (chemical v. mechanical)
7) Identifying necessary permits and processing time based on response method(s)
8) Determining the need for and scope of outreach/recruitment of stakeholders.

Most of the following alternatives were derived from the National Management Plan for the Genus Eriocheir (Mitten Crabs), as submitted to the Aquatic Nuisance Species Task Force. Some are specific to dealing with very large numbers of adult crabs, as was the case at the
Tracy Fish Collection Facility, in Tracy, California (TFCF). Others are associated with efforts in Germany during the 1930s to control huge, migrating adult populations located in rivers many miles inland from the North Sea. [see Panning, A. (1939) The Chinese mitten crab, Annual Report Smithsonian Institution, 1938, pp. 361-375].

Alternative #1 No Response

The inherent risk in this decision is that a reproducing population may become established and lead to long-term impacts. Prior to choosing this option it is critical to understand to the greatest extent possible the types of impacts that may result. A fundamental consideration is whether the biodiversity of an affected native ecosystem can maintain itself under an invasion scenario. A thorough analysis of potential impacts on specific habitats (i.e. river banks) and native species (crabs and other species that directly compete with Chinese Mitten crabs) should be conducted. The No Response option may be viable if it can be shown that the establishment of a Chinese Mitten crab population will not result in the loss of or significant impacts on critical native resources. It is important however to consider the impact of a negative public response to this option should any predictions of “no significant impacts” prove false. Ultimately, this option must be weighed against a State’s responsibility to protect its environmental resources. In general, this alternative is not recommended.

Alternative #2 Physical Control Methods/Trapping

Physical control methods or trapping was the method for capturing Chinese Mitten Crabs in the 1930s in Germany. Multiple methods were used, some examples are as follows. Barrels, covered with wire netting or canvas, were lowered with davits to be bottom of dams. The crabs, pushed up against the dam then crawled high up onto the barrels, fell into them and then were caught. In 1935, from January to May, 12,166kg of mitten crabs (3,444,680 specimens) were caught. However, some crabs that were pushed up against the dam would find an alternate route around the dam. They would crawl up the walls and finally out on the shore so as to pass the dam by land. However, shore regions below the dam were shut off by means of sheet iron and trenches dug in the ground. The crab would fall into the metal trench after wandering along the sheet iron. This method caught 787,100kg of mitten crab in 1935 and 58,300kg in 1936. One last method utilized was eel-basket pots set in the water behind the dam outlets. Multiple crabs were caught this way as well.

More recently, researchers have experimented with a variety of physical control methods to reduce the mitten crab population. In California, a pilot project to evaluate the feasibility of capturing adult crabs via a diversion and pitfall trap during fall downstream migration. Success of this method was very high, with an estimated 11,000 crabs captured on one small creek during a 6-week period, with 85% of the crabs caught in less than 3 weeks. Additional experimentation with various types of traps, artificial substrates, and baits has been
conducted. Trapping methods have shown variable success, and may not in all cases be an effective population control option.

One interesting caveat to this method of prevention is the need for structural barriers to be installed in the waterways where the mitten crab is present. Recently, dams have been removed in order to restore habitat. It is recommended that each state and province assess the susceptibility of rivers to support reproducing Chinese Mitten Crab populations, and determine if there are any plans to remove dams. If the dams in these areas are removed, then this control method is not applicable to those rivers. Depending on the method chosen trapping be a low impact/low cost control option. However, as trapping has not been shown to eradicate Chinese Mitten crab populations, its effectiveness may be enhanced in combination with other control methods.

**Alternative #3 Fishing Licenses/Bounty Species**

There are incentives and disincentives inherent in relying on a bounty program as a Chinese Mitten crab control method. Regarding incentives, a bounty can transfer the cost of detecting new populations, monitoring existing populations, and reducing impacts from the public to private sector. Innovative and efficient capture methods may be developed as individuals who invest personal resources in a bounty program seek to lower their participation costs. As for disincentives, the financial incentive provided by a bounty program could encourage the intentional release of Mitten crabs into non-affected waterbodies to establish new populations. Researching bounty programs that have been implemented in the past as population control methods may provide valuable insights regarding how maximize incentives and minimize disincentives. Prior to any such effort however, it should be determined whether a State or Province has the funding necessary to support a bounty program. If funding is either not available or insufficient, it may be necessary to provide non-monetary incentives to encourage participation.

