Zooplankton and Mysid Abundance Trends

Randall Baxter, Kathy Hieb and W. Lee Mecum (DFG)
lmecum@delta.dfg.ca.gov
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Introduction

Trends in zooplankton and mysid abundances have been monitored since the early 1970s. Since project inception, data processing and the resulting databases have been routinely checked for errors. However, in 2005 examination of taxon density data identified some unusual patterns and led to an extensive review of these databases. Substantial corrections were made, changing some historical and recent abundance indices for important food web species and changing our perception of the feeding environment for young fishes. In the case of the copepod *Pseudodiaptomus forbesi,* an important food of young pelagic fishes, these corrections changed an abundance decline in 2004 to a substantial increase, and necessitated a re-evaluation the food web-pelagic fish decline link. Here we provide a summary of abundance trends, based upon corrected data, for taxa important in the diets of juvenile fishes. For zooplankton, we were able correct and calculate abundance indices through the summer months of 2005; this was not the case for the mysid data, which are reported only through 2004.

Methods

The term zooplankton includes animals of varying lengths: rotifers, which average 0.1-0.2 mm, cladocerans at 0.6-2.0 mm, and copepods at 1.0-1.2 mm total length as adults. Mysid shrimp, considered to be macro-zooplankton, range from 2 to 18 mm in total length. Since 1972, the Mysid-Zooplankton Study has estimated the annual abundance, by season, of various zooplankton taxa in order to assess the size of the fish food resource in the upper estuary. Zooplankton samples have been taken monthly at 19 discrete and 2 “floating” sites, the latter moving up and down estuary with the entrapment zone and targeting bottom electrical conductance of 2 and 6 mS/cm (Figure 1). Eleven of the 19 discrete sites have been sampled since the inception of the study and are termed “core” stations. At each site three different gears were deployed: a pump for micro-zooplankton, a modified Clarke-Bumpus (CB) net for meso-zooplankton, and a macro-zooplankton net for mysids.

