CHAPTER 4

94320-H The Role of Zooplankton in the Prince William Sound Ecosystem

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Abstract

Net zooplankton populations were sampled in Prince William Sound from March through September, 1994. Calanoid copepods dominated the pelagic community. Of this group, members of the genera *Neocalanus*, *Calanus* and *Pseudocalanus* accounted for most of the abundance and biomass in all collections. A vertical series of deep closing tows at station SEA22 demonstrated ontogenetic migratory behavior for each of these species, and revealed that most of the *Neocalanus* were *N. flemingeri* rather than *N. plumchrus*. In the upper layers (50 m), the large calanoid bloom consisted of *Neocalanus plumchrus/flemingeri* in late April and May, while *Calanus marshallae* was phased later, May and June. By early July, *Neocalanus* was absent from the surface layer, and *Calanus* populations were diminishing as well.

Introduction

The authors of the original SEA plan (December, 1993) suggested that populations of large zooplankton could provide significant forage resources for all higher trophic levels in Prince William Sound, including apex birds, mammals and fishes. One multi-year time- series for spring-time net plankton (AFK hatchery) demonstrated a very predictable May peak in zooplankton biomass (settled volume). Examination of hatchery samples taken during this bloom indicated that much of the biomass was associated with large calanoids in the genera *Calanus* and *Neocalanus* (Tuttle, unpublished). Both copepods are common in subarctic Pacific coastal waters and swarm near the surface as their early life stages couple efficiently to each years phytoplankton production (Miller, et

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al., 1984; Miller and Clemons, 1988). Following a period of rapid growth at the surface, late stage copepodites of both species migrate to depth, enter a several month-long period of diapause, and then reproduce prior to, or during the next year's phytoplankton bloom. *Neocalanus* spp. anticipates the period of plant growth by reproducing at depth, whereas *Calanus marshallae* migrates back to the surface to first feed before depositing eggs. The adults of both species die after spawning (Parsons and Lalli, 1988).

The presence of these, and other macrozooplankters (euphausiids, amphipods and pelagic shrimp) provides a potential source of food for higher trophic levels because these organisms are large (5-20 mm) and exhibit layering or swarming behavior in the water column. This behavior results in a series of alternative prey populations for consumers that target both fish and plankton forage.

SEA investigators hypothesize that upper-layer populations of large calanoids actually shift predation pressure away from juvenile fishes during the time these copepods are present at the surface (April-May). Because this is also the period of entry for wild and hatchery-released pink salmon, these juveniles should also accrue survival benefits during years of elevated large copepod populations if the prey switching phenomenon occurs.

The long-term record of spring-time zooplankton biomass from the AFK hatchery in southeastern Prince William Sound agrees reasonably well with average April-May upwelling indices computed from surface pressure fields south of Hinchinbrook Entrance (Figure 1). Years of diminished downwelling correspond to years of elevated south Sound zooplankton (a relatively uncommon event). Conversely, years of strong April-May downwelling generally correspond with diminished upper-layer zooplankton biomass. SEA investigators hypothesize that wind influenced flushing and redistribution of upper-layer plankton stocks account for these differences. The terms "lake" and "river" are used to differentiate between weak or strong surface circulation conditions.

These reproductive/growth patterns and relationships between seasonally abundant calanoid populations and upper layer circulation processes identifies two roles for large zooplankton in Prince William Sound: 1) serving as a major forage resource for all higher trophic levels (including juvenile fishes); and 2) occasionally providing a predation refuge for 0-age juveniles when larger fishes, birds and mammals switch their feeding to macrozooplankton. The implications of this plankton modulated, physically-forced and seasonally time-gated predation mechanism may be central to

understanding pink salmon and herring production histories in the region - the overall SEA goal.

Methods

Macrozooplankton populations are being assessed in Prince William Sound using nets initially, and then later (1995 and beyond) with nets and acoustic and optical means. Plankton nets include 0.5-m open and open-closing ring nets; 60 cm bongo nets, 1-m opening-closing NIO/Tucker trawls, and eventually a MOCNESS sampler (in 1996). For 1994, most samples were collected with 0.5-m nets (0.335-mm Nitex) fished vertically in the upper 50 m, or in an open-closing mode (Puget Sound style closing net) over selected depth intervals in a deeper water column. A calibrated flow-meter was used to measure volumes filtered by the Tucker trawl. In addition, PWSAC hatchery samples collected in the upper 20 m using a 0.5-m net (0.249-mm Nitex) at the WN and AFK hatcheries were retrieved and processed in Fairbanks for species composition and abundance.

In the plankton laboratory, each sample is examined for large or otherwise obvious species (euphausiids, larval fishes, amphipods) which are counted directly. The remainder of each sample is diluted to a know volume and subsampled for the other more numerous taxa. Between 150 and 200 specimens are counted from each quantitative subsample. The species composition and wet weight contributions of individual taxa (literature values) are reported for each sample (Coyle et al, 1990). This data is screened for errors and entered in the SEA data base.

