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ABSTRACT: The abundance and composition of mesozooplankton in the top 20 m of the water column were compared between NORPAC nets having 105-, 243- and 303-µm meshes to evaluate net retention and gear suitability for sampling prey fields of age-0 and age-1 forage fish. Single, consecutive vertical hauls were made with each net in daylight at 3 stations in northeastern Prince William Sound, Alaska, on August 5–6, 1995. Individual samples were examined microscopically, and data were pooled by mesh size for analysis. Total zooplankton abundance differed by an order of magnitude between 105- and 303-µm mesh nets (41,000 and 1,400 organisms·m^{-3}). Small calanoid copepods comprised ≤86% of the composition in all the net mesh sizes. Net retention in the smallest meshes was significantly higher for the small species and stages of calanoids and for several other small taxa (bivalve larvae, invertebrate eggs, barnacle larvae) compared to the largest mesh; conversely, retention for chaetognaths was significantly higher in the largest mesh. The 105-µm mesh net best represented abundances and composition of mesozooplankton consumed by forage fish in summer, predominantly small calanoids, because the others undersampled taxa present in the diets of Pacific herring *Clupea pallasi*, pink salmon *Oncorhynchus gorbuscha*, walleye pollock *Theragra chalcogramma*, Pacific tomcod *Microgadus proximus*, capelin *Mallotus villosus*, and Pacific sand lance *Ammodytes hexapterus*. Although sampling gear bias has long been recognized as critical to estimates of zooplankton production and community structure, this study demonstrates the importance of selecting the appropriate sampling net mesh to characterize prey selection and consumption by planktivorous fish.

INTRODUCTION

Zooplankton abundance and composition are important aspects of marine trophic studies. These measures are commonly used in studies of production (e.g., McLaren et al. 1989; Napp et al. 1996), abundance (e.g., Bollens, Frost, Schwaninger et al. 1992), carrying capacity (e.g., Simenstad and Salo 1982; Cooney 1993), and prey selection (e.g., Parsons and LeBrasseur 1970; Checkley 1982; Suzuki et al. 1994). Selection indices are used to estimate prey preference by comparing the proportional number of prey consumed by a predator to the proportional abundance of the prey in the environment (Krebs 1989). Adequate representation of both the diet and the prey resources is essential to an accurate description of prey selection (e.g., Feller and Kaczynski 1975; Frank 1988; Siefert 1994).

Choice of gear for sampling zooplankton in pelagic nearshore and oceanic habitats is also of concern in trophic studies. The mesh size and type of net used are typically chosen based on the predator's expected prey preference given its life history stage (e.g., Hauser 1982), size and depth distribution (Celewycz and Cordell 1988; Paul and Paul 1996), as well as on net filtration efficiency (Smith et al. 1968), the relationship of net size to prey avoidance (McGowan and Fraundorf 1966), and other factors (UNESCO 1968; Jacobs and Grant 1978; Omori and Ikeda 1984). Microzooplankton prey fields targeted by larval fish are often sampled with a water bottle or pump and a fine mesh sieve (Haldorson et al. 1989; Paul and Paul 1996) or are sampled directly with fine mesh nets (e.g., 73–216 µm, Bollens, Frost, Thoreson, and Watts 1992). Mesozooplankton typically eaten by juvenile fish is sampled with nets having mesh openings between 105 µm and 335 µm (e.g., Bailey et al. 1975; Cooney et al. 1994; Celewycz and Wertheimer 1996; Napp et al. 1996). Macrozooplankton typically eaten by larger fish

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is captured with nets having larger mouths and mesh openings between 300 and 1,000 µm (e.g., Karpenko and Piskunova 1985; Bollens et al. 1993; Landingham et al. 1998). Zooplankton nets may be towed horizontally, vertically, or (double-) obliquely in the water column ranging from near surface to slightly off the bottom (e.g., Feller and Kaczynski 1975; Celewycz and Cordell 1988; Napp et al. 1996) depending on the study objectives and habitat sampled.

Although no single gear type or sampling methodology is appropriate for characterizing the prey community of all ages and species of fish or in all seasons and habitats, since the early 1980s a standard methodology termed "Plankton Watch" has been widely used in Alaska. Plankton Watch was developed by biologists involved in Alaskan salmon hatchery programs and salmon ecology studies who were interested in food abundance and other factors that affect marine survival of juvenile pink *Oncorhynchus gorbuscha* and chum *O. keta* salmon. Plankton Watch standardized the materials and methods used to monitor prey fields of young salmon to a 0.5-m diameter, conical ring net (NORPAC net) with 243–335 µm mesh towed vertically from 20-m depth (Hauser 1982; Sturdevant and Landingham 1993; Cooney et al. 1994; Moulton 1997). This simple method targets the near-surface water column where juvenile salmon feed, but has been adapted for studies of other species (e.g., Coyle and Paul 1992; Foy and Norcross 1999a, 1999b; Sturdevant et al. 2001). Zooplankton abundance and biomass estimates based on many different nets and for different fractions of the prey field have been reported, but few studies have directly compared the abundance and species composition collected with different meshes (Wing 1988a, 1988b; Siefert 1994).

