2010 Status and Trends Report
Common Crabs of the San Francisco Estuary

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Introduction

This report summarizes abundance trends and distributional patterns of the 4 most common *Cancer* crabs and *Eriocheir sinensis* (the Chinese mitten crab) through 2010 in the San Francisco Estuary. Most of the data are from the San Francisco Bay Study (Bay Study) otter trawl, with additional *E. sinensis* data from the UC Davis Suisun Marsh otter trawls and the Central Valley Project (CVP) and State Water Project (SWP) fish salvage facilities. Indices of relative abundance were used for Bay Study annual and seasonal abundance, while catch-per-unit-effort (CPUE) as crabs per 5-minute tow was used for Bay Study regional and channel-shoal distribution. More detail about the Bay Study sampling methods and the referred to ocean temperature and upwelling figures can be found in the companion Bay Study 2010 Fishes Status and Trends Report. UC Davis otter trawl mitten crab CPUE was also number per tow, while the fish facilities data was the estimated number of adult crabs salvaged in fall. Daily upwelling indices from the NMFS Pacific Fisheries Environmental Laboratory were plotted for 2010 39ºN.

Cancer crabs

Cancer magister

Cancer magister, the Dungeness crab, is a valuable sport and commercial species that reproduces in the ocean in winter and rears in nearshore coastal areas and estuaries. Small juvenile *C. magister*, 5-10 mm carapace width (CW), immigrate to the San Francisco Estuary in spring, rear for 8-10 months, and then emigrate from the estuary when approximately 100 mm CW. Estuary-reared crabs reach legal size at the end of their 3rd year, 1 to 2 years before ocean-reared crabs. This faster growth is hypothesized to be due to warmer temperatures and more abundant prey resources in the estuary (Tasto 1983).

Cancer magister recruitment is episodic and cyclic, with several extremely strong year classes often followed by poor year classes or no recruitment. The 2010 age-0 *C. magister* abundance index was the fourth highest for the 31-year period of record (Figure 1) and the second consecutive year of strong recruitment. Favorable ocean conditions in winter 2009-2010, when larval *C. magister* hatched and reared in the Gulf of the Farallones (GOF), likely resulted in this strong year class. GOF sea surface temperatures (SSTs) were about 1°C cooler than the long-term mean in late 2009 (Figure 3A, Bay Study 2010 Fishes Status and Trends Report), which would have increased larval survival. Infrequent storms in winter and spring should have resulted in a weak northward-flowing surface current and retention of *C. magister* larvae and megalopae (the last larval stage, which is planktonic for weeks) in the GOF. We expected good recruitment of age-0 *C. magister* in the estuary in 2010 from this combination of cooler SSTs and weaker surface currents. Most small juvenile *C. magister*, <10 mm CW, entered the estuary in May 2010, which is the usual period of peak settlement. This is additional evidence that larvae and megalopae were not transported some distance offshore by unfavorable ocean currents in winter or early spring.

