## *PICES XIII W2-2074 Oral*

## The seasonal cycle of euphausiid zooplankton in the California Current system: A predator's perspective

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The abundance of euphausiid crustaceans varies both spatially and temporally, and is likely influenced by both local and basin-scale ocean climate conditions. Although long-term data sets of annual abundance of euphausiids exist for the California Current System (*e.g.* CalCOFI), few studies have examined the seasonal trends in this ecosystem. Our objective is to compare and contrast the seasonal patterns of relative euphausiid abundance at several sites in the California Current System (CCS). To meet this objective we examined the diet composition of a planktivorous marine bird (*Ptychoramphus aleuticus*). Euphausiids comprise a substantial proportion of auklet diet in this region, and these data may provide a reasonable index to relative euphausiid abundance. Seasonal patterns of euphausiid utilization appeared to differ both annually and latitudinally. Generally, in the central CCS, adult *Euphausia pacifica* was consumed more frequently in the early spring, while adult *Thysanoessa spinifera* was taken more frequently in the early summer, with seasonal peaks occasionally evident for both species. However, there were years where conspicuous seasonal trends in use were absent. *Nyctiphanes simplex*, a subtropical species, was not typically observed in the central CCS, but was present in low numbers from 1993-1995, in the El Niño year of 1998, and in 2003. In the southern CCS, *N. simplex* was consistently the most abundant species, followed by *T. spinifera or Nemetoscelis difficilis*, and seasonal trends in use were variable. We are currently attempting to elucidate causal mechanisms that drive euphausiid abundance and use by marine birds at different latitudes and on multiple time scales.

## *PICES XIII W2-1933 Poster*

## Egg production and early development of *Thysanoessa inermis* and *Euphausia pacifica* (Crustacea: Euphausiacea) in the northern Gulf of Alaska

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Early life history patterns were studied in the dominant euphausiids *Thysanoessa inermis and Euphausia pacifica* from the northern Gulf of Alaska in 2001-2004. Gravid females of *T. inermis* were observed in April and May. Most of females started to release eggs within the first 2 days of incubation. The average number of released eggs per female was similar in Day 1 and 2, but significantly smaller on Day 3 and 4. About 25% of females were continuously releasing eggs over 3 days rather than producing a single distinctive brood. In contrast, gravid females of *E. pacifica* were observed from early July through October. Most of females released eggs on the first day of observation and only 2 females produced eggs repeatedly. Average brood size appeared to increase with female size. Hatching and early development (from egg to furcilia stage) was studied at 5, 8 and 12°C. Hatching was nearly synchronous, occurring over only a few hours depending on incubation temperature. Development times from egg to the first furcilia stage ranged between 20 days and 33 days for *T. inermis* and 15 days and 45 days for *E. pacifica* at 12 and 5°C respectively.

## *PICES XIII W2-1932 Poster*

## Growth rates, fecundity and development times of *Neocalanus flemingeri* in the Gulf of Alaska: A synthesis of laboratory and field approaches

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*Neocalanus flemingeri* is one of the dominant copepods in the subarctic Pacific, yet there are few estimates of the rates at which many processes occur during its life-cycle. Growth and development of *N. flemingeri* CI to CIV copepodites were determined in the field by both the artificial cohort method, and the incubation of single stages, each March, April and May over 3 years at ~5°C. Development, growth, and egg production were also determined at 5°C in the laboratory at saturating food concentrations. In the field, CI to CIV stage durations ranged from 7 to more than 100 days, dependent on chlorophyll concentration, with the duration of each stage~10 days under optimal conditions. Stage durations varied from 5-24 days for NI to NVI, and 6-15 days for CI to CIV in the laboratory, with development time from egg to CV of 117 days. Weight-specific growth rates ranged from 0.23 $d^{-1}$to close to zero in the field, but was typically between 0.20 and 0.08 $d^{-1}$ under more optimal conditions. This compares favorably to 0.07 to 0.27 $d^{-1}$ obtained in the laboratory. In both cases, growth rate typically decreased with increasing stage. Fecundity of *N. flemingeri* was 534 ± 43 (mean ± S.E.) eggs $female^{-1}$-, representing close to 100% of the female's weight. Results are compared to rates of other copepod species determined concurrently in this ecosystem.