In the field, samples were taken from approximately 10 locations (oceanographic stations) in each of several western Sound regions designated as trawling sites (Figure 2). The intent was to provide index values of upper-layer plankton as forage for fishes taken in midwater trawls, and also to document the timing, duration, and magnitude of the upper-layer macrozooplankton bloom in western Prince William Sound. At SEA22 (Lone Island deep area) a vertical series of closing vertical tows in 50 and 100 m increments was obtained to document the ontogenetic migrations of the large calanoids. A vertical series consisted of duplicate samples taken from each of seven different depth strata between the surface and 500 m.

A Tucker trawl was fished at selected times and locations in conjunction with acoustic observations to provide preliminary indices of community composition and abundance/biomass associated with subsurface layers and swarms of macrozooplankton. Trawl depth was measured in

real-time using the trawlers "netsonde" system, a technique that was judged only marginally successful because depth could not be continuously monitored (for unknown reasons).

Results

At this time, most of the 320 0.5-m SEA and PWSAC hatchery samples have been processed. Those that remain were taken in September and are only now entering the sample processing. Processing is also incomplete for 68 Tucker trawl samples; I am prioritizing these collections according to the acoustic records and fishing characteristics for each tow. Emphasis will be placed on working up samples that targeted specific acoustic phenomena and also fished discrete layers (a subset of the best tows). Some of these samples came from tows that started at a specified depth but either sank or rose to other depths because of vessel steering problems. Because several strata are inadvertently sampled under these conditions, collections integrating broad depth zones are of lesser value in assessing acoustic target identity and density.

Approximately 80 species were sorted from plankton samples taken in Prince William Sound between April 21 and late September. In all collections, the Copepoda (large and small forms) dominated by abundance and biomass (Figure 3). Other taxa such as the gastropod *Limacina* sp. and larvaceans were occasionally numerous. Of the smaller copepods, *Pseudocalanus* was the most important (number and biomass).

Copepods also dominated populations sampled deeper in the water column, although this dominance was sometimes shared with ostracods and amphipods (Figure 4). *Pseudocalanus* spp. were a somewhat surprising component of the ontogenetic descent to depth. A large proportion of *Pseudocalanus* populations (probably two species or forms; Coyle et al., 1990) of mostly stage V copepodites was resident below 150 m in July. The vertical distributions of all species exhibited diminished numbers and biomass between 50 and 150 m. This depth interval was consistently the coolest part of the water column (see Observational Physical Oceanography - Chapter 8) and the depth distributions may represent active avoidance of the winter remanent cold zone.

An examination of plankton settled volumes from the AFK and WN hatcheries demonstrated 1994 was weakly "river-like" in the southern portion of the Sound, but not so in the north (Figure 5). Further, historical comparisons suggest that north and south are probably decoupled in some way

through differing circulation processes (see Observational Physical Oceanography - Chapter 8).

A comparison of the timing, magnitude and duration of late stage *Neocalanus* (copepodites IV and V) sampled from the trawler (upper 50 m; F/V Alaska Beauty) and by the WN hatchery (upper 20 m) suggests some major differences in depth distribution (Figure 6). If most the large calanoid population was in the upper 20 m (probably not true; Tuttle, unpublished), these records of abundance and biomass should have tracked reasonably well. They did not. Populations of stage V *Neocalanus* below 20 at this time could mean a more rapid development time then reported (Miller, 1993) or that some substantial portion of the population never invades the surface water (or both). The timing of diminishment of surface populations however, seems to have been captured similarly by both hatchery and vessel collection schemes. This critical vertical distribution issue will be studied more carefully in the spring of 1995 when nets, acoustics, and optical means will all be used in the field to document the vertical extent of upper-layer macrozooplankton populations.

Large scyphozoans (two or three species of jellyfishes) made up a conspicuous part of the surface zooplankton community in June and July. These medusae are known to be common in the region and probably consume huge quantities of zooplankton during the season. Though not formally sampled by SEA in FY94, this category of plankton will receive more attention in 1995 (acoustic target strengths and isotope composition) as will the role of zooplankton in the diet of squids. Preliminary analyses of some squid stomachs indicate a fish and crustacean diet.