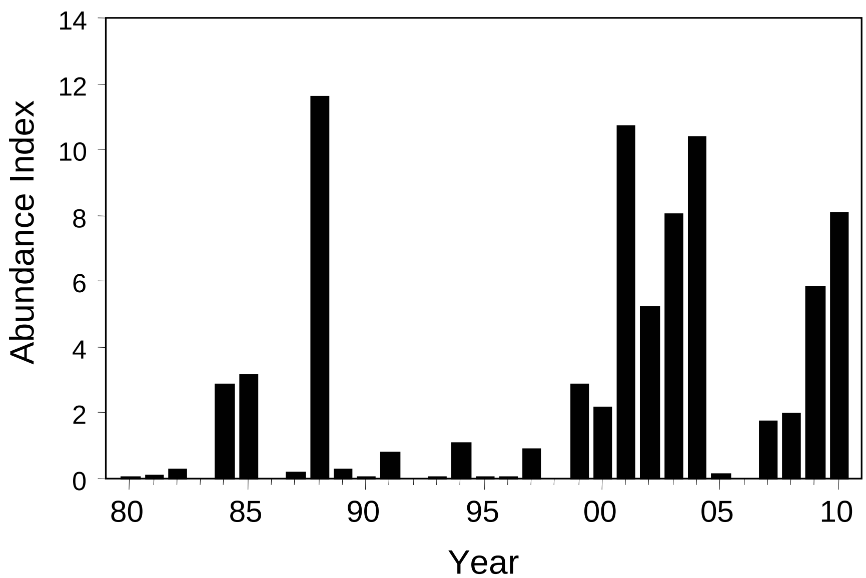

Figure 1. Annual abundance indices of age-0 *Cancer magister*, Bay Study otter trawl, May to July, 1980-2010.

Cancer magister commercial fishing landings are also cyclic, and often reflect the strong and weak year classes in the estuary. Central California commercial landings surpassed 5 million pounds annually from the 2002-03 to 2006-07 fishing seasons, dropped to about 1 million pounds in 2008-09, but then increased to a record 19 million pounds in the 2010-11 fishing season (Figure 2). The strong year classes of estuary-reared crabs from 2001 to 2004 reached legal size and entered the fishery consecutively from the 2003-04 to 2006-07 fishing seasons, while the weaker 2005, 2006, and 2007 year classes contributed to the fishery from the 2007-08 to 2009-10 seasons. However, the record landings in 2010-2011 were unexpected based on the relatively week 2008 year class of estuary-reared crabs. The larger 2009 year class did not contribute to the fishery until the 2011-12 season, which was in progress when this report was written.

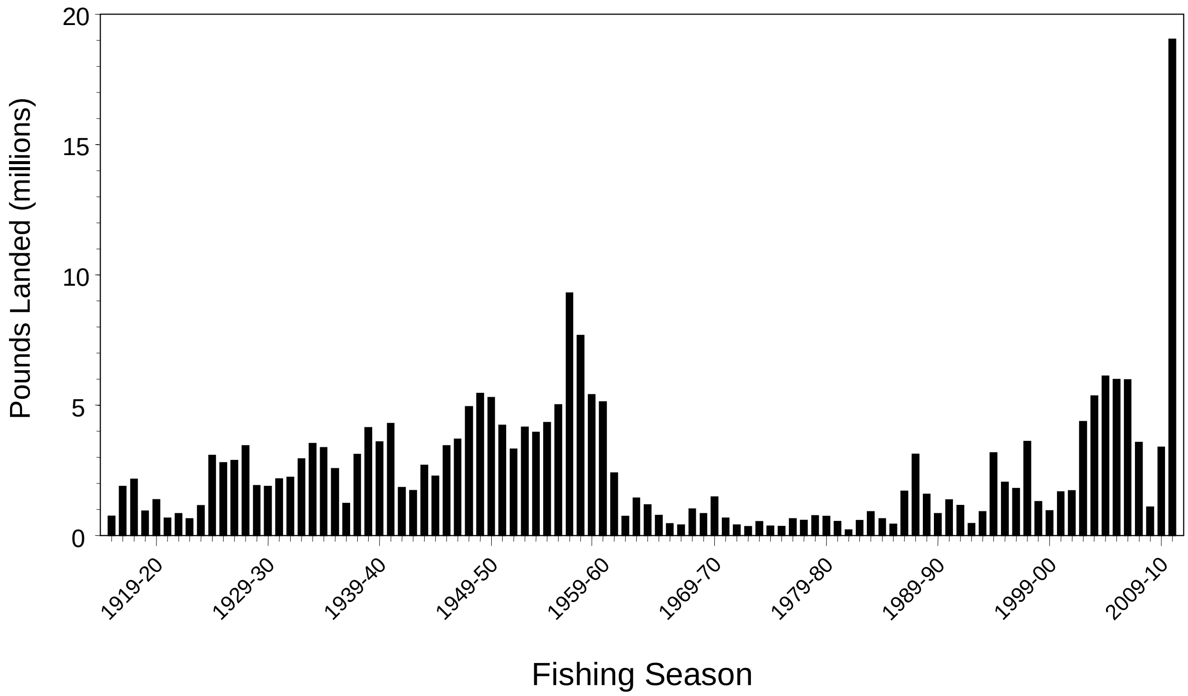

Figure 2. Annual landings of *Cancer magister* in the Central California Management Area (south of the Mendocino-Sonoma County line), 1915-16 to 2010-11 fishing seasons. Data from DFG's Marine Region.