## *PICES XIII W2-2057 Poster*

## Seasonal variation of the neustonic zooplankton community in the central region of the South Sea, Korea

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In order to describe species composition and distribution patterns of the neustonic zooplankton, samples were collected using a David-Hempel neuston net during six field expeditions from April 2002 through January 2003 in the central region of the South Sea, Korea. Zooplankton abundance fluctuated greatly over a range of 51 ind./$m^3$ in November to 965 ind./$m^3$ in April. Copepods made up ca. 80% of the total organisms during the study periods and the other important groups were invertebrate larvae, cladocerans, chaetognaths and fish eggs. The spatial differences of neustonic zooplankton in species composition showed that cladocerans, cirripede larvae and fish eggs were abundant in the coastal area while salps, appendicularians and oceanic copepods (*Eucalanus* spp., *Euchaeta* sp.) were dominant in the offshore waters. This suggests that the distribution pattern of the neustonic zooplankton are seasonally affected by both neritic and oceanic waters as well as hydrological conditions.

Microstratification in surface water divided into two layers; upper layer (0-10 cm) and lower layer (10-25 cm). In generally, the population abundance was higher in the upper layer than in the lower layer. In particular, abundance of oceanic species such as pontellid copepods, siphonophorids, medusae and salps increase with high temperature periods in the upper layer. It seems that in spite of its rapid environmental fluctuation the upper layer may provide good habitats to some organisms.

## *PICES XIII W2-1954 Poster*
## *In situ* egg production rate of the planktonic copepod *Acartia steueri* in Ilkwang Bay, southeastern coast of Korea

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Egg production rate (EPR) of the planktonic copepod *Acartia steueri* was investigated in *in situ* incubations from October 1997 to September 1998 in Ilkwang Bay, southeastern coast of Korea. Water temperature ranged from 11.5 to 25.6°C, and chlorophyll *a* concentration was 0.99~11.63 mg $m^{-3}$ with peaks in late February, early April and May-June. *A. steueri* occurred in the plankton throughout the year, except September and October, with the highest peak in March. The EPR ranged from 3.8 to 10.1 eggs $female^{-1}$ $d^{-1}$ (mean: 7.3 eggs $female^{-1}$ $d^{-1}$), and the rate was the lowest in December and then increased gradually until June. Seasonal variation of population egg production rate (eggs $m^{-3}$ $d^{-1}$) was similar to the abundance of *A. steueri* in this bay, showing the highest peak in March. Relationship between EPR and chlorophyll *a* concentration was highly significant and ~85% of EPR was explained by the variation of the chlorophyll *a* concentration. However, only ~37% of EPR was related to the variation of water temperature. Weight-specific growth rate ranged from 0.022 to 0.071 $d^{-1}$ (mean: 0.047 $d^{-1}$) and decreased with increasing body weight of the adult female. The mean EPR in terms of eggs per female per day of *A. steueri* measured by the incubation method was similar to the result from Kang and Kang (1998), in which EPR was estimated using the equation obtained in laboratory experiments relating temperature and chlorophyll *a* concentration to egg production.

## *PICES XIII W2-2126 Invited*
## Variability in seasonal cycles of zooplankton in the seas surrounding the Korean peninsula

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The seas surrounding the Korean peninsula were representative of the Yellow Sea (the west sea of Korea), the East-China Sea (the south sea of Korea) and the East/Japan Sea (the east sea of Korea). These seas have very different physical characteristics. Considering that zooplankton production probably responded to physical oceanographic conditions, it was hypothesized that the seasonal cycles of zooplankton will be different in response to hydrographic conditionis in the three different seas, and to climate regime shifts. The seasonal cycles of zooplankton biomass and four zooplankton assemblages, copepods, amphipods, euphausiids and chaetognaths, were analyzed with long-term data in the seas surrounding Korean peninsula with consideration seasonal cycles in each sea and regime shifts, using harmonic analysis. Seasonal cycles of zooplankton biomass and four zooplankton assemblages were also analyzed to investigate step changes in response to the regime shifts in the East/Japan Sea. Three periods before and after regime shifts were compared: 1st period (1966~76), 2nd period (1977~88) and 3rd (1989~2000).