Discussion

The seasonal appearance of upper-layer (50 m) populations of *Neocalanus* and *Calanus* confirms earlier observations that much of the spring-time surface zooplankton biomass is contributed by these large calanoids (Tuttle, unpublished). An analysis of the stomach contents of pollock and other large fishes taken by trawling also demonstrates these copepods serve as a major food item during the period of surface swarming (see Prey/Predator Studies - Chapter 2). Coupled with a decline in juvenile fish in the stomachs of larger pollock during this same time, 1994 results provide a suggestive (but not definitive) test of the SEA prey switching hypothesis. Apparently, upper-layer swarms of large copepods can deflect some (perhaps significant) predation away from 0-age and

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other small forage fish during this time. For herring that are hatching near the end of this "sheltering event", the refuge remains problematic. In fact, herring may have evolved a mechanism (delayed entry) to avoid the large upper-layer plankton bloom because some of these zooplankters can prey on weakly swimming larval fishes. Also, the time that herring emerge (beginning in mid May) corresponds to the transition between wind forced upper-layer flow and weak upwell'.ng, presumably a time of weak and variable currents. That strategy might minimize washout from the region.

Because of a marked difference in the reproductive strategies of *Neocalanus plumchrus* and *N. flemingeri* (Miller, 1988), it is possible to differentiate between the two by determining the timing of the molt from stage V to adult. In the case of *N. plumchrus*, stage V copepodites descend to overwintering depth and then coast on energy reserves for several months before molting to stage VI and then reproducing. For *N. flemingeri*, the molt to adult occurs just after the ontogenetic descent, but the act of reproducing is also delayed into late winter (like *N. plumchrus*). Data collected this year (Figure 7) clearly demonstrates most *Neocalanus* molted directly to the adult stage after leaving the surface and thus were *N. flemingeri* (confirmed taxonomically by C. Miller).

Consistent differences in overall settled volumes between the northern and southern regions of the Sound beg a more refined understanding of mechanisms forcing these patterns. Originally, SEA hypothesized that the entire region would exhibit either lake or river characteristics, and that these flow patterns would modify upper-layer plankton populations everywhere. However, observations from the WN hatchery in the northwest corner of the Sound do not track the south Sound observations in most years. That this may be associated with a decoupling of north and south Sound flow fields is part of the physical record for 1994 (see Observational Physical Oceanography - Chapter 8). A competing hypothesis for 1995 asserts that the north/south gradient in upper-layer zooplankton stocks is really forced by Ekman transport in the region responding to predominately easterly winds blowing around the low pressure systems that influence the region in April and May and drive strong or weak downwelling along the outer coast. This conjecture places new emphasis on understanding ocean state (particularly currents) as a function of wind and buoyancy forcing. An ocean state model is planned for FY95 as part of the Information Services and Modeling component of SEA. The model will have immediate application to questions about macrozooplankton distibutions in the surface and deep layers of Prince William Sound.

References

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Scatter Plot of LZOOP vs APRMAY
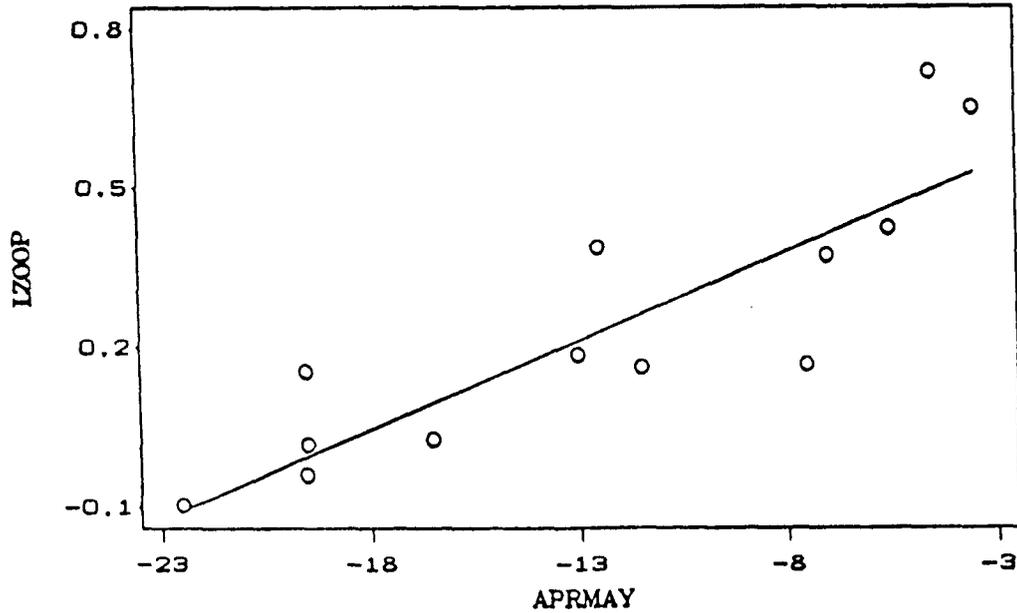
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STATISTIX 4.0                                    NUPWELL4, 10/01/94, 13:0(