In 2010, the first age-0 *C. magister* were collected in April, with peak immigration of the smallest juveniles in May and peak age-0 abundance in July and August. Age-0 abundance decreased substantially in September but increased again in November and December. The fall increase was primarily due to upstream age-0 crabs that moved from shallow subtidal areas to depths sampled by the otter trawls, as they staged for emigration. The 2009 year class, as age-1 crabs, was collected through November 2010. Age-1 abundance peaked in March and April and dropped off rapidly after May.

Age-0 *C. magister* were collected from south of the Dumbarton Bridge in South Bay, to just upstream of Ryer Island in Suisun Bay in 2010. A distinct group of age-0 crabs entered the estuary in May and June and migrated upstream to rear, ultimately from eastern San Pablo Bay through western Suisun Bay. From special studies in past years, we assumed that this group was also common in the lower Napa River and Napa-Sonoma Marsh. Another group either remained in Central Bay after immigration or was composed of crabs that moved between the ocean and Central Bay. As expected based on water temperature, the upstream group grew faster than the Central Bay group, although the Central Bay group may have had constant recruitment of slower growing crabs from the ocean. By December, the upstream group had a mean size of 72 mm CW, while the Central Bay group had a mean size of 50 mm CW. A size difference of approximately 20 mm has been common for these 2 regions in recent years.

Since 1999, there has been a trend of proportionally more age-0 *C. magister* collected in Central Bay in summer and fall, especially at the Alcatraz Island station. In 2010, 85% of the age-0 catch from June to October was from Central Bay, but only 4% from the Alcatraz Island station. The largest Central Bay catches in 2010 were from the 3 channel stations between Angel Island and the San Rafael-Richmond Bridge. We have hypothesized that the proportionally larger percentage of the *C. magister* catch from Central Bay much of the past decade was somehow related to colder than normal ocean temperatures and strong upwelling in summer (Figures 3A and 3B, Bay Study 2010 Fishes Status and Trends Report). We have reported similar trends for English sole, speckled sanddab, plainfin midshipman, and several other demersal marine fishes (see the Bay Study 2010 Fishes Status and Trends Report).

Age-0 *C. magister* were, overall, more common at channel stations in 2010, with an average of 13.2 crabs/tow for the channels and 3.6 crabs/tow for the shoals (May to December, South through Suisun bays). However, there were seasonal shifts to and from the shoals. Age-0 crabs were more common in the channels from May through August, largely due to immigration and upstream migration, but shifted to the shoals from September through November for rearing and back to the channels in December, as they staged for emigration. Some of the high channel catches in summer were the group that may have moved between the bay and ocean. These catches confounded the channel-shoal shifts, but the group that migrated upstream in spring and early summer to rear over the shoals in San Pablo and Suisun bays was distinct.

Age-1 *C. magister* were, overall, most common in Central Bay in 2010, with some consistently collected in San Pablo Bay and Carquinez Strait through August. There was a large downstream migration of age-1 crabs to Central Bay early in the year, associated with an outflow peak in late January and early February. Age-1 crabs were, as in past years, more common in the channels, with an average of 3.1 crabs/tow for the channels and 1.0 crabs/tow for the shoals (January through November, South Bay through Suisun Bay).

Cancer antennarius

Cancer antennarius, the brown rock crab, is common to rocky areas and other areas with structure. It and *C. productus*, the red rock crab, are targeted by sport anglers fishing from piers and jetties in the higher salinity areas of the estuary. *C. antennarius*, *C. productus* and *C. gracilis* (the graceful rock crab) reproduce in the nearshore ocean and higher salinity areas of the San Francisco Estuary, primarily in winter. Therefore, estuary and ocean conditions may control larval survival and year-class strength of these 3 species.