The following alternatives may be most applicable to facilities similar to the Tracy Fish Collection Facility (TFCF) in Tracy, California as outlined in the Chinese Mitten Crab National Management Plan.

**Alternative #4 Traveling Water Screen (TWS) with minor operational changes**

A method that showed a great deal of promise at the TFCF facility was a scaled down version of traveling water screen which removed over 80% of crabs from the water column. This would be an investment as it requires building a specialized TWS, and the amount of money required to build this device could be considered a disadvantage. But it has many advantages as well such as low impacts on fish salvage and water supply. It has high crab
elimination efficiency and would be popular with the public and stakeholders. The utilization
of the TWS was the method of choice at TFCF.

Alternative #5 Traveling Water Screen (TWS) with Reduced Pumping

This is similar to the previous alternative only with reduced water pumping. This alternative
would reduce water supply which is a huge disadvantage to this alternative and it would not
garner public support even if it is effective at removing mitten crabs.

Alternative #6 Lifting the Louvers (only) to allow crabs to pass through the Fish Collection
Facility

This solution requires lifting Louvers about 6 inches along the bottom. This allows most
topwater and midwater fish to enter a bypass system in the fish collection facility, but would
allow debris and bottom dwelling fish to flow down to a water pumping plant. This is not a
high cost alternative, but there may be a large loss of fish and risks for to the water supply.
This plan would not have optimal efficiency for capturing mitten crabs, and because of the
effects it has on both fish and water supply it would not be popular with the public or
stakeholders.

There were other alternatives that involved lifting Louvers outlined in the Chinese Mitten
Crab National Management Plan; some were considered unacceptable because of the risks
that they held to the water supply or fish supply. Others that involved coupling lifting the
Louvers with the Traveling Water Screen were found to be redundant because of the use of
two effective ways of removing crabs, but these two methods are mutually exclusive.

Alternative #7 Harvest Crabs from in Front of the Fish Collection Facility either by the
agency in charge of the facility or by contract

This involves the removal of crabs in front of the trash rack structure. If the agency does the
work the benefit is that the agency has knowledge of the facility and work will be better
coordinated. In the alternate this job could be contracted out if the agency did not have the
time to design, plan and implement a crab harvest program for this area. This plan would be
very expensive, and have moderate fish salvage and water supply risks. The actual efficiency
of crab removal is unknown.

Alternative #8 Harvesting crabs from within the Fish Collection Facility by contract

This plan explores the possibility of removing crabs from within the facility. Contractors
would remove crabs from all areas within the compound. All the equipment would be on site
and no facility employees would be utilized unless there is a problem. However there may be space constraints and interference with “criteria” flows that are required to efficiently salvage fish. This plan would be high cost due to the contract and could potentially have moderate impacts on fish salvage and water supply depending on the method used to harvest the crabs. Due to the unknowns and possible risks, this plan may not be popular with stakeholders.

Alternative #9 Trash Rack Alteration

Crabs can penetrate the trash rack structure, but not the louvers; it would be possible to prevent crabs from entering the fish collection facility if the trash rack spacing was narrowed to the same size, or smaller, than that of the louvers. However, the rack would most likely become fouled with debris and crabs; not filtering fish properly and in time lowering the downstream water elevation. It would be a high cost to build, and would have a high fish salvage and water supply risk. It may also not be popular with stakeholders as there is a large probability of decreased operation of the facility.

3.4 Models for Rapid Response

Regardless of which rapid response model is chosen to administer a control/eradication plan, it is important to have a complete understanding of every level of government jurisdiction over each proposed control event. Federal, state, and perhaps in some cases local government agencies require permits for activities such as the applying chemicals, deploying capture gear, possession of wild animals and other activities. As such, coordinating and streamlining the permitting process in order to accommodate rapid response without delay is of utmost importance.