UNWEIGHTED LEAST SQUARES LINEAR REGRESSION OF LZOOP

PREDICTOR
VARIABLES      COEFFICIENT      STD ERROR      STUDENT'S T        P
-----------    -----------      ---------      -----------      ------
CONSTANT         0.64656         0.07866          8.22          0.0000
APRMAY           0.03337         0.00572          5.83          0.0001

R-SQUARED                0.7391     RESID. MEAN SQUARE (MSE)    0.01701
ADJUSTED R-SQUARED       0.7174     STANDARD DEVIATION          0.13042

SOURCE          DF        SS            MS          F          P
----------      ---    ----------   ----------    -----      ------
REGRESSION       1      0.57833      0.57833      34.00      0.0001
RESIDUAL        12      0.20410      0.01701
TOTAL           13      0.78243

CASES INCLUDED 14     MISSING CASES 0
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Figure 1. Statistical relationship between the upwelling index and average spring-time zooplankton settled volumes measured at the AFK Hatchery in southwestern Prince William Sound since 1981.

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Alaska Beauty Station Locations
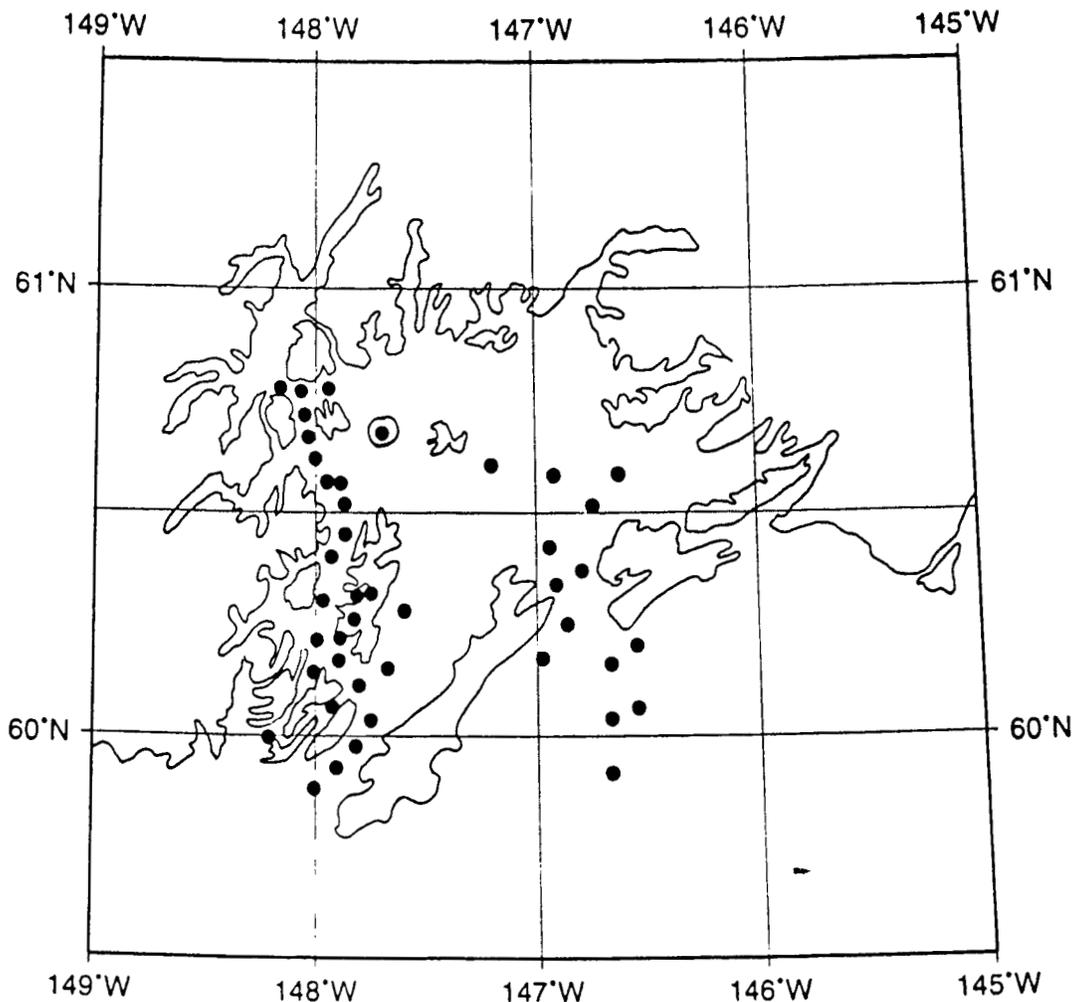
Figure 2. The locations of sampling sites for zooplankton and physical oceanographic measurements in 1994. The vertical-series station at Lone Island is indicated by the circled dot.
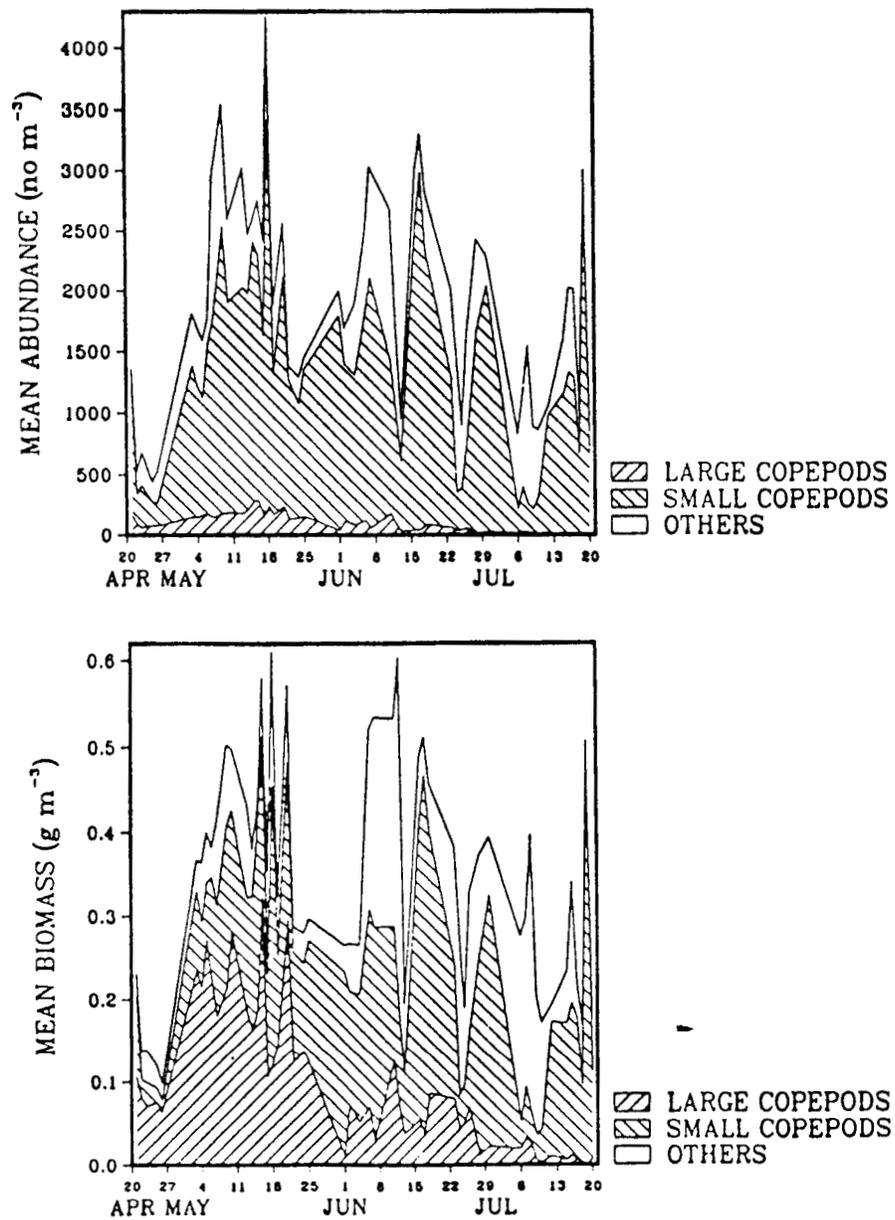
Figure 3. Time-series of large and small copepod abundance (top) and biomass (bottom) and other taxa sampled during the spring and summer of 1994.