The 2010 age-0 *C. antennarius* abundance index was slightly higher than the 2009 index, and the fourth consecutive above average index (Table 1). *C. antennarius* abundance in the estuary is probably related to ocean temperatures, with the highest abundance often, but not always, in years with the coldest winter-spring SSTs. SSTs in early winter 2009-2010 were about 1°C cooler than the long-term mean, but not as cool as long as the previous 3 winters (see Figure 3A, Bay Study 2010 Fishes Status and Trends report). In 2010, age-0 *C. antennarius* abundance peaked November, with smaller peaks in January, July, and September. Small, newly settled juveniles, <10 mm CW, were collected all months except for March and May, with most in November, followed by July and September.

Year	*C. antennarius* age-0	*C. gracilis* age-0	*C. productus* age-0
1980	102	17	0
1981	76	152	6
1982	0	87	4
1983	28	151	4
1984	50	154	41
1985	20	216	38
1986	0	59	89
1987	71	93	79
1988	21	223	138
1989	29	203	30
1990	113	159	160
1991	171	656	128
1992	60	371	62
1993	398	616	71
1994	603	1,017	166
1995	367	227	40
1996	1,126	411	198
1997	351	1,131	86
1998	718	1,621	149
1999	90	222	249
2000	849	251	93
2001	276	1,921	142
2002	119	796	238
2003	424	522	140
2004	1,765	112	139
2005	144	132	57
2006	46	81	71
2007	987	418	58
2008	1,703	543	50
2009	556	471	68
2010	630	321	193
1980-2010 Average	**384**	**431**	**96**

Table 1. Annual abundance indices of age-0 *Cancer* crabs from the Bay Study otter trawl, 1980-2010. The index period is from May to October for *C. antennarius* and *C. gracilis* and from April to October for *C. productus*.

C. antennarius was collected from South Bay, near Coyote Point, through lower San Pablo Bay in 2010. The highest age-0 catches were from the shoal stations off Oakland and Alameda, near Berkeley Marina, and just downstream of Point Pinole and the 2 channel stations near Hunter's Point in South Bay. Except for January, age-0 crabs were more common at shoal stations in 2010, with an annual CPUE of 1.8 crabs/tow for the shoals vs. 0.6 cabs/tow for the channels (January to December, South Bay through San Pablo Bay). Age-1+ *C. antennarius* were collected primarily from channel stations south of the Bay Bridge and at Alcatraz Island, with a few from nearby shoal stations.

Cancer gracilis

Cancer gracilis, the graceful rock crab, is the smallest of the 4 *Cancer* crab species reported here, rarely exceeding 85 mm CW. It is common in open sandy or sand-mud habitats rather than rocky areas; researchers have hypothesized that because of its small size it cannot compete with the rock crabs for the more "preferred" protected habitats with structure. The 2010 abundance index of age-0 *C. gracilis* again declined from the previous year (Table 1) and was below the long-term study mean. Age-0 abundance peaked in August, but this peak was comprised of larger crabs, 30-39 mm CW. Recently settled juvenile *C. gracilis*, <10 mm CW, were collected from March through July, with most in March, followed by May.

In 2010, *C. gracilis* was collected from the shoal station near Coyote Point in South Bay to the channel station near Point Pinole in San Pablo, with 78% (n=226) of all crabs collected from the Central Bay. The highest catches were from the shoal stations near Candlestick Point in South Bay and Treasure Island, Southampton Shoal, and Paradise Cay in Central Bay. There was a seasonal channel-shoal pattern, with crabs more common in the channels in winter and the shoals from May through October. However, *C. gracilis* annual CPUE was the same at channels and shoals, with an average of 0.8 crabs/tow (January to December, South Bay through San Pablo Bay).

