

**PICES XIV S2-2541 Oral**

**Change in habitat conditions of euphausiids as a cause of sharp decline in the Aniva Bay productivity (La Perouse Strait)**

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The study area is situated in the northern part of the La Perouse Strait (Okhotsk Sea). Zooplankton community of the bay is formed under the influence of the Okhotsk (East - Sakhalin Current) and Japan (Soya Current) seas and redistribution of waters from the northern Japan Sea caused by upwelling (near Opasnost Rock) and anticyclonic circulation in the southern part of the bay. There is a developed neritic complex of planktonic organisms in the bay due to its shallow waters.

In 1987-2005, 29 surveys were conducted by a standard scheme of stations. A total of 669 zooplankton samples were collected using Juday nets (0,1 m<sup>2</sup>, 0.112 mm) towed vertically from near the bottom to the sea surface.

Based on samples collected from 1987-1995, Aniva Bay was determined as the most productive subregion around Sakhalin Island. The cold-water euphausiid *Thysanoessa raschii* (*Th. inermis* in the extremely cold period) was found to be a dominant in spring. The highest-density zone of euphausiid aggregations coincided with the northern periphery of the quasi-stationary anticyclonic eddy A1. Under the two-core structure of this eddy, a zone of aggregations coincided with that of the deep water rising between two anticyclonic eddies. The low water temperature (-2 - 0°C) and high oxygenation (117-123% in the subsurface layer) were common for a zone of euphausiid aggregations.

In autumn, the cold-water (CW) medium-size copepods (*Pseudocalanus minutus*, *Ps.newmani*, *Acartia longiremis*) dominated as usual. However, during a significant positive SST anomaly, the moderately-cold-water neritic copepod *Centropages abdominalis* dominated the biomass. On the whole, zooplankton biomass in autumn was significantly lower compared to spring.

By the results obtained during 2001–2005, it was concluded:

- a) substitution of large cold-water euphausiids and chaetognaths for copepods of the same ecological group (*Pseudocalanus minutus*, *Ps. Newmani* and *Acartia longiremis*) in the Aniva Bay zooplankton community took place in the spring period, and a total zooplankton biomass in spring decreased significantly;
- b) along with the gradual rise of SST, there was intensive development of a neritic copepod complex, which resulted in shifting of the annual maximum of total biomass dynamics for the autumn period;
- c) south - boreal, subtropical and tropical copepod species increased in biomass in the Aniva Bay waters, and their distribution was observed up to the northern coast of the bay;
- d) zones with high concentration of euphausiids *Thysanoessa raschii* and *Th. inermis* were observed to be formed in late autumn – winter.

Changes in euphausiids taxonomic composition and age structure, as well as hydrochemical indices and oceanological conditions of their habitat will be discussed.

**PICES XIV S2-2497 Poster**

**Euphausiid distribution near Uljin with special reference to its importance as a food source of demersal fish and impingement on the cooling water intakes of a power plant**

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Diel and seasonal variation of vertical and horizontal distribution of euphausiids in the vicinity of Uljin, the eastern coast of Korea was examined from the autumn of 2002 to summer of 2003, and during the spring of 2004 using a multiple opening and closing net and an echosounder equipped with a 200 kHz transducer. *Euphausia pacifica* dominated the biomass and often aggregated near the bottom at 100-200 m depth and/or the

submarine channel (>200 m depth approximately) during the day time from the autumn to winter, and performed active diel vertical migration, showing shallow depth distribution around mixed layers at night. The distribution shifted to near-shore during the springs of 2003 and 2004 when the maximum chlorophyll *a* concentration markedly increased (3.6  $\mu\text{g l}^{-1}$  and 15.5  $\mu\text{g l}^{-1}$ , respectively, while showed range of 0.2-0.9  $\mu\text{g l}^{-1}$  during the autumn and winter and 0.6  $\mu\text{g l}^{-1}$  in the summer). Samples coincident with acoustic scattering layers in the springs contained high number of eggs and metanauplii accompanied by matured individuals in breeding condition. Thus, intake impingement of euphausiids at Uljin nuclear power plant may relate to the breeding activity. The gut content analysis of dominant demersal fish in the study area, *Pleurogrammus azonus*, also showed that euphausiids played an important role as a food source (100.0 % of food item frequency).