The objective of this study was to compare the abundance and species composition of the mesozooplankton in the upper 20 m of the water column of Prince William Sound (PWS) in summer as retained by 3 NORPAC nets with different mesh openings and to evaluate their representation of the prey composition of forage fish. The study was conducted in conjunction with the Alaska Predator Ecosystem Experiment (APEX), a multiyear, multidisciplinary project designed to examine the trophic interactions of seabirds, forage fish, and their prey (Haldorson et al. 1996, 1997; Duffy 1998). Forage fish include several species of small, planktivorous, schooling fishes (Springer and Speckman 1997), such as juvenile Pacific sand lance *Ammodytes hexapterus*, walleye pollock *Theragra chalcogramma*, capelin *Mallotus villosus*, Pacific herring *Clupea pallasi*, pink salmon *O. gorbuscha*, and Pacific tomcod *Microgadus proximus*. Detailed results of forage fish diet and prey selection investigations are presented elsewhere (Sturdevant and Hulbert 1999; Sturdevant et al. 1999; Sturdevant et al. 2001). Here, I briefly discuss the diet compositions of those 6 species of forage fish collected in PWS over the time period that zooplankton net-mesh trials were conducted to illustrate the importance of zooplankton net selectivity in relation to fish feeding studies.

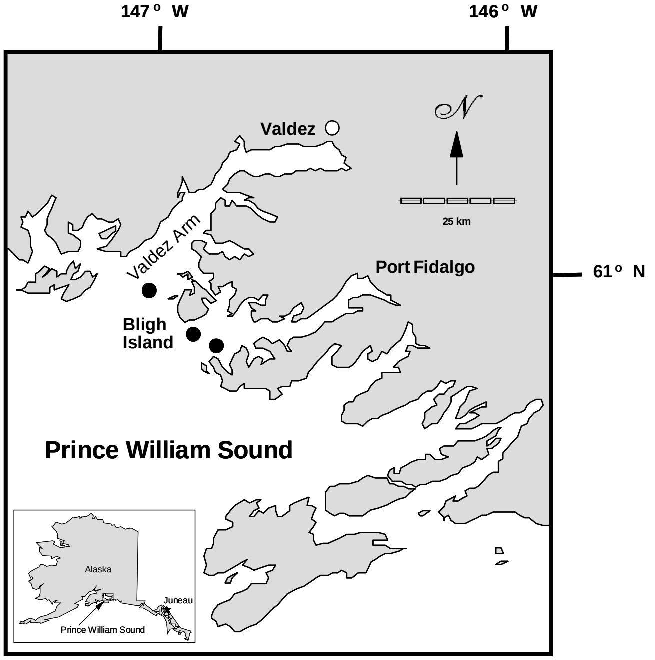

Figure 1. Northeastern region of Prince William Sound, Alaska, where sampling for zooplankton (stations indicated with closed circles) was conducted in July–August, 1995.

METHODS

Mesh trials were conducted at 3 stations in northeastern PWS using conical, NORPAC nets identical in their mouth sizes (0.5-m diameter) but with 3 different meshes, 105-µm, 243-µm, and 303-µm openings. Stations were located in northeastern PWS at the mouth of Port Fidalgo (station 81), at the mouth of Valdez Arm (station 85), and south of Bligh Island (station 84; Figure 1). Single, consecutive 20-m vertical tows were made with each net at each station on August 5–6, 1995, during daylight, between 0945 and 1820 Alaska time. Samples were preserved individually in 5% formalin-seawater solution.

In the laboratory zooplankton samples were individually subsampled using a Folsom splitter to achieve

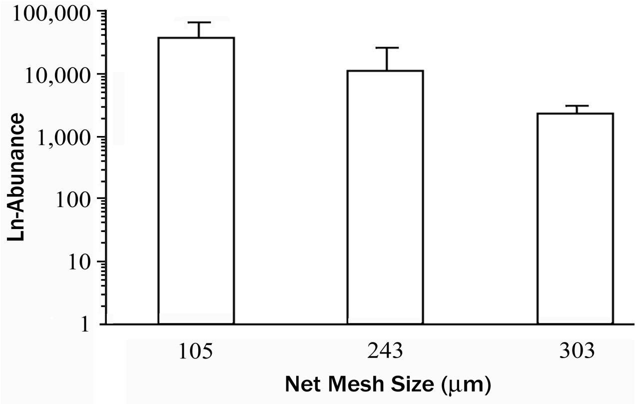

Figure 2. Abundance of zooplankton (logarithmically-transformed, mean and standard deviation) by mesh size from pooled stations in northeastern Prince William Sound, Alaska, July–August, 1995.

