small peak occurred in autumn, October. In the south area this pattern is very clear, while in the west and east areas it was not clear.

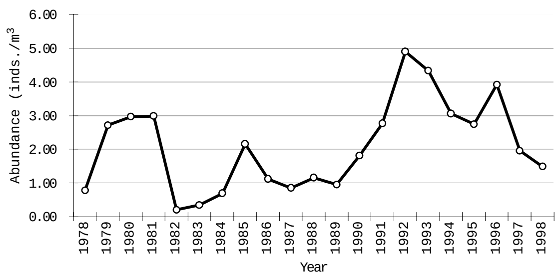

Fig. 2 Year-to-year changes in euphausiids abundance in the Korean waters during 1978-1998.

The annual average abundance from 1978-1998 was 2.52 ind.•m^{-3}. The euphausiids showed an increasing trend since the early 1990s with two increasing periods (Fig. 2). The first occurred from the late 1970s to the early 1980s and the second occurred after 1990. The increase after 1990 was closely associated with the increase of surface water temperature in winter, February and December.

Year-to-year changes in catches of major fish resources, *Engraulis japonica, Scomber japonicus* and *Todarodes pacificus* were compared to euphausiid abundance. *Engraulis japonica* and *Scomber japonicus* are major fish resources in the South Sea, while *Todarodes pacificus* is in the East Sea of Korea. *Engraulis japonica* and *Scomber japonicus* began to increase since 1992 with extraordinary increase in 1993 and 1996, respectively. It did not coincide with euphausiid abundance, but there was a possibility that the increasing trend after 1990 in euphausiids abundance accompanied with increases of *Engraulis japonica* and *Scomber japonicus* after 1992.

Todarodes pacificus increased continuously after 1990. It was closely related to the increase of euphausiid abundance in the East Sea of Korea.

Ecological Zonation of euphausiids off central Oregon

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Introduction

The euphausiids *Euphausia pacifica* and *Thysanoessa spinifera* dominate the euphausiid assemblage along the west coast of North America from Baja California to the Gulf of Alaska. Research in the northeast Pacific has shown that the two species share a common latitudinal range but that *T. spinifera* is a coastal species, restricted to shelf waters while *E. pacifica* is an oceanic species. For example, off southwestern Vancouver Island, Mackas (1992) showed that *T. spinifera* is the dominant euphausiid species in shelf waters and is the only euphausiid common in water depths shallower than about 150 m whereas *E. pacifica* is dominant along and seaward of the shelf break. Off Newport, OR, Smiles and Pearcy (1971) found that *Euphausia pacifica* was far more abundant near the shelf-break than offshore, peaking at a station 25 miles from shore (250 m water depth). In the same data set, *T. spinifera* was found chiefly at a station 15 miles from shore (90 m water depth) but not farther offshore (Smiles, unpublished data). Peterson and Miller (1976), who worked off Newport in 1971 and 1972, did not find *E. pacifica* closer to shore than 20 miles (150 m depth), nor *T. spinifera* further from shore than 20 miles. Thus, off central Oregon the two species have their maxima in abundance at stations within a few miles of each other, with little or no overlap in their zonal distributions, but how they are maintained in separate ecological zones remains a puzzle. The two species do co-occur in Barkley Sound, a deep fjord that penetrates southwest Vancouver Island (Tanasichuk, 1998a, b). Curiously, in Puget Sound, Dabob Bay, Saanich Inlet and the Straits of Georgia only *Euphausia pacifica* is present (and abundant) whereas *Thysanoessa spinifera* is either uncommon or absent (Ross et al. 1982; Bollens et al. 1992).

The patterns observed off the Oregon coast are not as clear-cut in California waters. CalCOFI Atlas No. 5 shows that *T. spinifera* inhabit both shelf and oceanic waters off northern and central California (Brinton 1967); *E. pacifica* is chiefly an offshore species but has a biomass maxima at the shelf break (Brinton 1962). *T. spinifera* has been found far to sea off northern and central California when associated with mesoscale eddies, filaments and jets -- Mackas et al. (1991) reported high concentration of this species along the shoreward edge of an upwelling filament. Also, Peterson (unpublished data from a survey of the jet/eddy complex off Monterey, July 1991) found large concentrations of *T. spinifera* (40-150 juveniles + adults m^{-3}) in the cool waters of an upwelling filament, 120 miles from shore. On the other hand, Huntley et al. (1995) did not report the presence of *T. spinifera* in their survey of a large eddy off Monterey in June 1993. Mackas et al., Huntley et al. and Peterson all found enhanced concentrations of *E. pacifica* within these mesoscale features. Based on analysis of acoustics data, Swartzman (personal communication) found that the pronounced zonation patterns observed off central Oregon begin to break down south of Cape Blanco.

We have been sampling euphausiid larvae in the coastal zone off Newport, OR during biweekly cruises since 1996 at stations 5 and 15 miles from shore (9 and 28 km respectively). *Thysanoessa spinifera* larvae were always most abundant at the nearshore station whereas *Euphausia pacifica* were usually most abundant at the offshore station. Table 1 compares the densities at each station, where we show data averaged over the growth season of March of one year to February of the next (following Tanasichuk 1998). During the 1997-98 El Niño, both species had their highest overall abundances, probably due to strong onshore advection during this period. With the onset of the 1999-00 La Niña (a period of cool water and high upwelling), densities of *Euphausia pacifica* declined markdly (possibly due to transport offshore).