MEAN BIOMASS (g m^{-3})

CALANOID COPEPODA
GAMMARIDEAN AMPHIPODA
HYPERIID AMPHIPODA
CARIDEAN DECAPODA
ANOMURAN DECAPODA
MAJIDAE DECAPODA
LARVACEA
GASTROPODA
CNIDARIA
OSTRACODA
CTENOPHORA
OTHERS

6-July-94 at SEA22

MEAN BIOMASS (g m^{-3})

CALANOID COPEPODA
GAMMARIDEAN AMPHIPODA
HYPERIID AMPHIPODA
CARIDEAN DECAPODA
ANOMURAN DECAPODA
MAJIDAE DECAPODA
LARVACEA
GASTROPODA
CNIDARIA
OSTRACODA
CTENOPHORA
OTHERS
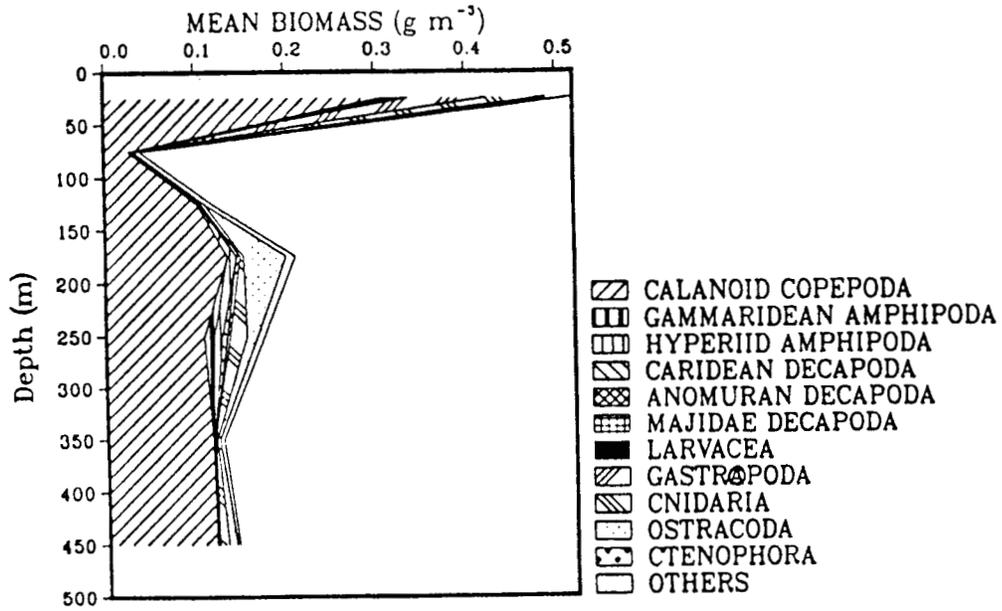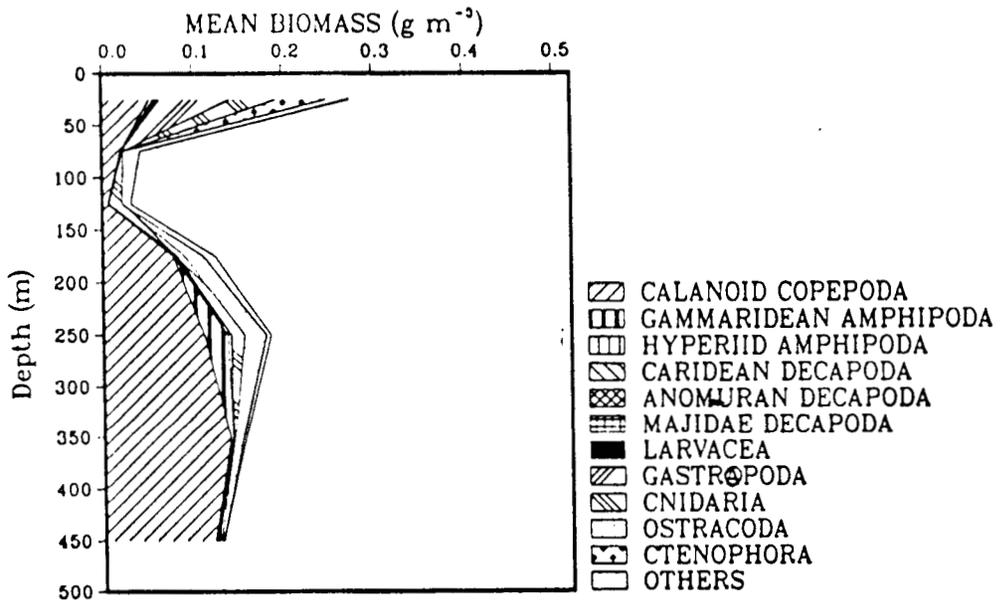
Figure 4. Vertical distributions of pelagic taxa sampled in June (top) and July (bottom) at the deep station near Lone Island.