Zooplankton biomass showed a typical seasonal cycle with two peaks in spring and autumn in the seas surrounding Korean peninsula. However, there are differences in seasonal cycles in each sea. In the Yellow Sea, zooplankton biomass and copepods showed a large peak in June and a small peak in October, while the other zooplankton assemblages did not show such a peak. Chaetognaths appeared abundantly in August after the copepod peak and amphipods and euphausiids showed a peak in August and June, respectively. In the East-China Sea, zooplankton showed a large peak in October and a small peak in April and June. Copepods had a similar seasonality with zooplankton biomass. Chaetognaths appeared abundantly during August~December and euphausiids were abundant in June. In contrast with the Yellow and East China Seas, the East/Japan Sea showed the highest zooplankton biomass in February and April. Copepods were also abundant in April, while the other zooplankton assemblages had different seasonal cycles.

As compared among three periods in the East/Japan Sea, zooplankton biomass showed a large peak in February and April in the 1$^{st}$ period, a small peak in October in the 2$^{nd}$ period, and peaks in April and October in the 3$^{rd}$ period.

Copepods were abundant in April and June in the 2nd period and April in the 3rd period, while amphipods showed a large peak in June in the 3rd period. Chaetognaths appeared abundantly in August in the 2nd period and October in the 3rd period. Euphausiids showed peaks in April and October in 3rd period, while a small peak in June in the 2nd period.

It is concluded that zooplankton biomass showed seasonal variations that responded to physical characteristics and regime shifts. The Yellow and East China Seas showed a similar seasonal variation in zooplankton biomass, while the East/Japan Sea was different.

### *PICES XIII W2-2016 Oral*

## Variability in timing and magnitude of the spring bloom in the Oyashio water: An analysis from the "A-line" oceanographic database (1990-2003)

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Hokkaido National Fisheries Research Institute (HNFRI) has an oceanographic survey line, which is called the "A-line". The "A-line" is located in the area off eastern Hokkaido and northern Honshu in the western subarctic Pacific, and crosses the Oyashio current perpendicularly. In order to examine the spatial and temporal variability in the oceanographic environment in the Oyashio water, the "A-line" observations have been carried out 4-8 times a year since 1990. Physical, chemical and biological measurements were made using standardized methods throughout the survey period. Quality-checked data was accumulated into the database (1990-2003), and HNFRI has openeds this database to scientists at their website (*http://www.mirc.jha.or.jp/HNF/a-line/index.html*). In order to analyze the long-term variability in the oceanographic environment in the Oyashio water, we extracted the data in the Oyashio water from the database, and examined the variability of the surface concentrations of chlorophyll *a* and nutrients, and the standing stocks of netplankton within the upper wind mixed layer. The mean concentration of chlorophyll *a* at the surface in March and April was higher after 1998 than that before 1997, suggesting early initiation and development of the spring blooming after 1998. These differences in the characteristics of spring blooming between before and after 1998 seem to be associated with some phenomenon after 1998, such as high consumption of nutrients during blooming, high standing stock of netplankton in April and May, and so on. In our presentation, results from further analyses are showed, and effects of the regime-shift in 1998 to the oceanographic environment related primary productivity in the Oyashio water are discussed.

### *PICES XIII W2-1887 Oral*

## Relation between phytoplankton blooming and wind stress in the central Japan/East Sea

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The seasonal dynamics of phytoplankton in the central Japan/East Sea showed pronounced year-to-year variability as observed from SeaWiFS (1997~now) and MODIS/Terra (2000~now). The variability seems to be strongly influenced by the wind, as the timing of spring blooms has a negative correlation with wind stress while the timing of fall blooms has a positive correlation with wind stress. To study this relationship, we hypothesize as follows: in spring, the bloom will start after the water column has stabilized, which requires weakening of the wind-induced vertical mixing. In the autumn, the bloom will start when wind-driven vertical mixing resumes with seasonal increases in wind stress. To test these hypotheses, we analyzed the daily remotely sensed wind stress data (AMI-wind, NSCAT and QuickSCAT: 1997~2003) and daily chlorophyll *a* concentration from the ocean color data. The results agreed well with the hypotheses. In spring, the phytoplankton bloom started 6~10 days after the wind weakened. In fall, blooming started 1~4 days after with winds strengthened, which mixes water and supplies nutrients to the euphotic layer. We try to explain the possible mechanism by a simple box-model.