This section discusses two possible models for Rapid Response: the Incident Command System and the SCCAT model used in California in response to *Caulerpa taxifolia* as described by Lars Anderson. Much of this material was excerpted from A Model Response Plan for Aquatic Invasive Species. Mississippi River Basin Panel On Aquatic Nuisance Species, 2010.

The Incident Command System

This section serves as an overview of the Incident Command System and the way it is applied in the event of invasion by a nuisance aquatic species.

The following flowchart (Figure 3) details the general plan of operations for responding to an Aquatic Invasive Species incident utilizing the Incident Command System. The chart
provides an overview of what needs to be done in response to a new introduction. Toward the bottom half of this chart is where the Incident Command System comes into play.

Figure 3. Overview of the rapid response process. (Source: A Model Response Plan for Aquatic Invasive Species. Mississippi River Basin Panel On Aquatic Nuisance Species, 2010.)
The Incident Command System (ICS) is structured to provide a systematic approach to guide departments and agencies at all levels of government, nongovernmental organizations, and the private sector to work seamlessly to rapidly respond to an Aquatic Invasive Species (AIS) introduction, regardless of cause, location, or complexity. ICS establishes common processes for planning and managing resources and allows for the integration of facilities, equipment, personnel, procedures, and communications operating within a common organizational structure.

ICS provides an organizational structure for incident management (Figure 4) and guides the process for planning, building, and adapting that structure. The ICS organizational structure has 5 major functional elements (i.e., command, operations, planning, logistics, and finance and administrations) and develops in a modular fashion as needed based on the size and complexity of the incident. Responsibility for the establishment and expansion of the ICS modular organization ultimately rests with Incident Command, which bases the ICS organization on the requirements of the situation.

Incident command is accomplished using one of two approaches. When an incident occurs within a single jurisdiction and there is no jurisdictional or functional agency overlap, a single Incident Commander (IC) is designated with overall incident management responsibility by the appropriate jurisdictional authority. However, when an AIS rapid response involves multiple jurisdictions, a single jurisdiction with multiagency involvement, or multiple jurisdictions with multiagency involvement, Unified Command (UC) allows agencies with different legal, geographic, and functional authorities and responsibilities to work together effectively without affecting individual agency authority, responsibility, or accountability. This second approach is most likely the one that would be utilized by the NEANS Panel region, as it involved multiple jurisdictions. By working together as a team under UC, all agencies with jurisdictional authority or functional responsibility for the incident jointly provide management direction through a common set of incident objectives and a single planning process. Under UC, a single agency may still be designated as the overall lead and that agency’s official identified as the IC for incident management.
Centralized, coordinated incident action planning is used to guide all response activities and communicates management by objectives throughout the entire ICS organization. Management by objectives is accomplished through a systematic planning process that • establishes incident objectives, • develops strategies based on incident objectives, • develops and issues assignments, plans, procedures, and protocols, • establishes specific, measurable tactics or tasks for various incident management functional activities, and directs efforts to accomplish them, in support of defined strategies, and • documents results to measure performance and facilitate corrective actions.

The Planning “P” (Figure 5) is a visual representation of the ICS planning process and serves as a step-by-step guide to response, from the onset of an incident to monitoring and evaluation of the response actions. The Planning P can be broken into two functional components: the leg of the “P” describes the initial response period, and the planning cycle at the top of the “P” is completed during each operational period of a rapid response action.

An Incident Action Plan (IAP) for the next operational period is developed during each planning cycle to provide a concise, coherent means of capturing and communicating the overall incident priorities, objectives, strategies, and tactics in the context of both operational and support activities. Most initial response operations are not captured with a formal IAP; however, if an incident is likely to extend beyond one operational period, become more complex, or involve multiple jurisdictions and/or agencies, preparing a written IAP will
become increasingly important to maintain effective, efficient, and safe operations. The IAP consists of a series of standard forms and supporting documents available on-line at: http://www.fema.gov/emergency/nims/JobAids.shtm. Once the initial set of forms has been completed, the IAP can be rapidly revised and updated for the next operational period.