**PICES XIV S2-2584 Poster**

**Egg production and molting rates of the subtropical sac-spawning euphausiid *Nyctiphanes simplex* in the southern part of the California Current System**

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*Nyctiphanes simplex* is the most prominent euphausiid from the neritic region of the southwest coast of Baja California peninsula, México. During three oceanographic cruises (Mar, Jul & Dec, 2004) females were incubated under shipboard laboratory conditions (48 h, 16-18°C, 24 h dark, without food) to measure brood size, interbrood period and molting rates. Females ready to spawn (9-16 mm length, older than 60 days) have a pale pink ovary that extends from the back of the stomach to the first abdominal segment, filling most of the haemocoel. This sac-spawning species produces one batch of oöcytes per cycle of the ovary, leaving an 'empty' space in the cephalothorax where the spent ovary is located. After spawning, the embryos develop in the ovigerous sac and hatch as nauplius stage, but they leave the ovigerous sac as metanauplius stage five days after spawning. Females are not ready to spawn again until at least two days after the previous batch of embryos leaves the ovigerous sac. Brood size (BS) had a significant linear association with female length ( $r^2=0.24$ ,  $p<0.001$ ). *N. simplex* spawned between 7 and 105 eggs per ovigerous sac, with larger BS in March and July and significantly smaller BS during December (<30 eggs fem<sup>-1</sup>), when spawning of unfertilized eggs was common. The interbrood period (IBP) observed ranged between 7 and 15 days. The IBP is about one fourth to half than was previously assumed for this species, suggesting a significant underestimation of its fecundity. If the average female reproductive life-span is about 6 months, producing between 12 and 24 ovigerous sacs, and the average BS is 50 eggs fem<sup>-1</sup>, the female life-span fecundity likely range between 600 and 1200 eggs fem<sup>-1</sup>. Instantaneous growth rate calculations indicate this species has a significant increase in body size in spring and summer when upwelling events are intense. Negligible body growth or even negative instantaneous growth occurred during winter associated with the northward advection of warmer Equatorial water mass, characterized by deep thermocline and oligotrophic conditions.

**PICES XIV S2-2447 Oral**

**Krill and krill-predators: Habitat associations in the dynamic Gulf of the Farallones, California**

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We tested the hypothesis that krill and krill-predators aggregate at predictable locations in the continental shelf and slope waters of the Gulf of the Farallones. We conducted research cruises in 2004 (May-October) and 2005 (February-July). We characterized the physical oceanography using CTD casts and continuous CT and fluorometry measurements. We concurrently determined the distribution and abundance of krill using hydroacoustics and nets, and of krill-predators (*i.e.*, birds and mammals) using standardized transects. Physical oceanographic conditions varied greatly between months and years. Strong northwest winds resulted in upwelling and elevated fluorescence early in 2004, but these events were delayed in 2005. Acoustic backscatter indicated strong habitat association for krill along the shelf break-slope region with large aggregations near

canyons and other topographic features. Acoustic backscatter in the upper 50-m increased as a positive function of SST, decreased with distance from Cordell Bank, and increased with high fluorescence. Cassin's auklets *Ptychoramphus aleuticus*, a krill-eating seabird, foraged in large numbers at the upwelling front during strong upwelling conditions in 2004, but were widely dispersed along the shelf break when upwelling was absent in late 2004 and 2005. Auklet habitat affinities in 2004 showed positive associations with Cordell Bank, the Farallon Islands, and the shelf break and with increasing salinity, the latter indicative of foraging near the upwelling plume off Point Reyes; however, this model was not validated by data collected in 2005. Among marine mammals, humpback *Megaptera novaeangliae* and blue whales *Balaenoptera musculus* were generally sighted near the shelf break and Cordell Bank.