## *PICES XIII W2-1816 Oral*

## Seasonal changes in plankton biomass, production and community structure in southern Japan


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It is known that carbon flow in marine ecosystem is associated with structure of plankton food web. Since available resources for animals at higher trophic levels decrease (increase) in complex (simple) food web, such information might be important for understanding the influence of climatic variability on marine ecosystem. There are some previous studies on plankton food web and dynamics in the productive waters such as equatorial and subarctic Pacific. However, we have little knowledge on plankton food web in the subtropical waters dominated by pico- to nanoplankton. Thus, seasonal changes in plankton biomass, production and community structure were investigated from pico- to mesoplankton samples collected monthly to bimonthly in southern Japan (30˚N, 131˚E) to show structure and carbon flow in the planktonic food web. In southern Japan, bacteria, autotrophic nano-flagellate (ANF) and copepods dominated plankton biomass throughout the year, although no seasonal pattern was observed for both phyto- and zooplankton biomass. ANF dominated daily phytoplankton production but showed no clear seasonal patterns. Bacteria and heterotrophic nano-flagellate (HNF) contributed to daily zooplankton production and increased during summer. Annual phytoplankton and zooplankton production was estimated to be 177.0 and 244.3 gC $m^{-2}$ $year^{-1}$ (in 0-50 m strata), respectively. ANF (103.7 gC $m^{-2}$ $year^{-1}$) and bacteria (135.8 gC $m^{-2}$ $year^{-1}$) were major producers. These results suggest that the microbial food web is important in subtropical waters of southern Japan. However, community structure and planktonic food web dynamics in southern Japan might be associated with the coastal waters with low salinity in the East China Sea.


## *PICES XIII W2-2100 Oral*

## Seasonality in the community structure of planktonic ecosystem in the epipelagic layers of the subtropical water off Kuroshio


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We examined seasonal changes in community structure of planktonic ecosystem in the subtropical water off the Kuroshio based on the samples collected seasonally from May 2002 to January 2004 during the O-line monitoring by National Research Institute of Fisheries Science. In winter, when the vertical mixing reaches to deeper than 200 m, the annual highest biomass of phytoplankton occurred, though the primary production rate was lowest, which indicates the low feeding pressure on the primary producers in winter. Pico-sized eukaryotic phytoplankton which was mainly distributed in the lower euphotic layer during the stratified seasons was dominant in the phytoplankton community through the water column in winter. Biomass of the centric diatoms, the dominant phytoplankton groups in the spring bloom in the subarctic waters, was low in the all seasons. Biomass of members of microbial loop such as HNF and cilliates was highest in spring when annual highest primary production occurs, and lowest in autumn. Biomass of large copepods whose prosomal length is longer than 1mm was lowest in summer, and tended to increase from autumn to spring. On the other hand, seasonal pattern of biomass of small copepods, the major component of the copepod communities, was obscure. In the subtropical water, diversity of copepod communities are generally high as compared with subarctic waters, which may have contributed to the obscure seasonality in the biomass of small copepods.

## *PICES XIII W2-2082 Oral*

## Seasonal cycle of nutrients, phytoplankton and zooplankton in the coastal upwelling zone off Oregon, U.S.A.

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Measurement of the seasonal cycles of temperature, nutrients, phytoplankton and zooplankton is a fundamental activity within most long-term ecological observation programs. Examples include monitoring at ocean time series stations such as at P, KNOT, A-Line, HOTS and CalCOFI, and more coastally oriented time series studies carried out at various points around the Pacific Rim by institutions associated with the PICES nations. Multi-year sampling programs allow study of year-to-year variations in the timing of the initiation and magnitude of production cycles and of how climate variability may affect production cycles. We have been sampling the hydrography and nutrients at biweekly intervals for the past nine years at several stations across the continental shelf off Newport Oregon (44 40'N latitude). In this paper, we show climatologies of seasonal cycles of temperature, nutrients, chlorophyll and zooplankton biomass and species composition, and compare seasonal cycles among years and between stations using anomalies from the nine-year averages, for a mid-shelf station (9 km from shore) and an outershelf station (40 km from shore). We show that the mid-shelf station is dominated by copepods whereas the outershelf station is dominated by euphausiids giving rise to very different seasonal cycles of plankton biomass, production and grazing potential. Thus knowledge of the species composition of the zooplankton (rather than just total biomass) may be a necessary condition if one is to understand the dynamics of seasonal cycles. However for the purposes of developing NPZ models, it should be sufficient to know the biomass of functional groups: copepods, euphausiids, and others.