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Macrozooplankton Time-Series
AFK Hatchery; PWS
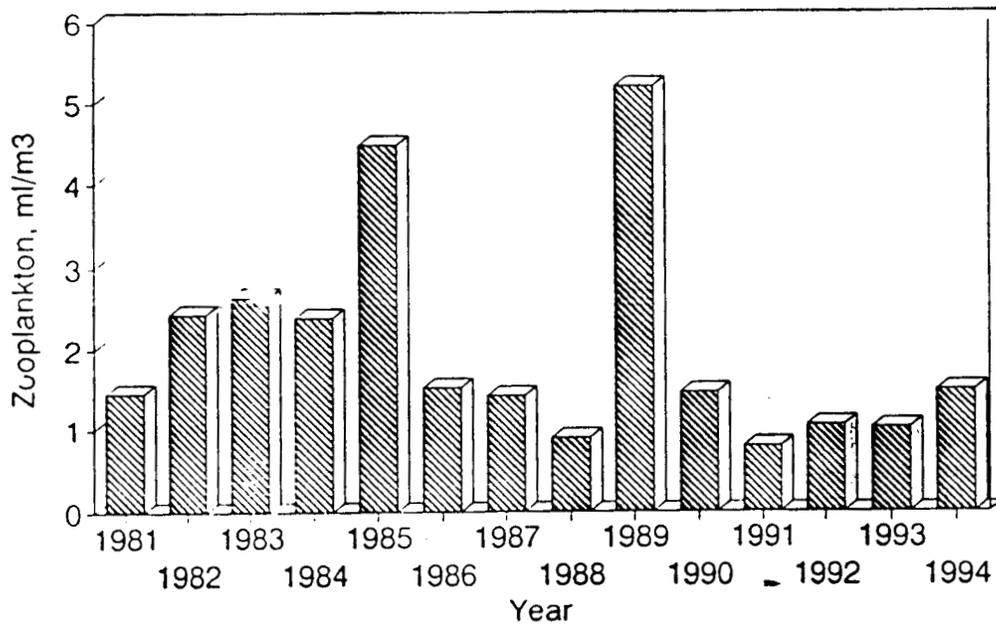
Figure 5. Time-series of average spring-time zooplankton settled volumes from the AFK Hatchery.
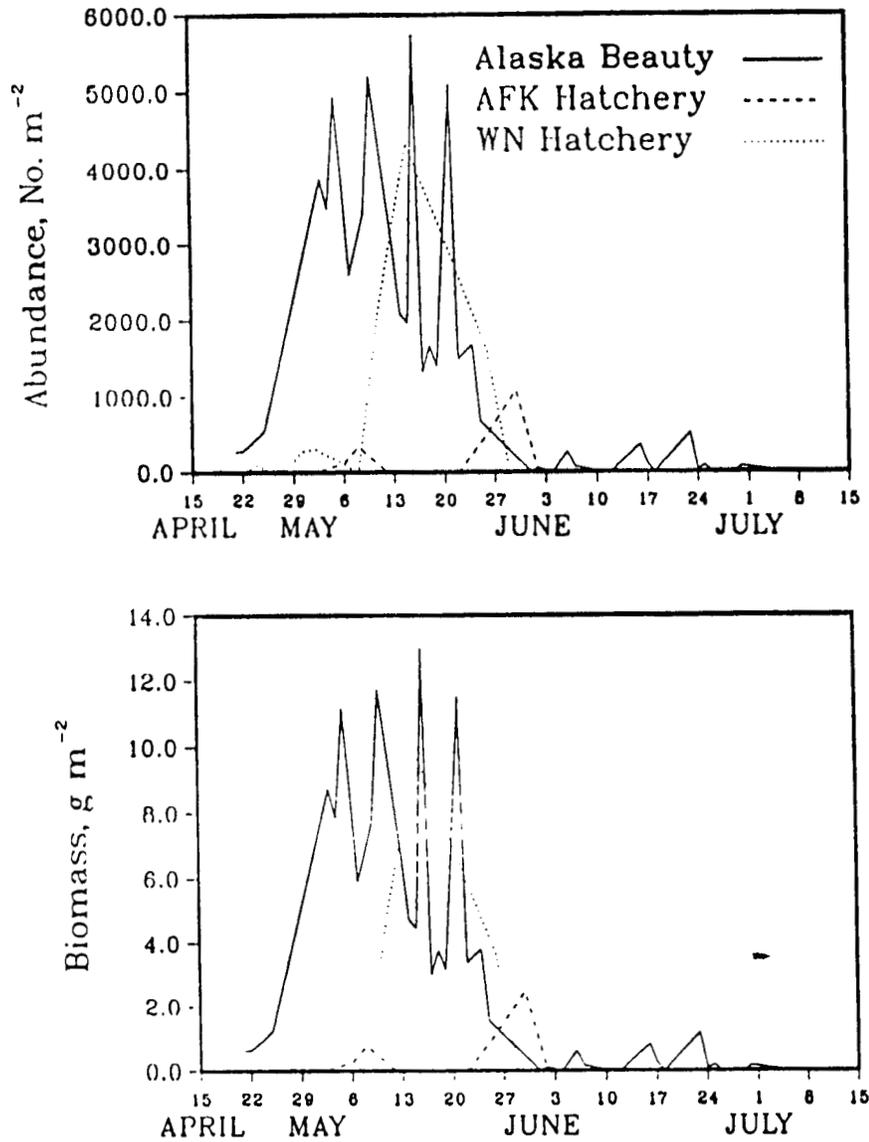
Figure 6. A comparison of the abundance and biomass of late-stage *Neocalanus* spp. sampled in the upper 50 m by the F/V Alaska Beauty and in the upper 20 m by the AFK and WN hatcheries.