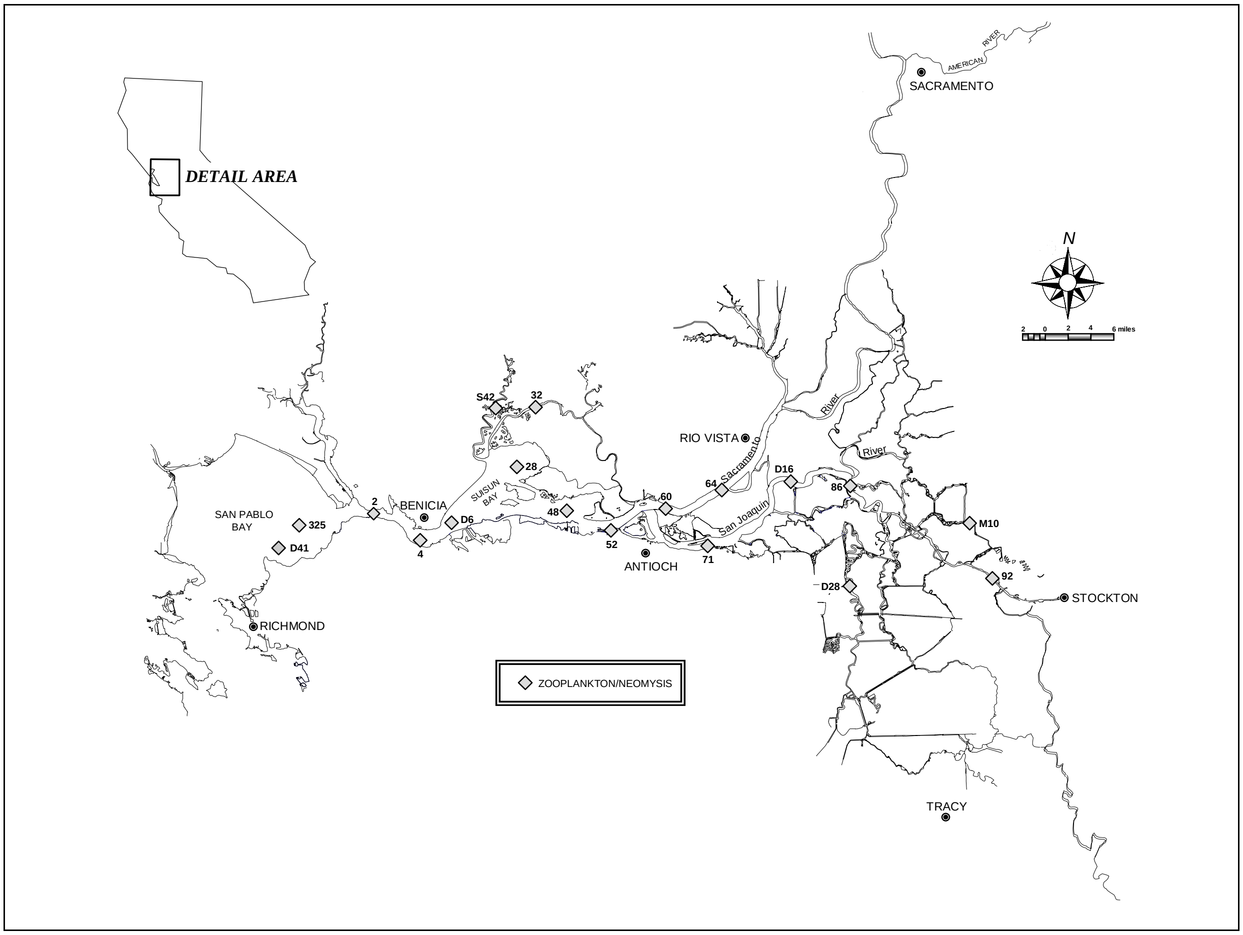

Figure 1. Mysid - zooplankton core sampling stations, 1972-2005.

Abundance indices were calculated and reported separately for each gear as the Log_{10} of the mean number per cubic meter +1 by taxon, season and year for all core stations plus the 2 floating stations. This differs from past reports where pump and CB abundance indices were summed and reported together. Seasons were defined as: 1. Spring, March – May; 2. Summer, June – August; and 3. Fall, September - November. Indices were reported only for the gear that collected each taxon most efficiently: the pump for *Limnoithona tetraspina* and rotifers, the CB net for adult copepods, and the macro-zooplankton net for mysids.

Results

Since 1972, all of the native zooplankton of the upper estuary decreased in abundance. Abundance declined for many fish food taxa in spring and summer from 2003 to 2005, with several important exceptions.

Since its introduction in late 1993, the cyclopoid copepod *Limnoithona tetraspina* has been numerically the most abundant copepod in the upper estuary (Figure 2). It has been most abundant in Suisun Marsh, Suisun Bay and the lower Sacramento River. Spring pump abundance peaked in 1998 and has subsequently declined. The spring 2004 index, less than half the 2003 value, was followed by a modest increase in 2005. Typically summer and fall pump abundances have been higher than spring levels. Summer pump abundance declined slightly over 2003-2005 and fall abundance declined similarly in 2003 and 2004, yet *L. tetraspina* remains the most abundant copepod species. This small copepod was believed to be a poor food source, and despite its high abundance in 2005, was not often eaten by juvenile delta smelt or striped bass; though it was eaten by inland silverside (See Appendix A: 3c, Slater and Nobriga)

The native brackish water rotifer, *Synchaeta bicornis*, has been most abundant in summer and fall (Figure 3). Its spring abundance pattern has been erratic, but declining and none have been collected in spring since 2001. Its summer and fall abundances showed long-term declines since the late 1970s. Summer abundance increased modestly in 2004 and then declined in 2005. Fall abundance declined sharply in 2004 after a modest increase in 2003.

Abundance of all rotifers except *S. bicornis* declined from the early 1970s through the 1980, but stabilized since the early 1990s (Figure 3). A sharp to slight decline occurred in all seasons of 2000 followed by steady increases through 2003 (and 2004 for fall abundance), after which spring and summer abundances declined through 2005.

The calanoid copepod, *Eurytemora affinis*, was introduced to the estuary before monitoring started in 1972 and has been an important food item for larval and young-of-the-year fishes (Nobriga 2002, Bryant and Arnold in press). Its abundance has declined in all seasons, but particularly during summer and fall subsequent to the introductions of the clam, *Corbula (Potamocorbula) amurensis*, in about 1987, and the copepod *Pseudodiaptomus forbesi* prior to 1989 (Figure 4). *E.* affinis spring abundance decreased cyclically after 1972, reaching a recent low in 2001 followed by a modest increase in 2004 and a decline in 2005. Summer and fall abundances have been quite variable and relatively low since the introduction of *P. forbesi*. Summer and fall abundances have also been out of sync in recent years, with summer abundance peaking 2002, while fall abundance was declining. Summer abundance increased slightly in 2005, whereas fall abundance increased substantially in 2004, the last year for current data. *E.* affinis has been rare or absent in diets of young upper estuary fishes since the early 1990s (Nobriga 2002, Bryant and Arnold in press).

The abundance of *Pseudodiaptomus forbesi*, an introduced calanoid copepod first detected in summer 1988, has also been declining in all seasons since its introduction (Figure 4). After recent low abundances in 2001 (summer and fall) and 2002 (spring) abundance rebounded strongly to varying peaks: a relatively high abundance for spring 2004; a sustained summer abundance increase through 2005; and a fall abundance increase in 2002. Thus, subsequent to 2002, abundance did not appear especially low in any season. *P. forbesi* has become a major food source for young fishes particularly during summer (Nobriga 2002, Bryant and Arnold in press, Slater and Nobriga Appendix A: 3c).