a count of 200–500 of the predominant taxon. Organisms in each sample were identified to species and size class, where possible, and enumerated using a binocular microscope. Calanoid copepods were staged as adult male or female, C5 copepodite, ≤C4 copepodite, or nauplius. Calanoid species with adult total lengths (TL) ≤2.5 mm were grouped as small calanoids, while those >2.5 mm TL were grouped as large calanoids. The cyclopoids *Oithona* spp. were included in the small calanoid category. General categories were devised for taxa such as unidentified small copepodites. Other identified taxa were pooled into broad taxonomic categories, generally by order. Organism counts were expanded (X) by the zooplankton sample fraction examined. Zooplankton abundance per cubic meter (D) was calculated for species, principal taxa, and total organisms in each vertical tow:

$$D = \frac{X}{V} = \frac{X}{\pi \times r^2 \times h},$$

where V is the cylindrical volume sampled by the 0.5-m diameter net towed from depth h.

Zooplankton samples from identical mesh sizes and different stations were considered to be replicates. At each station, a consistent pattern of zooplankton abundance and composition by mesh size was observed, allowing the data to be pooled for analyses. ANOVA was used to test for differences in total zooplankton abundance [ln(x+1) transformed] among mesh sizes and in abundances and proportional abundances (rank or square root transformed) of principal taxa among mesh sizes. When significant differences were indicated ($\alpha = 0.05$), post hoc Student–Newman–Keuls (SNK) comparisons were performed to determine differences between mesh pairs.

RESULTS

Differences in logarithmically transformed total abundances of zooplankton were significant (ANOVA, $P = 0.001$) and existed between all pairs of mesh sizes (SNK, $P < 0.05$; Figure 2). The greatest difference in mean total abundance of zooplankters, an order of magnitude, was observed between the smallest- and largest-mesh nets, approximately 41,000 organisms·m^{-3} from the 105-µm net compared to 1,400 organisms·m^{-3} from the 303-µm net (Table 1). The estimate from the 243-µm mesh was intermediate in value, 12,000 organisms·m^{-3}, nearly 9 times greater than from the 303-µm mesh net and more than 3 times lower than from the 105-µm mesh net.

Zooplankton taxonomic composition from all meshes was dominated by small calanoids (Figure 3), but their abundances decreased with increasing mesh size, from approximately 36,000 to 10,000 to 1,000 organisms·m^{-3} (Table 1). Net retention of small calanoids differed significantly between all mesh pairs (ANOVA, $P = 0.001$, SNK $P < 0.05$). Retention of the second most abundant group, "other" (mostly invertebrate eggs and bivalve larvae), and of barnacle larvae and chaetognaths also differed significantly (ANOVA, $P = 0.025$, $P = 0.001$, and $P = 0.029$, respectively). Differences among meshes varied by taxon. The group "other" decreased significantly with increasing mesh size from approximately 2,800 organisms·m^{-3} in the 105-µm mesh to 28 organisms·m^{-3} in the 303-µm mesh (Table 1; SNK, $P < 0.05$). Significantly fewer barnacle larvae were retained by the 243- and 303-µm nets than by the 105-µm net (SNK, $P < 0.05$), but significantly more chaetognaths were retained by the 303-µm mesh net than by either of the smaller mesh nets (SNK, $P < 0.05$). Abundance estimates did not differ among mesh sizes for any other principal taxon (large calanoids, larvaceans, cladocerans, or gastropods; ANOVA, $P > 0.10$). Minor taxa were not tested because of patchy occurrence in samples.

The percentage composition of zooplankton taxa also varied among the 3 mesh sizes. Small calanoids comprised 86% and 90% of zooplankters in the 243- and 105-µm mesh nets, dropping to 73% in the 303-µm mesh net (Figure 3); however, the percentage of small calanoids was not significantly lower in the largest mesh net (ANOVA, square root transformation, $P = 0.054$).

Table 1. Abundances of zooplankton taxa (mean number·m^{-3}, standard deviation) estimated from 3 mesh sizes at 3 stations in Prince William Sound in summer 1995. The total per major taxon is shown in its header row.