6-June-94 at St. SEA22

MEAN BIOMASS (g m^{-3})

CALANIDAE STAGE I
CALANIDAE STAGE II
NEOCALANUS SPP. STAGE III
NEOCALANUS SPP. STAGE IV
NEOCALANUS SPP. STAGE V
NEOCALANUS SPP. FEMALES
NEOCALANUS SPP. MALES

6-July-94 at SEA22

MEAN BIOMASS (g m^{-3})

CALANIDAE STAGE I
CALANIDAE STAGE II
NEOCALANUS SPP. STAGE III
NEOCALANUS SPP. STAGE IV
NEOCALANUS SPP. STAGE V
NEOCALANUS SPP. FEMALES
NEOCALANUS SPP. MALES
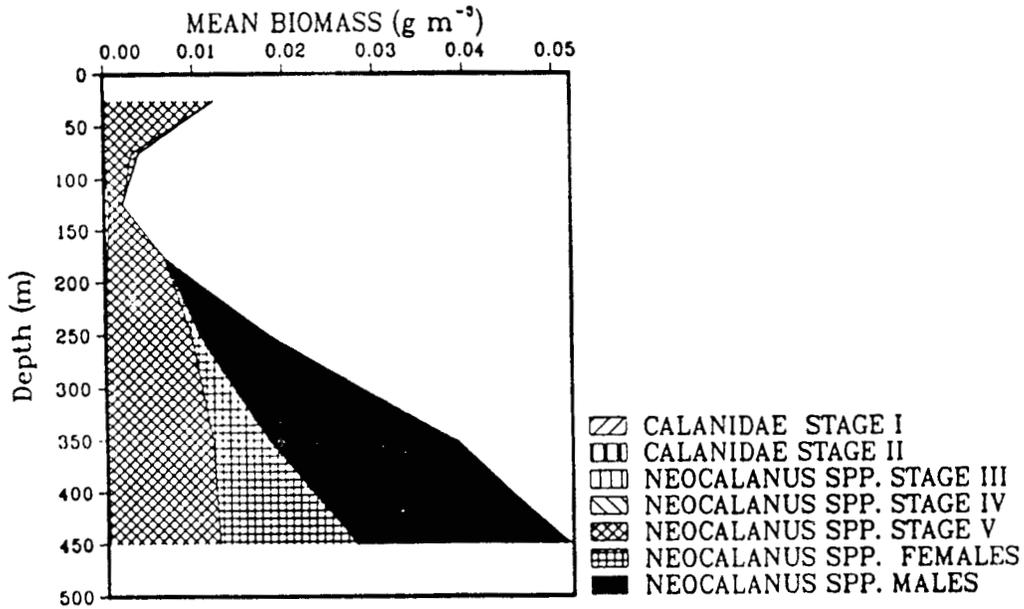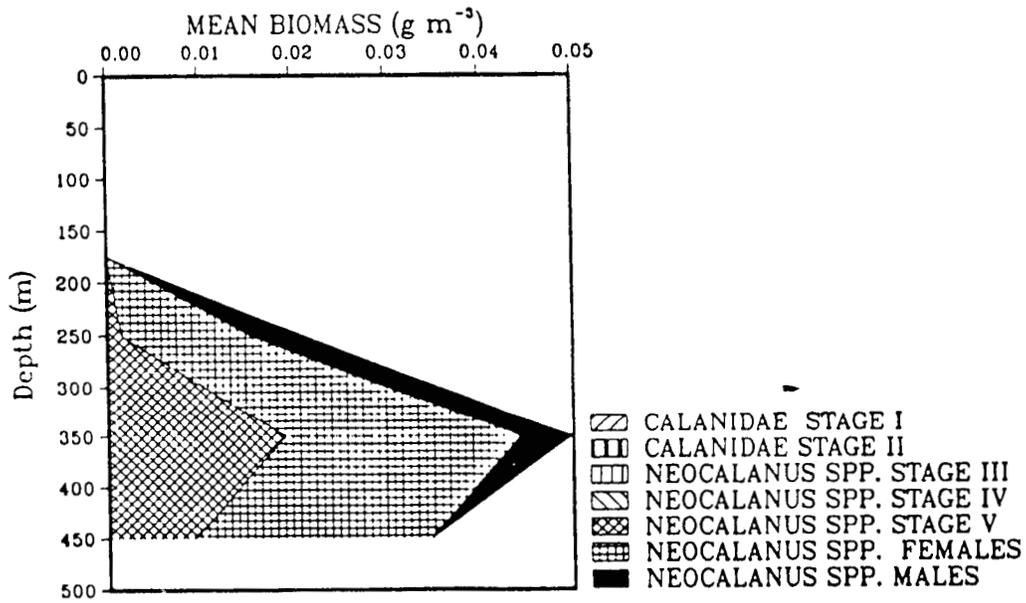
Figure 7. Vertical distribution of *Neocalanus* spp. by copepodite stage at SEA22 near Lone Island.