The Incident Command System has its merits. It provides a consistent framework with which to deal with emergencies, but it does not take into account local resources and expertise as the SCCAT model from California does. This difference will be discussed in the next section.

The Southern California Caulerpa Action Team or SCCAT Model

SCCAT was developed in California to deal with the invasion of Caulerpa taxifolia in the area. While it started with just “official agencies,” it would later come to include several public and private groups as well. SCCAT acted as an advisory consortium with the goal of implementing eradication plans. This is the type of group that the NEANS panel could be a part of and even help moderate in order to implement eradication plans in a timely and effective manner. Meetings were held between Federal, State, and Local agencies on a monthly basis and more frequently as needed. A separate committee to address public education, outreach, and technical issues was also formed. The Steering Committee also deals with stakeholders in the area; this was in an effort to develop consensus based use plans.

With all of these groups involved, there were initially some issues in developing consensus on both a technical and sociological level, they were ultimately worked through a solution based upon the advice of local experts and user groups was formed. One other issue with SCCAT was due to its “virtual status” it could not handle money from sources such as the federal government, but this issue was remedied by funneling the money through other channels. This may not be a problem in the case of the NEANS Panel though.

As this was a successful eradication, it highlights the fact that early and effective response is essential. This method is essentially the opposite of the Incident Command System because it relies on a “bottom-up” approach. It engages key local stakeholders, and local resources needed to carry out the eradication. Local resources include expert knowledge of the terrain and ecosystems, as well as the target species and its possible eradication methods, but may also include funding and man-power.

To implement this system effectively, Anderson recommends implementing a pest alarm. This system does incur some investment, but in the end will determine where the expertise lies, resolve regulatory issues, and discern if there are any gaps in operational abilities. A
Non-native Invasive Pest Intervention Team would be formed from the utilization of this alarm. The following is summary of the pest alarm system (Figure 6).

![Diagram of the pest alarm system]

Overall, it is recommended that the NEANS Panel look into this alternative approach. It focuses more on the individual areas and utilizing the expertise of both the government agencies involved but also user groups in a coordinated manner.
Part Four – Post Response Monitoring

4.1 Post-Response Assessment Period

In order to measure the effectiveness of a rapid response initiative it is necessary to conduct a post-response assessment. The criterion for eradication is simple: no living portion of an invasive species can remain to re-infest a site. Assessment should take place for a minimum of one reproductive cycle after eradication. Based on the success of SCAT, it is recommended that a multi-year monitoring plan be conducted before a successful eradication can be announced.

4.2 Long-term Monitoring Networks

Regular monitoring is just as important after a species has been eradicated from an area, as it is before an invasive species establishes itself. Section 2.4 of this plan deals with the Monitoring Capacity of the NEANS Panel Region and methods can be implemented for monitoring. It is recommended that governmental and user group systems are once again established and the same or improved methods should be re-established and monitoring continued after the Chinese Mitten crab has been eradicated.

4.3 Public Outreach

Just as public outreach is important before an invasion of a nuisance species occurs, it is important to continue working with the public after the eradication is complete as well. Public outreach at educational facilities, interest group meetings, and other non-governmental organizations will be a vital component to ensure that there is not a recurrence of an infestation of the nuisance species. It is important to use various methods of outreach as well as media events to ensure that people are kept aware of the possible threat of invasion and to encourage them to help participate in such things as continued monitoring for the species.
References


Eriocheir sinensis/zooplankton sampling methods, California Department of Water Resources Accessed 9/19/14 at: http://www.water.ca.gov/bdma/meta/zooplankton.cfm


APPENDIX I

Chinese Mitten Crab Identification Guide

Mitten Crab
Eriocheir sinensis

History
* Between 2005-2008, 19 individuals were confirmed along the U.S. Atlantic coast in the Chesapeake Bay (2005-2007), Delaware Bay (2007), Hudson River (2007-2008), and Raritan Bay and Toms River, New Jersey (2008)
* In Quebec, specimens have been collected from St. Lawrence River at Notre-Dame-de-Pierreville in 2004 and Quebec City in 2005
* Both females and males have been found, but an established reproductive population in eastern U.S. has not been confirmed as of the summer of 2008