Several species of the native calanoid copepod genus *Acartia* enter Suisun Bay and the delta from the lower bays as salinity increases seasonally. Due to its brackish water distribution, *Arcartia* has been strongly influenced by outflow, such that high outflows shift the population seaward of the sampling area, artificially reducing the abundance index. Thus, spring and summer abundance peaked in low outflow years and declined substantially in years with protracted high flows (e.g. 1982, 1983, 1995, 1998; Figure 5). Beginning in 1997, spring abundance increased annually until reaching the second highest level recorded in 2003, but it decreased substantially in 2004 with only a modest improvement in 2005. For summer and fall, abundance increased somewhat cyclically reaching coincident local peaks in 1999 and 2002 before declining sharply. Summer abundance continued to fluctuate at a lower level through 2005. The summer 2004 index was somewhat greater than the 2003 index, while the fall 2004 index was slightly lower.

Acartiella sinensis, an introduced brackish water calanoid copepod, was first observed in spring 1994 and has become abundant in Suisun Bay. In 2005, it appeared to become an important food item for young pelagic fishes (See Appendix A: 3c Slater and Nobriga). Its numbers typically increase from spring though summer and fall (Figure 5). Its spring abundance was highly variable prior to 2002, but after 3 years of low abundance from 1999 to 2001, spring abundance increased in 2002 and has been more stable and moderately declining through 2005 (Figure 5). Summer and fall abundances were also at local minima about 1999-2000 before climbing rapidly to approach survey maxima in 2004 and 2005 for summer and from 2001-2004 for fall.

Sinocalanus doerrii, an introduced freshwater calanoid copepod, was first recorded in spring 1979 and was most abundant in summer and fall during the early 1980s (Figure 6). *S. doerrii* may be a regionally important diet component of juvenile fishes (see Appendix A: 3c, Slater and Nobriga), but it apparently evades capture well by larval fishes (Meng and Orsi 1991, Nobriga 2002). Its abundance fluctuated broadly in spring through 1995, and then increased through 2004 before dropping sharply in 2005. Summer and fall abundances declined from the early 1980s through the mid-1990s before turning upward once again. Summer abundance reached a local peak in 2002 before declining and fall abundance reached a local peak in 2000 before declining; both dropped through 2004 to levels not much higher than record lows of the mid-1990s. *S. doerrii* was a modest component of the diet of delta smelt in 2005 and was present in both striped bass and inland silverside diets (see Appendix A: 3c, Slater and Nobriga).

The native mysid, *Neomysis mercedis,* was once the only common mysid in the upper estuary, where it served as an important food source for juvenile fishes (Orsi and Knutson 1979). It suffered a population decline in all seasons between 1986 and 1989 (Figure 7), probably because of predation and competition from the introduced clam, C*orbula amurensis* (Kimmerer and Orsi 1996). Another mysid, *Acanthomysis bowmani,* was introduced into the upper estuary prior to fall 1993. Subsequently, *N. mercedis* underwent another abundance decline from which it has not recovered. *N. mercedis* abundance remained low for all 3 seasons through 2004. It was detected in low numbers in striped bass stomachs in 2005 (See Appendix A: 3c, Slater and Nobriga).

The introduced mysid, *Acanthomysis bowmani*, has been the most abundant mysid in the upper estuary since 1994 (Figure 7), yet it has never attained the same abundance levels as *Neomysis mercedis* when the latter was in its peak from the 1970s through mid-1980s. Spring abundance for *A. bowmani* has become less variable since 2000, but shows no apparent trend. Conversely, summer and fall abundances declined from 2000 to 2004. *A. bowmani* remained an important food for young striped bass in 2005 (See Appendix A: 3c Slater and Nobriga).