**PICES XIV S2-2234 Poster**

**The role of lipids during egg development in *Euphausia pacifica* and *Thysanoessa spinifera***

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To understand the role of lipids during early embryogenesis, major lipid classes together with individual fatty acid and sterol composition was determined in eggs from three different embryonic development stages of *Euphausia pacifica* and *Thysanoessa spinifera*. Average lipid content in eggs of *E. pacifica* and *T. spinifera* from the earliest stage (multiple cells) were 4.45 and 3.69  $\mu\text{g egg}^{-1}$ , respectively. Phospholipids were the dominant lipid class throughout all embryonic stages with rapidly decreasing concentrations during the later embryonic stages during embryo development, lipid content decreased at the similar rates in the eggs of both species. Lipids were slowly utilized without preferential usage of specific lipid classes prior to the gastrula stage. Yet more than 60 % of lipids, mainly phospholipids were lost (or consumed) between blastula or gastrula and early or late limb-bud stages for both species. Total fatty acid and sterol contents showed similar trends as lipid content during early embryogenesis. Among fatty acids, 16:0, 16:1 $\omega$ 7, and 20:5 $\omega$ 3 were dominant with significant changes during early embryo development. Grouped fatty acid composition found that polyunsaturated fatty acids were preferentially metabolized throughout early embryogenesis. An exception was 22:6 $\omega$ 3, which remained at constant levels or only decreased slightly through all stages. Cholesterol was the dominant sterol (>82% of total sterols) found in euphausiid eggs with minor changes during embryogenesis. The appearance of algal sterols, however, together with phytol in *T. spinifera* eggs suggests significant direct lipid transfer from adult krill. Although egg density calibrated using chemical composition of egg showed significant changes through early embryo development for both species, egg sinking rate changes only slightly with the exception of later stages (*i.e.* limb-bud stage). These results suggest that, in terms of biochemical components, lipid of eggs is related to energetic and nutritional requirements, but not strongly associated with egg density and sinking rate during embryogenesis.

**PICES XIV S2-2233 Invited**

**Understanding the nutritional status, diet, and demographic structure of *Euphausia pacifica* through multiple organic markers**

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*Euphausia pacifica* is one of the most abundant krill species in north Pacific coastal waters and plays a key link between primary producers and top predators. However, their ecology and vital rates remain difficult to understand due to the strong spatial and temporal heterogeneity of their physical environment. In this study, a suite of organic markers (including algal pigments and lipids) in animals and seston were analyzed to better understand the feeding ecology and nutritional status of *E. pacifica* and thus trophic transfer of energy. Pigment distributions indicate that large diatoms were the most abundant algal species in nearshore upwelling regions while a greater diversity and smaller sized algal communities were found offshore, both displaying both

temporal and spatial variability. Lipid levels and compositions in krill were closely linked to their life cycle (*i.e.* reproduction) and environmental condition (*i.e.* food availability). The lipid composition of *E. pacifica* collected across shelf transects reflected the varied food resources available in the water column, but also suggested selective feeding. Other lipid markers (fatty acids and sterols) are well correlated with algal pigment signatures including the distribution of diatom specific fatty acids (*i.e.* 16:1(n-7) and 20:5(n-3)). Combined results of algal pigment and lipid analysis show substantial changes in many of these markers in animals and seston along physico-chemical features and coastal topography, most notably in upwelling regions where diatoms are important. To assess growth and recruitment as well as to determine how changes in environmental conditions alter their condition and distribution, an additional understanding of precise demographic structure in *E. pacifica* is needed. Since age determination of euphausiids cannot be accomplished using traditional approaches, we evaluated the potential of age pigments (collectively termed lipofuscin) to determine the demographic structure of the field population of *E. pacifica*. Lipofuscin was extracted from neural tissues (eye and eye-stalk), quantified and normalized to protein content to allow comparisons across animal sizes. Lipofuscin contents in known-age krill reared for over 1 yr were significantly correlated with chronological age (correlation coefficient=0.85; n=46, p<0.01). Field-collected krill contained variable levels of lipofuscin dependant on size and age. Based on biochemical measures of age, the lifespan of *E. pacifica* in the northeast Pacific is no longer than 2 yrs. The results suggest that the application of multiple molecular organic indices allows a more detailed understanding of the feeding ecology and population age structure of *E. pacifica* and thus its role in dynamic ecosystems.