## *PICES XIII W2-2045 Oral*

## Seasonal dynamics of plankton in the northern California Current ecosystem: A model-data comparison

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Seasonal dynamics of nutrients and plankton in the northern California Current ecoystem were examined using a modification of the PICES NEMURO model. The NEMURO model was coupled to a one-dimensional cross-shelf mixed-layer hydrographic model, designed to provide a computationally simple representation of wind-driven upwelling and east-west transport in the mixed layer. Physical data (winds, temperature, solar radiation) driving the model were selected to closely match conditions along the Newport Hydrographic (NH) Line. Analyses were conducted for seven years (1997-2003) for which a time-series of observations (temperature, nutrients, chlorophyl, and zooplankton) are available. These years represent a wide range of climatic conditions, and span a possible regime change. Model predictions were compared with data, both at the scale of individual samples and as seasonal averages. The model provided a rough approximation to the temporal and cross-shelf patterns of nutrient and plankton abundance, but there is much room for improvement. Implications of results for production of small pelagic fishes are discussed.

## *PICES XIII W2-1866 Oral*

## Year-to-year variations in developmental timing of large grazing copepods at Site H in the Oyashio region

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To evaluate interannual variations in developmental timing of large grazing copepods (*Neocalanus cristatus, N. flemingeri, N. plumchrus, Eucalanus bungii* and *Metridia pacifica*) in the Oyashio region, time-series samplings were made at Site H (rectangle defined by 41˚30' to 42˚30'N and 145˚00' to 146˚00'E) during the periods of September 1996-October 1997 and May 2002-March 2004. Zooplankton samples were collected monthly or bimonthly by vertical hauls of a 60-cm ring closing net (1996-1997) or a NORPAC net (2002-2004) with 0.1 mm mesh openings from 500 m to the surface. The timing of recruitment of early copepodid stages was December-February for *N. cristatus*, March for *N. flemingeri*, and May-June for *N. plumchrus* and *E. bungii*, showing little year-to-year variations. As an exception, the recruitment of early copepodid stages of *M. pacifica* in 2003 and 2004 occurred 1-3 months earlier than that in 1997. The presence of interannual variations in the recruitment season in *M. pacifica* may be interpreted by the shorter generation length, no diapause phase, and close coupling of feeding and spawning of this species as compared with the other species mentioned above. The incidence of salp blooms in 2003 affected the recruitment of *N. plumchrus* and *E. bungii* but not recruitment of other copepods, suggesting possible food competition between young copepodid stages of the two species and salps. The relationship between year-to-year differences in zooplankton biomass and developmental timings of large copepods will also be discussed.

## *PICES XIII W2-1886 Invited*

## Extension of NEMURO to represent habitant segregation of plankton groups in the western North Pacific

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Our group joined in developing the NEMURO lower tropic level model, applied it to two stations in the western subarctic region (Fujii *et al.*, 2002; Yoshie *et al.*, 2004; Kishi *et al.*, 2004; Yamanaka *et al.*, 2004; Yoshie and Yamanaka, 2004) and coupled it with a 3-D model (Aita *et al.*, 2003; Hashioka and Yamanaka, *to be submitted*; Aita *et al.*, *to be submitted*). NEMURO originally focused on subarctic plankton groups, but we are now developing a model extended from NEMURO (eNEMURO) in order to apply the model to a subtropical planktonic ecosystem. Towards this end, we have introduced two additional phytoplankton groups, one zooplankton group and bacteria within the microbial loop. In eNEMURO, an introduced coastal species of diatom has a larger maximum photosynthesis rate and half-saturation constant for nitrate than those of the original species in NEMURO, and a pico-phytoplankton group that has a temperature dependency of photosynthesis without growth at temperature $< 15^{o}$C. These differences produce habitat segregation among phytoplankton groups, *i.e.*, differences in the two physiological parameters result in dominance of coastal and original species of diatom in the coastal and pelagic regions, respectively. Temperature dependency also leads to habitat segregation between nano- and pico-phytoplankton. The original NEMURO is regarded as having intermediate complexity. Introducing a greater number of compartments to the ecosystem model leads to further complexity, but each compartment needs to represent more than one specific plankton group. In order to represent different ecosystem between coastal and pelagic regions or between subarctic and subtropical regions, and correspondence between modeling and observation, we will need to discuss what level of complexity is best.