Cancer productus

Cancer productus, the red rock crab, is overall the least common of the 4 *Cancer* crabs most often collected by the otter trawl in the estuary, reflecting its strong preference for rocky intertidal and subtidal marine habitats not sampled by the trawl. In a survey conducted by CDFG from 1982 to 1994 with baited ringnets at piers, it was the second most common *Cancer* crab collected. The 2010 age-0 *C. productus* abundance index was the highest since 2002 and approximately twice the study-period mean (Table 1). In spite of this increase, we collected only 25 age-0 *C. productus* in 2010, with even fewer contributing to the annual index. Age-0 abundance peaked in September, with a slightly smaller peak in July. Most small, recently settled *C. productus* (<10 mm CW) were collected in September, but a few of these smallest crabs were also collected in March, June, and October.

C. productus was collected from near San Leandro in South Bay to Point Pinole in San Pablo Bay in 2010, with 76% (n=56) from Central Bay. Channel habitat was favored all months, with mean channel CPUE 4 times shoal CPUE (0.4 vs. 0.1 crabs/tow, January to December, South through San Pablo Bay). Juvenile *C. productus* reportedly settle on spatially complex substrates and move to areas with more open space as they grow (Orensanz and Gallucci 1988). Because we tow over soft substrates rather than rocky areas, we are likely not able to detect this type of distributional pattern. We did collect larger *C. productus*, > 50 mm CW, only in channels in 2010.

Ocean Conditions and Recruitment of *Cancer* Species

Ocean conditions in winter 2009-2010, with relatively cool winter temperatures in the first half and a weak northward flowing surface current, should have favored of *C. antennarius*, *C. gracilis*, and *C. productus* recruitment. *C. antennarius* and *C. productus* age-0 abundance indices increased from 2009 and were above the study-period mean, but *C. gracilis* abundance decreased from 2009 and was below the study-period mean (Table 1). Peak larval hatching of all 3 species is reportedly in winter, but multiple broods may occur and megalopae have been collected in San Francisco Estuary in other seasons (Hieb 1999). Since timing of juvenile settlement was not identical for these 3 species in 2010, they likely responded differently to upwelling and ocean currents. For example, based on the collection of the smallest juvenile *C. gracilis*, most settled before early May 2010, which was before the strongest upwelling (Figure 3). In contrast, the largest number of small, recently settled *C. antennarius* were collected in November 2010 and *C. productus* in September 2010, when upwelling weakened (Figure 3). These fall cohorts of *C. antennarius* and *C. productus* were likely from larvae hatched after winter 2009-2010, as larval development is usually 2 to 3 months and any crabs hatched in winter would be larger than 10 mm CW by the next fall. We also collected small juveniles of all 3 species sporadically through spring and summer, evidence of multiple cohorts or prolonged settlement from winter reproduction.

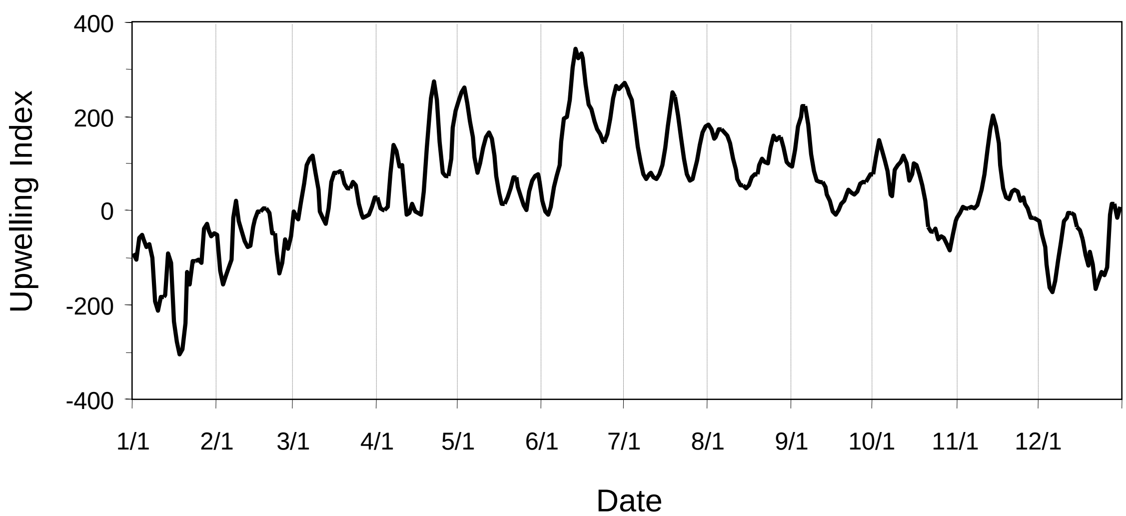

Figure 3. 2010 daily upwelling indices (m^3/sec along each 100 meters of coastline) from 39ºN, 5-day running mean. Data from NOAA's Pacific Fisheries Environmental Laboratory**.**