**PICES XIV S2-2439 Oral**  
**Euphausiid reproduction off the Oregon Coast, U.S.A.**

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Few will argue that we have not found a satisfactory way to accurately quantify the adult biomass of euphausiids in an oceanic environment. Extreme patchiness, interannual variability, ontogenetic and diel migrations, and imperfect sampling methods all contribute to our lack of confidence. However, we now have the tools, and most of the information to allow us to quantify euphausiid production through reproduction. Through 10 years of biweekly sampling off the Oregon coast we have defined the length and variability in the spawning season for *Euphausia pacifica* and *Thysanoessa spinifera*, and have developed an index of egg and larval abundance. Regular incubation of gravid females has allowed us to parameterize brood size for the two species, with averages close to 150 eggs per brood for both species. Long-term laboratory incubations of *E. pacifica* females have provided a median interbrood period of 5 days. All of the above measurements include a tremendous degree of variability, which allows us to calculate average, minimum and maximum production, and to compare production among years, seasons and some geographical areas. Using these data we can estimate the seasonal fecundity of an individual female off Oregon, and make first order predictions of total reproductive effort. These numbers are available for use in modeling at several levels of detail and though inherently variable, are quite reliable compared to direct measurements of adult biomass.

**PICES XIV S2-2438 Invited**  
**Seasonal variations in intermolt period and growth of *Euphausia pacifica* and *Thysanoessa spinifera* in the coastal Pacific Northwest**

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*Euphausia pacifica* and *Thysanoessa spinifera* are the two dominant species of euphausiids in coastal North America. Moulting rate experiments on these two species were conducted using animals collected off the coasts of Oregon, Washington and Northern California throughout 2001-2004. This time period encompasses some distinctly different oceanographic conditions with 2001 and 2002 being relatively cold and productive years, while 2003 and 2004 were warmer and less productive. Potential responses by the animals to environmental

changes will be investigated. Moulting experiments determine change in length and intermoult period (IMP) and allow us to calculate growth in mm per day. Positive growth ranged from 0 to 0.9 mm per day. Negative growth occurred during all seasons, usually in larger animals of both species. Negative growth during the reproductive season may be a result of reproductive activity rather than of poor environmental conditions. Individual growth tended to decrease as animals got larger but was highly variable. There was no clear relationship between growth and surface chl concentration or water depth. IMP was fairly constant over all size classes for both species, but varied seasonally. IMP tended to be shorter in summer months and longer during the winter, averaging approximately 6.9 d and 10.6 d respectively.

**PICES XIV S2-2290 Invited**  
**Distribution and life history of *Euphausia pacifica* off northeastern Japan**

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The abundance, spawning, growth pattern and life span of *Euphausia pacifica* were examined using widely collected samples off the Japanese coast of the North Pacific. Adults were widely distributed in the Oyashio area [OW; Temperature at 100 m depth ( $T_{100}$ )  $\leq 5^{\circ}\text{C}$ ] and the transitional area ( $5^{\circ}\text{C} < T_{100} \leq 15^{\circ}\text{C}$ ) throughout the year, but the occurrence of large adults ( $> 15$  mm) was limited to OW and the cold waters of the transitional area (CW;  $5^{\circ}\text{C} < T_{100} \leq 10^{\circ}\text{C}$ ). Spawning occurred in OW and the transitional area throughout the year, especially in CW in spring, but rarely in winter. Two modal cohorts of adults were consistently recognized in OW and CW. Cohorts of small males and females (10-11 mm length), which newly appeared in spring, grew remarkably to ca. 17 mm from the following spring to early summer, followed by a long period of little growth during spring-winter. Then, both male and female cohorts grew slowly and steadily after summer to a maximum of 18-19 mm by the following spring. Then, the cohort of males disappeared after spring, but that of females (ca. 20 mm length) was recognized until late summer. If the cohort of small adults is assumed to develop mainly from the spring hatching, the life span of male and female *E. pacifica* can be estimated to be 24 months and 28 months, respectively, off northeastern Japan.