We also compared our larval density numbers to those from a similar study conducted about 300 miles to the north of Newport, Oregon, in Barkley Sound, Vancouver Island, British Columbia, by Tanasichuk (1998a,b). Large differences in larval densities are seen, with Barkley Sound densities up to 10 fold greater than off Newport (Table 2). However, the ratio of densities of the two species (density of *E. pacifica* divided by density of *T. spinifera*) was very similar when NH 5 is compared to Barkeley Sound (but not NH 15), suggesting that despite differences in production, Barkeley Sound resembles our nearshore station but not our offshore station.

Some very unusual euphausiid species were found off Oregon during the El Niño, *Euphausia recurva* and *E. mutica*. These two species are ordinarily found only in Pacific Central water but occurred shelf waters off Oregon during winter 1997-98. This is the first record of these species off Oregon. Another unusual species was *Nyctiphanes simplex*, a coastal species that is normally most common off Baja California and in the southern California Bight (Brinton 1962, 1967). The meaning of this is that northward transport of coastal water carried *N. simplex* to Oregon (as noted previously by Brodeur et al. 1985. To account for the occurrence of *E. recurva* and *E. mutica*, there must also have been some northward and onshore transport of surface waters from the Central Gyre, due to intense southwesterly storms in winter 1997/98.

Table 1 Interannual variation in euphausiid abundance at inshore (NH5) and offshore (NH15) stations off Newport, Oregon from 1996-2000.

	Euphausia pacifica		*Thysanoessa spinifera*	
	NH 5	NH 15	NH 5	NH 15
1996 - 97	118 m^{-2}	366 m^{-2}	258 m^{-2}	112 m^{-2}
1997 - 98	569	1,077	577	337
1998 - 99	534	510	93	50
1999 - 00	38	59	373	102

Table 2 Euphausiid larval densities in Barkley Sound, Vancouver Island (Tanasichuk 1998) and the ratio of two species (*E. pacifica* : *T. spinifera*) abundance in Barkley Sound and Newport, Oregon.

	Barkley Sound		Ratio	Ratio	Ratio
	E.pacifica	*T.spinifera*	[Bark]	[NH 5]	[NH 15]
1991 - 92	479 m^{-2}	1,168 m^{-2}	0.41		
1992 - 93	2,723	2,742	0.99		
1993 - 94	1,205	669	1.8		
1994 - 95	537	450	1.19		
1995 - 96	1,303	7,372	0.18		
1996 - 97	1,286	2,222	0.57	0.46	3.3
1997 - 98	757	1,039	0.73	0.99	5.2
1998 - 99	4,555	889	5.12	5.74	10.2

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Environmentally forced variability in larval development and stage-structure: Implications for the recruitment of Euphausia pacifica (Hansen) in the Southern California Bight

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Summary

The intent of this field work was to provide empirical evidence in observed larval distributions, stage-structure, and inferred developmental pathways of whether the developmental regime affects the development and abundance of particularly elastic larval stages. Armed with the insights from life-history modelling and demographic analyses (Rumsey and Franks, 1999), I sought to address particular aspects of the *Euphausia pacifica* life-history. First, how are the larval stages distributed vertically in the field with respect to each other and the developmental environment? Second, as indicated by the vertical distribution of calyptopis I stage larvae, is there evidence that females restrict the depth-range of spawning to enhance the profitability of the initial developmental environment? Third, I investigated whether there was variability in furcilia I-II developmental pathways over short (mesoscale) spatial scales, and if found, with what oceanographic conditions particular pathways are associated. Fourth, I described the spatial variability of larval stage-frequency distributions, and the environmental conditions and/or developmental processes with which such variability was associated.

Oceanographic and Demographic Data

Two cruises were conducted in the Southern California Bight, south of the Santa Barbara Channel and Channel Islands, in the winters of 1996 (cruise S9602) and 1997 (J9701). Samples of *Euphausia pacifica* larvae were obtained by MOCNESS transects across mesoscale oceanographic features (Fig. 1). CTD-fluorometer profiles accompanied each station (Fig. 2). *E. pacifica* larvae were identified to stage using morphological criteria (Boden, 1955). The developmental instar of pleopod development was noted for furcilia I-II stage larvae, and the dominant furcilia I-II pleopod developmental pathways determined for each station (after Knight, 1984; Lavaniegos-Espejo, 1994).

Spawning Distribution

Despite differences in the vertical distribution of *E.* pacifica larval stages between cruises, the majority (>95%) of larval stages were found in the upper 100 m (Fig. 3). Eggs were not sampled during either cruise, nonetheless, the presence/absence of the initial larval stages (being weakly swimming, e.g. calyptopis I) with depth is indicative of the depth range of spawning by gravid females. Although the vertical distribution of post-larvae in the night-time samples of both cruises was predominantly in the upper 150 m, their daily ambit spanned 0-300 m depth