Characteristics
* Light brown to olive green
* Carapace (shell) up to 4 in (10 cm) wide
* 4 lateral spines on each side of carapace
* Notch between the eyes
* Claws hairy with white tips
* Claws normally equal in size
* Legs longer than twice the carapace width

Habitat
* Estuaries, lakes, riparian zones, water courses, wetlands
* Burrows in the bottom and banks of freshwater rivers and estuaries
* Tolerates wide range of temperatures
* Catadromous life cycle: begins as estuarine larva, migrates into freshwater streams for 1-4 years, then returns to coast to reproduce
* Able to survive in highly polluted aquatic habitats
* Adept at walking on land and around barriers

Known Distribution
* Native to east Asia
* Chesapeake Bay, Delaware Bay, Hudson River, New Jersey, Quebec

Impacts
* Efficient predator and competitor for food; may have a profound effect on native biological communities
* Damage to fishing gear
* Clogged pumps, screens, and intake pipes
* Burrowing activity may accelerate erosion of banks and levees
Identifying characteristics of an adult Chinese Mitten crab [http://www.delta.dfg.ca.gov/mittencrab/]

Female (top) and male (bottom) Chinese Mitten crabs [http://www.dfg.ca.gov/delta/mittencrab/photos.asp]
This photo shows the sub-adult Chinese Mitten crab found in the Mianus Pond fishway. Note the lack of front claws whose hairy “mittens” make identification much easier. It is important to be aware that other characteristics can be diagnostic when attempting to identify a specimen. Some of these characteristics include:

- light brown to olive green coloration
- u-shaped notch centered between eyes
- four spines on lateral edges of carapace
- long legs/greater than two times carapace width
- walking crab/tips of rear set of legs pointed and not flattened like a swimming crab’s
- carapace up to four inches wide
- bumpy carapace

Photo credit: Nancy Balcom, Connecticut Sea Grant
Fig. 3. Comparison of distinguishing morphological features in the megalopa stage of two species of mitten crabs (Eriocheir sinensis and E. japonica) and the Asian shore crab Hemigrapsus sanguineus. a = dorsal view of E. sinensis. b = dorsal view of E. japonica. c = dorsal view of H sanguineus. d = 1st maxilliped of E. sinensis. e = 1st maxilliped of E. japonica. f = 1st maxilliped of H sanguineus. g = 2nd maxilliped of E. sinensis. h = 2nd maxilliped of E. japonica. i = 2nd maxilliped of H. sanguineus. Scale bars for E. japonica and H sanguineus = 0.1 mm. Arrows indicate examples of differences in shape of rostrum and setation patterns on maxillipeds. (Taken from Kim and Hwang 1990; Hwang et al., 1993; Montu et al., 1996).
Comparison of various distinguishing morphological features of first zoeal stage of two species of mitten crabs and three species of shore crabs

Fig. 2. Comparison of various distinguishing morphological features of first zoeal stage of two species of mitten crabs (Eriocheir) and three species of shore crabs (Hemigrapsus). a = lateral view of E. sinensis. b = lateral view of E. japonica. c = lateral view of H. sanguineus. d = lateral view of H. nudus. e = lateral view of H. oregonensis. f = dorsal view of telson E. sinensis. g = dorsal view of telson E. japonica. h = dorsal view of telson H. sanguineus. i = dorsal view of telson H. nudus. j = dorsal view of telson H. oregonensis. k = maxillule E. sinensis. l = maxillule E. japonica. m = maxillule H. sanguineus. n = 1st maxilliped E. sinensis. o = 1st maxilliped E. japonica. p = 1st maxilliped H. sanguineus. Scale bars for E. japonica and H. sanguineus = 0.1 mm.; Scale bars for d and e = 40 μm; f, i, j = 10 μm; k = 100 μm (Taken from Kim and Hwang, 1990; Hwang et al., 1993; Montu et al., 1996; Rice and Tsukimura 2007).
APPENDIX II

