Environmental Conditions Affecting Mitten Crab Abundances in the San Francisco Bay-Delta

Brian Tsukimura, California State University, Fresno

SUMMARY

This project examines the environmental factors affecting the survival of mitten crab zoea, in the hopes of better understanding patterns of Chinese mitten crab abundance in the San Francisco Bay-Delta region. The basic idea behind the research is that under optimal conditions, zoeal survivorship should predict adult abundance three to four years later, the time it takes for the crabs to reach adulthood.

During the course of this project, the scientist showed that the temperature and salinity of waters in San Pablo Bay in northern San Francisco Bay are correlated with zoea survival and hence, in theory, should be correlated with adult mitten crab numbers four years later. The temperature-salinity link makes sense, since mitten crabs are native to the relatively warm waters off China. The crabs are also catadromous, meaning their life cycle requires both fresh and saline waters to complete.

Among the many findings of the project, mitten crab zoea cannot tolerate temperatures below 11.7º C. This was observed in plankton tow data and confirmed in subsequent laboratory experiments. Because of their temperature sensitivity, the bulk of zoea growth occurs between March and May, when waters in San Pablo Bay rise above 11.7º C.

There was also a compelling link between monthly freshwater flow rates by Chipp Island in the Sacramento-San Joaquin Delta and adult mitten crab abundance in San Pablo Bay. This link is the topic of ongoing research. However, it appears that when salinities top 22 parts per thousand (i.e., when flow rates by Chipp Island are relatively weak) anchovies can enter the bay and prey on zoea. Water diversions in the delta raise salinity levels in San Pablo Bay and likely help reduce adult mitten crab numbers.

Lee Mecum, California Department of Fish and Game

The Chinese mitten crab is native to estuaries and creeks in the Yellow Sea in China and Korea. Besides its furry pinchers, which earn it its sobriquet, it is a nondescript brown crab – about 3 inches in diameter.

MITTEN CRAB LIFE HISTORY MODEL

Much of the project was spent studying the life history of the mitten crab (*Eriocheir sinensis*). The more salient points of this are recapitulated here.

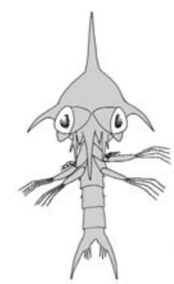
Mitten crab larvae hatch and develop in brackish waters. After metamorphosis, they migrate into freshwater tributaries to develop into adults, a process that can take one to four years depending on water temperatures and food availability.

In the year in which adults reach sexual maturity, they do so in late spring or early summer. These adults migrate downstream into brackish water a few months later, in late summer and fall. Here they mate and oviposit eggs, which are carried by females until the eggs hatch. The majority of ovigerous crabs (crabs carrying eggs) are found between December and March.

It is believed that mitten crabs, like salmon, reproduce once and die. However, one mitten crab breeding cycle can produce two brood classes, corresponding to larvae that settle prior to the winter temperature decline and those that hatch and settle afterward. The former group of juvenile crabs will be larger than the latter, complicating efforts to use environmental parameters as a means of predicting year-class strength.

LARVAE

Mitten crabs typically have one prezoeal and five zoeal stages. Zoea are euryhaline; however, in the later zoeal stages, they require at least 16 or 17 parts per thousand (ppt) salinity to survive.



Front view of Chinese mitten crab zoea.

As expected, water temperature has a strong influence on whether, and the rate at which, zoea develop. This was shown in laboratory experiments and by analyzing the contents of plankton tows from 1997 to 2005. (These tows are conducted by the California Department of Fish and Game.)

As mentioned previously, zoae were absent in tow data during periods when water temperatures were below 11.7º C. In terms of monthly abundances, zoea were found in San Pablo Bay from December to June, with the highest abundances in March and April. All zoea found in December and January were stage I; stage II zoea were found in February only in 2003. Larvae growing into stage II zoea were rare before March, likely because water temperatures were too cold earlier. In March, only stage I (84.7%), stage II (12.6%) and stage III (2.7%) zoea were present. No stage IV or V were found.