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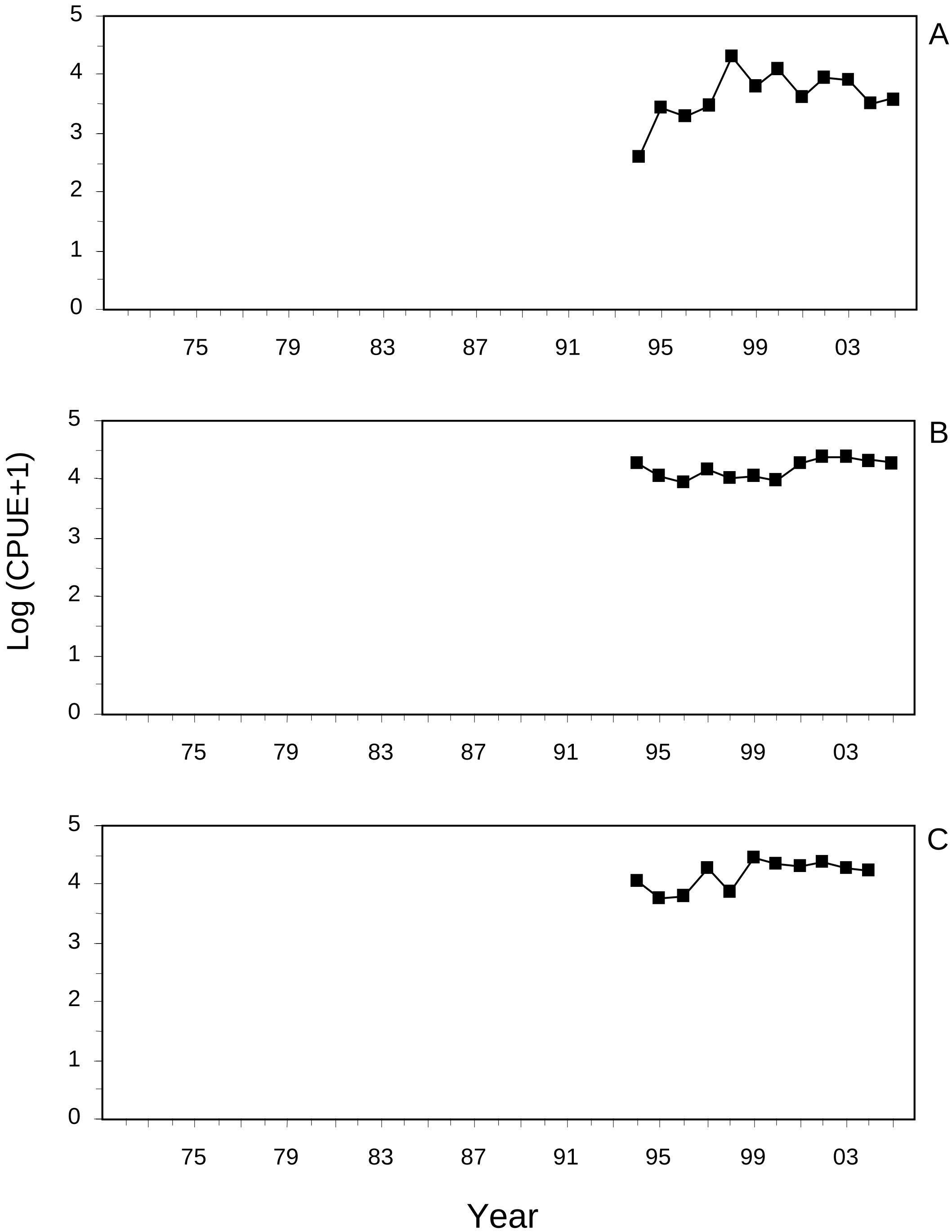

Figure 2. Log of mean abundance (number/m^3 +1) of *Limnoithona tetraspina* from the pump samples in Spring (A), Summer (B), and Fall (C), 1993 – 2005. Fall data is 1993-2004 only.

This is a draft work in progress subject to review and revision as information becomes available.