Chinese Mitten Crab Monitoring and Control Methods: Selected Gear Types

The following methods and gear types are not exhaustive. Some were recommended to the NEANS Panel by Dr. Brian Tsukimura, Professor, Department of Biology, California State University, Fresno, as they cover all life stages. Trawling for planktonic zoeae was recommended as an efficient way to track the spread of Chinese Mitten crabs along the coast after the establishment of a reproducing population has been confirmed in a specific location. Rhode Island initiated a plankton net trawl survey in Little Narragansett Bay and the Pawcatuck River after a sub-adult Chinese Mitten crab was found in Connecticut in 2012. As the establishment of a reproducing population in the Hudson River estuary has also been confirmed, the presence of this specimen may indicate the spread of this population along the southern New England coast.

Should zoeae be found via plankton trawls in a coastal river, monitoring could be expanded to include sampling equipment that targets adult crabs. Many adult and sub-adult specimens have been captured in the field opportunistically by existing gear types not designed for this purpose. The Connecticut specimen was a sub-adult collected from a fishway in Mianus Pond on the Mianus River in Greenwich (CT Dept. of Energy & Environmental Protection, 2012). Photos of this fish weir are included in this appendix. In addition, all the specimens captured in the St. Lawrence River at Quebec were found in fyke nets, gill nets, or eel weirs.

A. Mysid net

The mysid net, from 1968 through 1970, was made of 1 mm silk bolting cloth, was 1 m long and had a mouth area of 0.1 m². From 1971 through 1973 the Neomysis net was made of 0.93 mm mesh nylon cloth, had a 30 cm mouth diameter, and was 0.7 m long. From 1994 to the present, the mesh size has been 0.505 mm, the mouth diameter 30 cm and the length 1.48 m. All mysid nets tapered to 76 mm at the cod end where a polyethylene jar screened with 0.505 mm mesh wire cloth captured the mysids. Until 1973, Pygmy flow meters were used to estimate water volumes filtered by the mysid net. From 1974 to present General Oceanics model 2030 flow meters have been used. Samples are preserved in 10% formalin with Rose Bengal dye to aid in separating organisms from detritus and algae.

B. Clarke Bumpus net

The Clarke-Bumpus net, from 1971 through October 2004, was made of 0.160 mm mesh nylon cloth (No. 10 mesh), had an outer mouth diameter of 12.5 cm (interior mouth diameter of 12.4 cm), and a length of 76 cm. It tapered to 45 mm at the cod-end where a polyethylene jar screened with 0.140 mm mesh wire cloth collected organisms. The original brass CB net-frame possessed
an integrated flow meter. Beginning November 2004, the study began using a new CB frame design, because the manufacturer discontinued production of the historically used brass CB frames. The new frame consisted of an acrylic cylinder 12.5 cm outer diameter (interior mouth diameter of 12.0 cm, due to new acrylic frame being thicker than previous metal frame) by 19.0 cm long with a General Oceanics model 2030 flow meter bracketed inside; net mesh and dimensions remained the same. The CB and mysid nets were mounted on a tubular steel frame. The Clarke-Bumpus net was mounted directly above the Neomysis net. Samples are preserved in 10% formalin with Rose Bengal dye to aid in separating organisms from detritus and algae.

<table>
<thead>
<tr>
<th>Life Stage</th>
<th>Sampling Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zoeae/Megalopae:</td>
<td>Mysid net tows (300 μm mesh) or Clarke-Bumpus net tows (150 μm mesh)</td>
</tr>
<tr>
<td>Megalopae/Juveniles:</td>
<td>Recruitment collector (submerged Tuffy™ nylon dish scrubbing pads)</td>
</tr>
<tr>
<td>Juvenile crabs:</td>
<td>Shelter traps (stacked PVC tubes)</td>
</tr>
<tr>
<td>Adult crabs:</td>
<td>Otter trawls/nets or Collections from salvage tanks</td>
</tr>
</tbody>
</table>


**Zoeae/Megalopae:** Mysid and Clarke-Bumpus nets were towed behind a ship, with flow meters to record flow rate and calculate the catch-per-unit-effort (CPUE) using the volume of water moving through the net. Samples were collected monthly.