Nearly half of the total zoeae seen in April were later stages: stage II (22.3%), stage III (19.7%) and stage IV (3.5%). Stage V zoea first appeared in April and comprised 3.8% of the total zoea count in May. Zoea abundance declined rapidly in May and June as the zoea developed into megalopa (post-larvae); it takes about two months for zoea to develop into megalopa under typical conditions.

Laboratory experiments were conducted to quantify zoea growth rates at different water temperatures. For these numbers, the interested reader is referred to the scientist's full report to Sea


Carolynn Culver

A culinary delicacy in Asia, the mitten crab is a nuisance species in the San Francisco Bay-Delta.


Carolynn Culver

This fish salvage tank is supposed to hold fish diverted from the Bay-Delta. Instead, it is clogged with mitten crabs.


Carolynn Culver

The divots are mitten crab burrows.

Grant, which can be downloaded through the University of California eScholarship repository at http://repositories.cdlib.org/escholarship/.

CORRELATIONS WITH WATER TEMPERATURE

Although 11.7° C appears to be a critical thermal point, efforts to correlate water temperatures with adult year-class strength in tributaries of the bay failed. A warmer winter in 1996 was correlated with high adult year-class in 1999. The winter of 1999, however, was exceptionally cool and 2002 was a strong year-class. The life-history model is clearly more complicated than simply using larval water temperature to predict adult abundances four years out.

CORRELATIONS WITH FRESHWATER

To search for other environmental factors that might be modulating adult mitten crab numbers, the scientist compared monthly freshwater flows by Chipp Island, located just downstream from where the Sacramento and San Joaquin rivers merge, to adult mitten crab abundance, as estimated by adult mitten crab catch-per-unit effort in San Pablo Bay. A compelling link was observed for the years from 1993 to 2000: the higher the flows, the more mitten crabs. A casual relationship that might explain the pattern is being explored.

One theory is that decreasing freshwater flows cause a rise in salinity in San Pablo Bay throughout the season, allowing planktivores, such as anchovies, to migrate into the system and thus increase predation on zoea.

If this bears out, there is theoretically a window during which mitten crab zoea may grow and develop. On one end, at the beginning of the zoea life cycle, the window is defined by when water temperatures rise above 11.7° C. At the other end, salinity (vis-à-vis anchovies) defines zoea survival rates. Anchovies can enter the bay only when salinities surpass 22 ppt. When this happens, predation on zoea rises, in theory, and fewer adults are expected four years later. The scientist is hoping to test the hypothesis that the longer this temporal window, the greater number of adult crabs three to four years later.

TOOLS

In order to study the population dynamics of the mitten crab zoea, researchers developed and published an illustrated key to the brachyuran zoea of the San Francisco Bay Estuary. This key made it possible to identify zoea collected during plankton tows. A key of megalopa is under development.

STUDENTS

Daniel Bauer, Master's Thesis and Ammon Rice, Master's Thesis

COLLABORATING ORGANIZATIONS

California Department of Fish and Game
U.S. Fish and Wildlife Service
U.S. Geological Survey
Bureau of Reclamation

PUBLICATIONS

Rudnick, D., T. Veldhuisen, R. Tullis, K. Heib, C. Culver and B. Tsukimura. 2005. A life history model for the San Francisco Estuary population of Chinese mitten crab, *Eriocheir sinensis*. *Biol. Invasions*. 7:333–350.

Rice, A. and B. Tsukimura. 2007. An illustrated key to the brachyuran zoea of the San Francisco Bay Estuary. *J. Crustacean Biology*. 27:74–79.

CONTACT


CSU Fresno

Brian Tsukimura
Professor of Biology
California State University, Fresno
(559) 278-4244
BrianT@CSUFresno.edu

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California Sea Grant, University of California, San Diego, 9500 Gilman Drive, Dept. 0232, La Jolla, CA 92093-0232
Communications Phone: (858) 534-4446