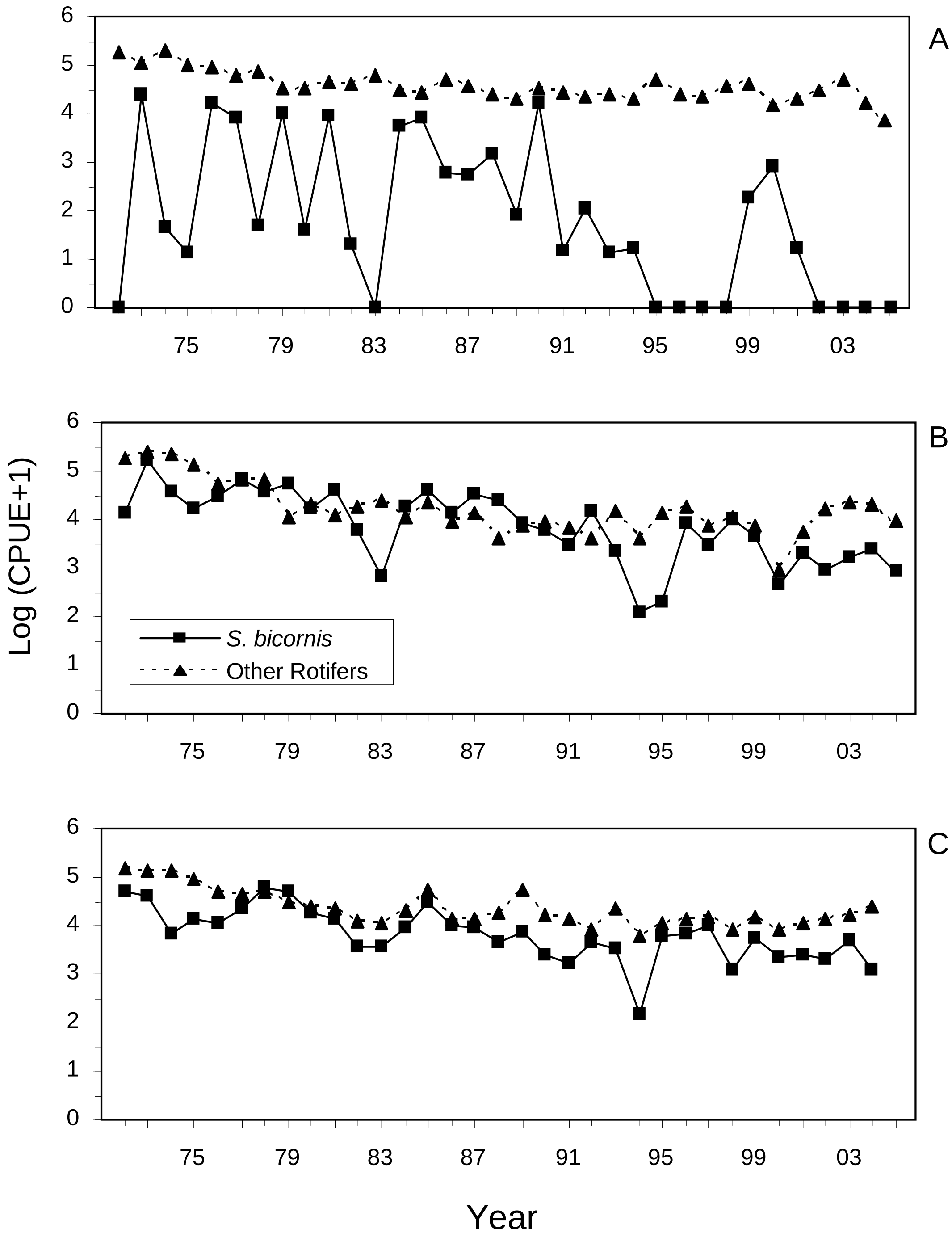

Figure 3. Log of mean abundance (number/m^3 +1) of *Synchaeta bicornis* and rotifers excluding *Synchaeta bicornis* from the pump samples in Spring (A), Summer (B), and Fall (C), 1972 – 2005. Fall data is 1972-2004 only.