**Megalopae/Juveniles:** Four Tuffy nylon dish scrub pads were held underwater by a rope or cord approximately one meter from the anchor. Collectors were sealed in a bag and frozen en route to the lab for organismal identification. The devices were collected twice a month.

**Juvenile crabs:** Shelter traps were a stack of multiple PVC tubes (total 6” diameter) and affixed to a submerged crate or cage, with openings on one end of the tubes. Traps were left out for two weeks.

**Adult crabs:** Otter trawls or bottom trawling by ship for benthic organisms have been used to detect adult and juvenile crabs taken at weekly to monthly intervals with transects of 0.5 km².
Table 1. Origin, methods, dates, and geographic coverage for Chinese mitten crab data

<table>
<thead>
<tr>
<th>Data collected by</th>
<th>Type of data collected</th>
<th>Methods</th>
<th>Years of data</th>
<th>Geographic coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine Science Institute</td>
<td>Adult population dynamics and morphology</td>
<td>Otter trawl</td>
<td>1995–2001</td>
<td>Open waters of South San Francisco Bay</td>
</tr>
<tr>
<td>California Department of Fish and Game</td>
<td>Juvenile burrow densities</td>
<td>5 m transects</td>
<td>1997, 1998</td>
<td>Suisun Marsh and tidally influenced portions of the Delta</td>
</tr>
<tr>
<td></td>
<td>Adult population dynamics and morphology</td>
<td>Otter trawl</td>
<td>1996–2001</td>
<td>North Bay and Delta</td>
</tr>
<tr>
<td>University of California at Davis</td>
<td>Adult population dynamics and morphology</td>
<td>Otter trawl</td>
<td>1996–1999</td>
<td>Suisun Marsh</td>
</tr>
<tr>
<td>US Bureau of Reclamation, Tracy Fish Collection Facility</td>
<td>Adult population dynamics and morphology</td>
<td>Collections from fish salvage tanks</td>
<td>1996–2000</td>
<td>southern Delta</td>
</tr>
</tbody>
</table>

Fish weir at Mianus Pond, Mianus River, Greenwich, CT.
http://www.greenwichct.org/upload/medialibrary/462/Fishway_Camera_Details_lg.jpg

Fish weir at Mianus Pond, Mianus River, Greenwich, CT.
http://ww1.hdnux.com/photos/12/74/65/2870648/7/628x471.jpg
This photo shows the eel ladder deployed by Dr. Robert Schmidt, Professor, Bard to capture adult Chinese Mitten crabs on the Saw Kill River in New York. The successful deployment of the eel ladder demonstrates that existing gear not designed for mitten crab monitoring can be used for that purpose.

Photo scanned from Dr. Robert Schmidt PowerPoint presentation given at the First Marine and Estuarine Invasive Species Conference, University of Rhode Island, August, 2012
APPENDIX III

Links to NEANS Panel AIS Monitoring Resources

1) Chinese Mitten Crab ALERT print-ready posters for the following states:
   - Massachusetts: http://www.northeastans.org/docs/macrab.pdf
   - Rhode Island: http://www.northeastans.org/docs/ricrab.pdf

2) Rapid Response to Aquatic Species in the Northeast: Developing an Early Detection and
   Eradication Protocol May 2003 Workshop Proceedings - document released September
   2003 (5.4M, pdf)
   http://www.northeastans.org/docs/rr-proceedings0903.pdf

3) Implementing Rapid Response to ANS in the Northeast: Key Components of a
   Successful Program. May 2005 Workshop Proceedings (5.4M, pdf)

4) Citizen Volunteer Monitoring Workshop packet with PowerPoint presentations October
   2006 (19M, pdf)

5) Freshwater Nuisance Species Prevention & Early Detection: Northeast Programs and
   Potential for Regional Collaboration. May 2008 Workshop Summary (145k, pdf)