Eriocheir sinensis

Eriocheir sinensis, the Chinese mitten crab, was first collected in the estuary in the early 1990s, but likely introduced to South San Francisco Bay in the late 1980s. After several years of rapid population growth and expanding distribution, the *E. sinensis* population peaked in 1998 (Table 2). All data sources indicate that the population steadily declined after 2001, with few or no crabs collected from 2005 through early 2011. In fall and winter 2010-2011, 3 adult *E. sinensis* were estimated salvaged at USBR's Central Valley Project facility, but no crabs were collected by either the San Francisco Bay Study or UC Davis Suisun Marsh trawl surveys (O'Rear, personal communication, see "Notes") in the northern estuary. There were also no reports of adult *E. sinensis* in South Bay trawls conducted by the Marine Science Institute (Seiff, personal communication, see "Notes"), the fifth consecutive year that none were collected there.

Year	Bay Study CPUE (#/tow)	Suisun Marsh CPUE (#/tow)	CVP salvage est. total	SWP salvage est. total
1996	0.02	0.00	50	not counted
1997	0.34	0.07	20,000	not counted
1998	2.51	0.89	750,000	not counted
1999	0.96	1.08	90,000	34,000
2000	0.93	0.02	2,500	4,700
2001	3.25	0.17	27,500	7,300
2002	1.07	0.04	2,400	1,200
2003	0.15	0.00	650	90
2004	0.12	0.00	750	370
2005	0.01	0.00	0	18
2006	0.00	0.00	12	0
2007	0.00	0.00	0	0
2008	0.00	0.00	0	0
2009	0.00	0.00	0	0
2010	0.00	0.00	3	0

Table 2. Annual adult *Eriocheir sinensis* CPUE and estimated total salvage, 1996-2010. Bay Study CPUE is from October (year) to March (year+1), Suisun Marsh CPUE is from July to December, and Central Valley Project (CVP) and State Water Project (SWP) fish facilities salvage is from September to November.

There were no public reports of *E. sinensis* made to the toll-free reporting line, the web page reporting form, or from the postage-paid mailer in 2010 (Thompson, personal communication, see "Notes"). One common impact of *E. sinensis* is bait stealing from sport anglers in the delta, and Suisun and San Pablo bays, which is often reported. From such public reports, we may learn of an increase in the *E. sinensis* population before it is detected by our surveys.

I previously hypothesized that ocean conditions may control *E. sinensis* recruitment to the San Francisco Estuary (Hieb 2009). The planktonic larvae, which have minimal or no estuary-retention mechanisms (Hanson and Sytsma 2008), would be transported to the coast in years with high freshwater outflow. In addition, successful development of *E. sinensis* larvae in the laboratory occurred only at temperatures ≥12°C, with the highest survival at 18°C (Anger 1991). Winter ocean SSTs were often ≥12°C during the El Niño events of the 1990s. Several of these years also had very high outflow, which would have transported larvae to the coastal ocean. Here, larvae could have survived and developed at the warmer temperatures, in contrast to the much cooler estuary. In winter 2009-2010, nearshore SSTs were between 11 and 13°C (Figure 4, Bay Study 2010 Fishes Status and Trends report) and freshwater outflow was low, a combination that would have resulted no or poor *E. sinensis* recruitment. This was supported by no reports or collections of juvenile *E. sinensis* in 2010 or 2011.

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Notes

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Jon Thompson, USFWS, email, February 10, 2012
Daily upwelling indices from
www.pfeg.noaa.gov/products/PFEL/modeled/indices/upwelling/NA/data_download.html

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