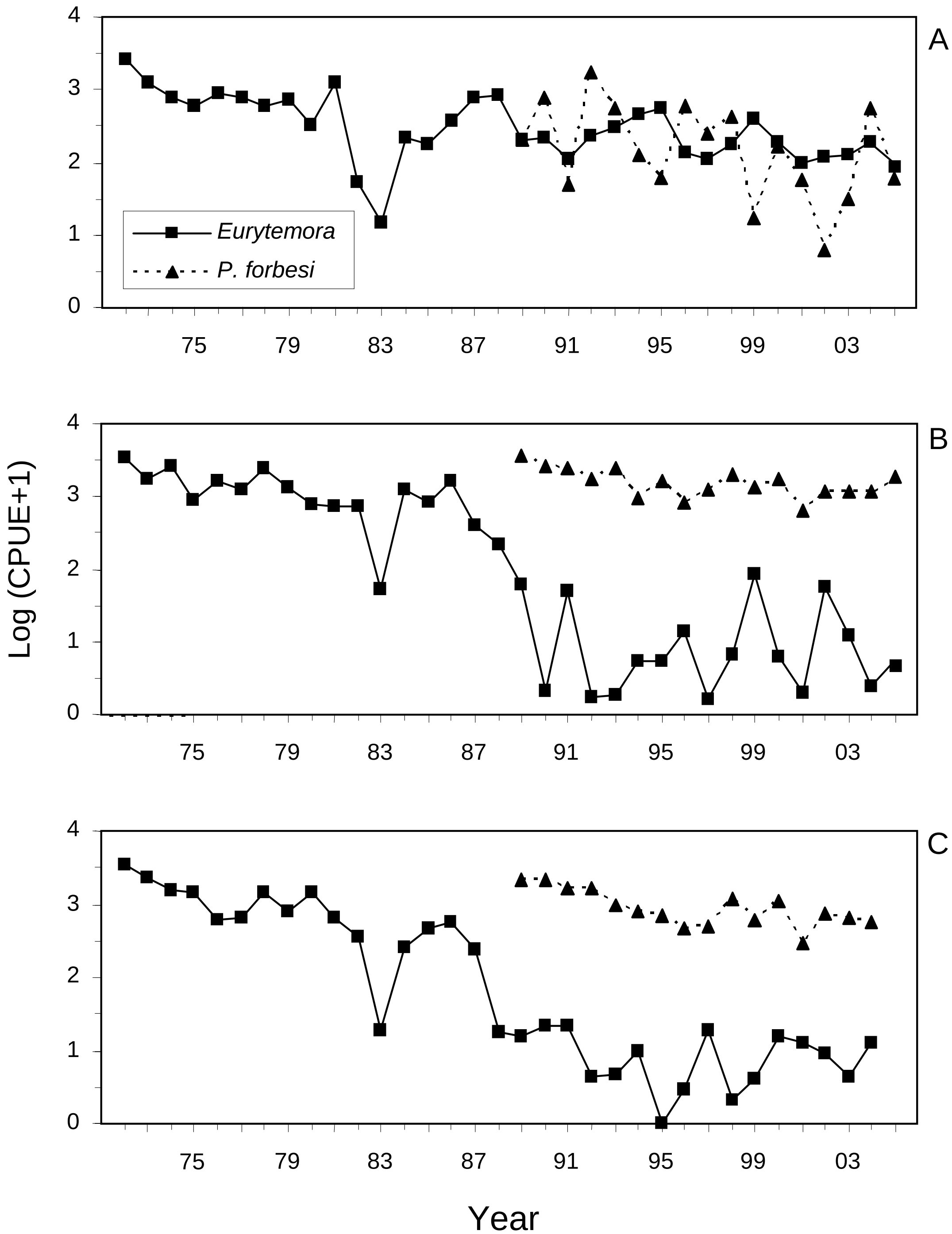

Figure 4. Log of mean abundance (number/m^3 +1) of *Eurytemora affinis* and *Pseudodiaptomus forbesi* from the CB net in Spring (A), Summer (B), and Fall (C), 1972 – 2005. Fall data is 1972-2004 only.

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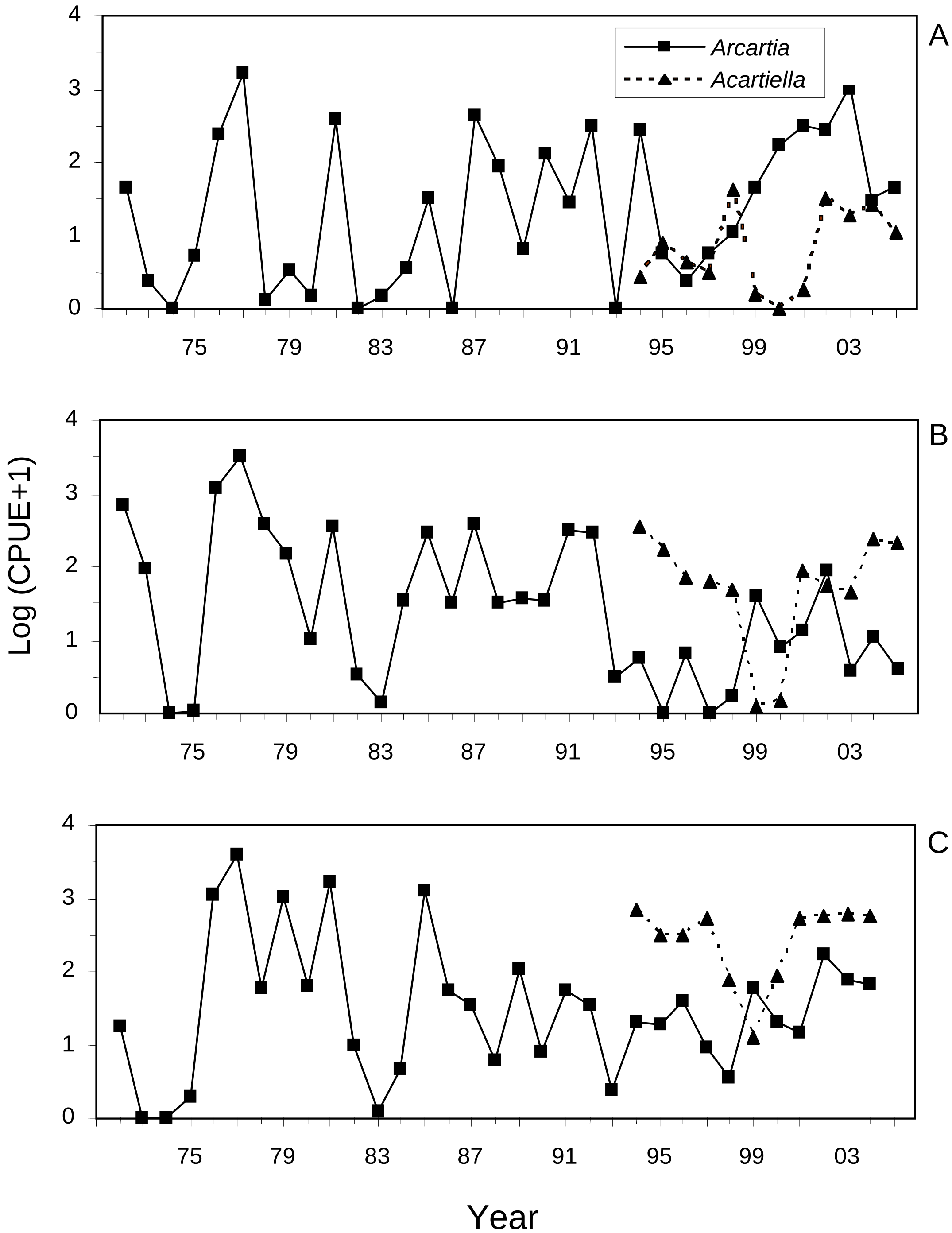