**PICES XIV S2-2414 Poster**  
**Quantitative distribution of euphausiids in the East China Sea and the Yangtze Estuary in relation to the environmental conditions**

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The quantitative distribution of euphausiids in the southern part of the Yellow Sea and in the shelf area of the East China Sea was studied based on the zooplankton samples collected during 2 cruises in Aug. 2002 and Aug 2003. Nine species were found including *Euphausia diomedea*, *Euphausia mutica*, *Euphausia nana*, *Euphausia pacifica*, *Nematoscelis gracilis*, *Pseudeuphausia latifrons*, *Pseudeuphausia sinica*, *Stylocheiron affine*, *Stylocheiron carinatum*, *Stylocheiron microphthalmum*. Among them *Pseudeuphausia sinica*, *Euphausia nana* and *Pseudeuphausia latifrons* were dominant. The *Pseudeuphausia sinica* was wide spread in the East China Sea with high abundance off the Zhejiang coast ( $41.5 \text{ ind}\cdot\text{m}^{-3}$ ) and Yangtze estuary ( $86.67 \text{ ind}\cdot\text{m}^{-3}$ ), the seasonal variation shows: Summer > Autumn > Spring > Winter. *Pseudeuphausia latifrons* was the dominant one distributed in the southern part of the East China Sea and was dominant in the outer - shelf waters but the high abundance center was in near-shore sea area. The other 6 species were rare. Most of them were warm water species with the exception of *Euphausia nana* and *Euphausia pacifica*. There are 7 species of euphausiids based on the investigation of 13 cruises during 1997 and 2004. Species diversity and abundance is higher in summer. *Pseudeuphausia sinica* was found all year around in Yangtze estuary.

**PICES XIV S2-2292 Oral**

**Seasonal distribution of euphausiids on a transect from the Gulf of Alaska to the Bering Sea**

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The Continuous Plankton Recorder was towed behind a commercial ship on a transect from British Columbia, across the Gulf of Alaska, through Unimak Pass and into the southern Bering Sea during 2002 and 2003 (June, October and December 2002, April 2003) collecting plankton samples. Cursory observations of the samples prior to detailed processing suggested that the abundance of euphausiids increased as the transect approached the Aleutian Islands shelf, irrespective of time of year. Given that this region is an important foraging ground for juvenile salmon (into at least the late autumn) as well as for marine birds and mammals, we investigated the euphausiid distributions in more detail. Ordinarily every 4<sup>th</sup> sample is processed for plankton taxonomic abundance but between 150°W and 175°W (the centre of the Alaska Gyre to the deep waters of the southern Bering Sea) all samples were processed to measure euphausiid abundances. Six species of euphausiid were identified: *Thysanoessa inermis*, *T. longipes*, *T. inspinata*, *T. spinifera*, *Euphausia pacifica*, *T. rachii* (just one individual). Although the five most abundant species were found all along the transect, we found clear differences in species distribution. Our expectation, based on our original observations, was that there would be a negative correlation between water depth and euphausiid biomass in both the Gulf of Alaska and Bering Sea, so that highest biomass would be found in shallowest water, *i.e.* over the Aleutian shelf. While this held true for the Bering Sea it was not the case in the Gulf of Alaska - in the fall and winter the highest biomass of euphausiids in the Gulf of Alaska were off the shelf, over the deep waters of the Aleutian trench. We speculate as to how this distribution may arise and its implications.