Figure 5. Log of mean abundance (number/m^3 +1) of *Acartia* spp. and *Acartiella sinensis* from the CB net in Spring (A), Summer (B), and Fall (C), 1972 – 2005. Fall data is 1972-2004 only.

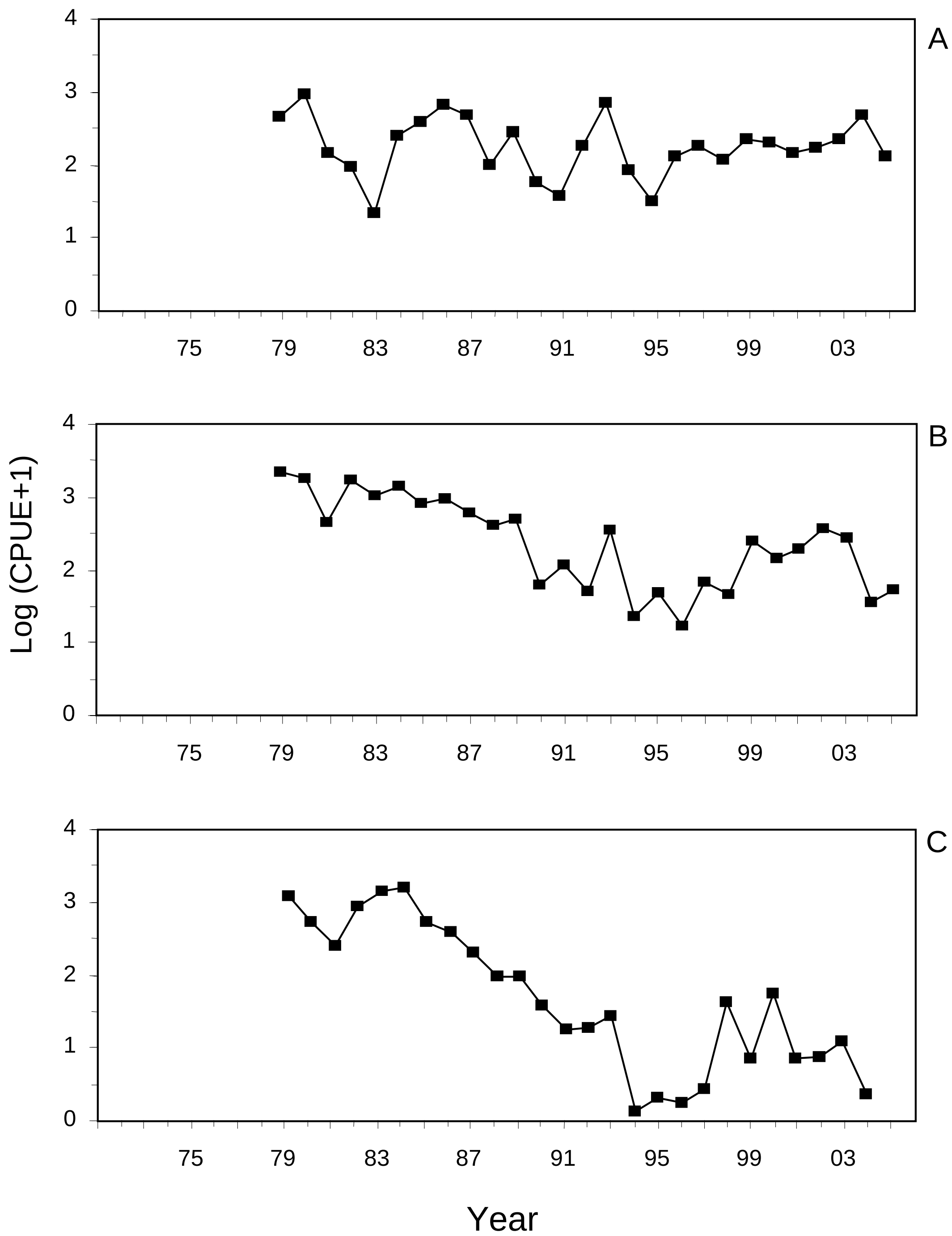

Figure 6. Log of mean abundance (number/m^3 +1) of *Sinocalanus doerrii* from the CB net in Spring (A), Summer (B), and Fall (C), 1972 – 2005. Fall data is 1972-2004 only.

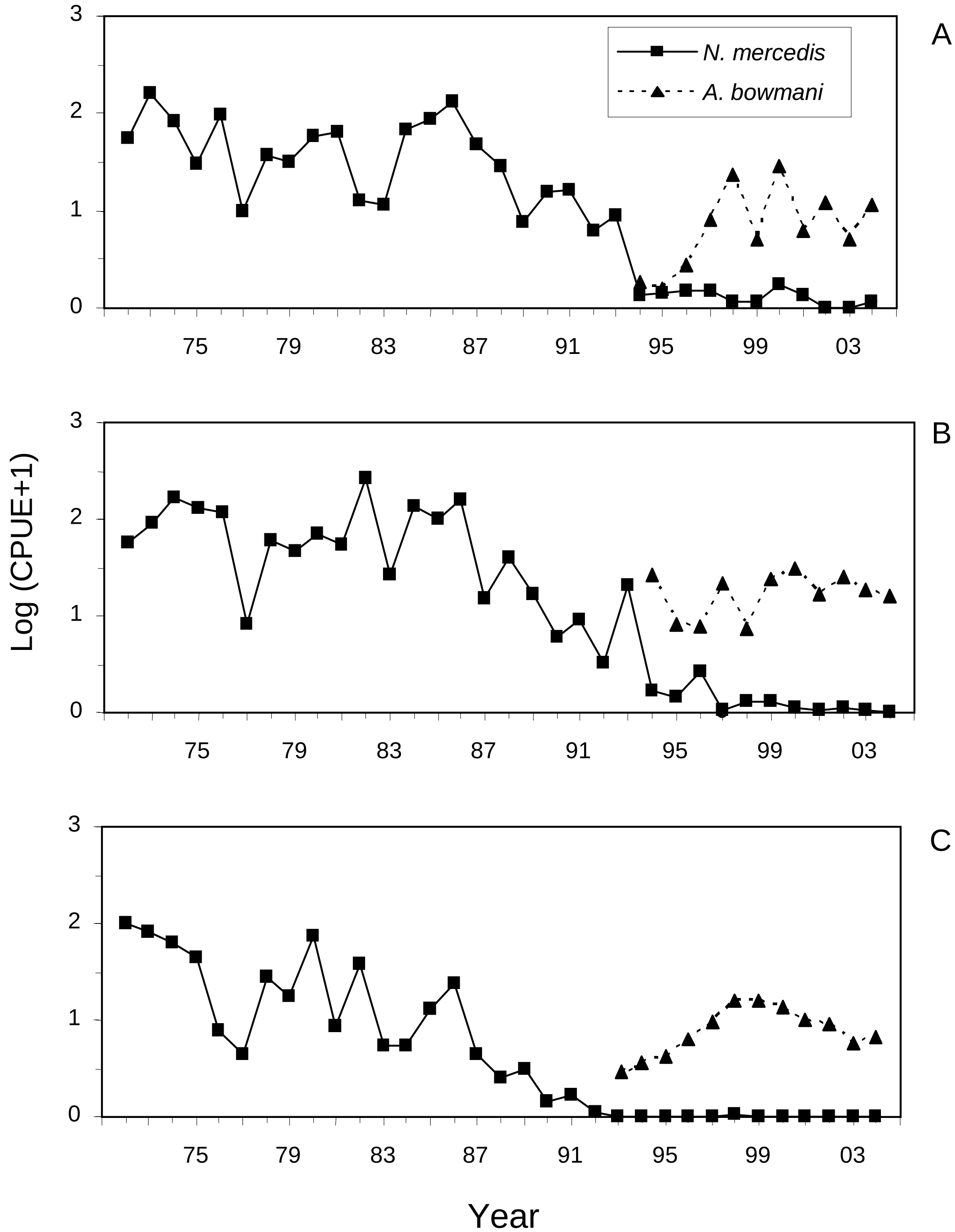

Figure 7. Log of mean abundance (number/m^3 +1) of *Neomysis mercedis* and *Acanthomysis bowmani* from the macro-zooplankton net in Spring (A), Summer (B), and Fall (C), 1972 – 2004.