**PICES XIV S2-2534 Poster**

**Species composition and diversity of pelagic euphausiids in the East China Sea**

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Based on the data of four seasonal oceanographic censuses in the East China Sea 23°30'~33°N, 118°30'~128°E in 1997-2000, this paper discussed the species composition and the diversity of Euphausiids as well as their relations with environmental variables. Results showed that there in total 23 different species of Euphausiids, in which 16 occurred in spring and autumn respectively; 15 were present in summer and only 10 were observed in winter. According to the calculated alternation fraction (*R*), the species composition showed a clear seasonal alternation with the changes of seasons. Moreover, the environmental variables had different impacts on the distribution of Euphausiids in different seasons. The distribution in summer was not significantly related to water temperature and salinity. However, the surface salinity was a major determinant of the distribution in spring. In autumn, both surface and bottom temperature were influencing factors. The distribution in winter depended on salinity at the surface and 10-m depth as well as the temperature at 10-m depth. Regarding the seasonal variation of species composition, the variations in spring, summer and autumn were not so significant as that in winter. Except in summer, the species number changed with synchronous water temperature and salinity, as a result of the presence of warm currents in the East China Sea and the habitability of the dominant species. Since Euphausiids tend to aggregate, the distribution of different species was uneven, which was the major reason to the low diversity of Euphausiids in the East China Sea.

**Study on abundance distribution of euphausiids in the East China Sea**

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Based on the data of four seasonal investigations in the East China Sea (23°30'~33°N, 118°30'~128°E) from 1997 to 2000, the distribution and the seasonal changes of Euphausiacea abundance and the relationship between euphausiid and fish abundance are discussed in this paper through qualitative and quantitative methods. Results showed that the total abundance of Euphausiacea peaked in autumn, was the second highest in spring and lowest in winter. Since *Euphausia nana* in winter, spring, summer and *Pseudeuphausia sinica* in autumn contributed more to the total abundance, they were the species dominating the total abundance variation. Moreover, it was found that the total abundance in summer showed linear correlation with bottom water temperature and 10-m salinity, while the abundance in other three seasons did not show significant correlation with hydrographic factors. A region of abundance of Euphausiacea was located in the converging area of Taiwan warm current and other water masses in autumn, suggesting that the variation of the total abundance was dependent on the influence of water masses and the contribution of dominant species, which was also related to the ecological habits of dominant species. It was also found that the high abundance area nearly overlapped the feeding grounds of *Trichiurus lepturus*, *Scomber japonicus* and *Larimichthys polyactis*.

**Study on the dominant species of euphausiids in the East China Sea and their ecological adaptability**

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The aim of this paper is to study the ecological characters of the dominant species of Euphausiids in the East China Sea. Four oceanographic cruises were conducted in the East China Sea (23°30'~33°N, 118°30'~128°E) during the period 1997 – 2000. Altogether four dominant species of Euphausiids were recorded in the East China Sea, *Euphausia nana* Brinton, *Euphausia pacifica* Hansen, *Pseudeuphausia sinica* Wang et Chen, and *Pseudeuphausia latifrons* (S. O. Sars). They were categorized according to their habitat conditions into two groups, temperate, sub-tropical and tropical species. During the winter and spring periods, the community is dominated by temperate species, *E. nana* and *E. pacifica*. Their densities peak in the spring for *E. nana*, winter for *E. pacifica*, respectively, and are low in the summer and autumn during which *E. pacifica* is not even represented. The dominant species during the summer and autumn are *P. sinica* and *P. latifrons*, both of which are represented in low density in the winter and peak in the autumn. The sub-tropical and tropical species exhibited higher abundances than the temperate ones. Mean densities in autumn were 95.46 ind/100m<sup>3</sup> for *P. sinica* and 37.77 ind/100m<sup>3</sup> for *P. latifrons*, while in the spring the maximum density of *E. nana* was only 35.55 ind/100m<sup>3</sup>. In the spring, *E. nana* represented up to 85.5% of total species diversity.