	105 µm mesh		243 µm mesh		303 µm mesh	
Taxon	Mean	SD	Mean	SD	Mean	SD
Barnacle larvae	195.6	130.4	0.0	0.0	0.1	0.1
Nauplius	130.4	65.2	0.0	0.0	0.0	0.0
Cyprid	65.2	112.9	0.0	0.0	0.1	0.1
Large calanoid copepods	43.5	37.7	16.3	16.3	21.0	15.4
Calanus marshallae C5	21.8	37.8	16.3	16.3	4.6	3.3
C. marshallae female	0.0	0.0	0.0	0.0	0.1	0.1
Subtotal	21.8	37.8	16.3	16.3	4.7	3.2
C. pacificus adult	0.0	0.0	0.0	0.0	2.7	4.7
C. pacificus general	0.0	0.0	0.0	0.0	2.7	4.7
Subtotal	0.0	0.0	0.0	0.0	5.4	9.4
Neocalanus/Calanus unidentified	0.0	0.0	0.0	0.0	1.4	2.0
Calanus/Neocalanus C1–C4	0.0	0.0	0.0	0.0	0.0	0.0
Neocalanus spp. C5	21.7	37.6	0.0	0.0	10.9	18.8
Subtotal	0.0	0.0	0.0	0.0	5.4	9.4
Small calanoid copepods	36,441.2	3,292.6	9,934.4	7,406.1	1,028.2	107.1
Acartia sp.	695.4	526.9	135.8	147.9	17.7	27.1
Acartia clausi male	21.7	37.6	0.0	0.0	0.0	0.0
Subtotal	717.1	509.1	135.8	147.9	17.7	27.1
Acartia longiremis adult	0.0	0.0	97.8	169.4	31.2	54.1
A. longiremis copepodite	108.6	135.7	54.3	94.1	2.7	4.7
A. longiremis female	65.2	65.2	54.3	94.1	36.7	12.2
A. longiremis male	195.6	195.6	54.3	94.1	4.1	7.1
Subtotal	369.4	271.4	260.8	451.6	74.7	53.2
Centropages abdominalis female	65.2	112.9	0.0	0.0	1.4	2.4
C. abdominalis male	0.0	0.9	0.0	0.0	1.4	2.4
Subtotal	65.2	112.9	0.0	0.0	2.7	4.7
Pseudocalanus sp. C1–C4, general	8,453.0	2,193.7	5,703.8	4,718.9	198.3	35.6
Pseudocalanus sp. female	1,803.6	815.1	2,914.5	2,357.8	721.2	137.4
Pseudocalanus sp. gravid female	43.5	75.3	32.6	32.6	4.1	4.1
Pseudocalanus sp. male	0.0	0.0	304.2	526.9	0.0	0.0
Subtotal	10,300.0	1,848.5	8,955.1	6,946.1	923.5	100.6
Nauplius, unidentified	9,756.8	3,217.7	13.6	17.0	0.1	0.1
Copepodite, unidentified	4,541.6	4,154.0	97.8	169.4	0.0	0.0
Subtotal	14,298.3	1,133.5	111.4	158.1	0.1	0.1
Oithona similis, general	8,453.0	3,080.8	134.5	130.6	1.4	2.4
O. similis copepodite	0.0	0.0	10.9	18.8	0.0	0.0
O. similis female	1,151.7	1,039.6	76.1	131.7	2.7	4.7
O. similis male	1,086.5	1,661.2	249.9	432.8	5.4	9.4
Subtotal	10,691.1	3,676.7	471.4	445.0	9.5	10.3
Chaetognaths	0.1	0.1	0.3	0.6	2.2	1.6
Unidentified	0.0	0.0	0.0	0.0	2.0	1.9
Sagitta elegans	0.1	0.1	0.3	0.6	0.3	0.4

– continued –

Table 1. (continued)

	105 µm mesh		243 µm mesh		303 µm mesh	
Taxon	Mean	SD	Mean	SD	Mean	SD
Cladocerans	282.5	99.6	388.4	419.7	73.3	29.4
Evadne sp.	130.4	172.5	249.9	326.5	34.0	20.1
Podon sp.	152.1	99.6	138.5	104.0	39.4	10.3
Bryozoa						
Cyphonautes larva	21.7	37.6	0.0	0.0	0.0	0.0
Decapod zoeae	0.0	0.0	16.6	28.7	6.6	6.6
Crab, Brachyura	0.0	0.0	0.0	0.0	0.3	0.4
Crab, Brachyrhyncha	0.0	0.0	1.4	2.4	2.7	4.7
Crab, general unknown	0.0	0.0	12.2	21.2	0.0	0.0
Crab, Lithodidae	0.0	0.0	0.0	0.9	2.7	2.4
Crab, Oregoninae	0.0	0.0	0.9	1.6	0.8	1.5
Crab, Paguridae	0.0	0.0	0.7	1.2	0.0	0.0
Shrimp, general	0.0	0.0	1.4	2.4	0.1	0.1
Euphausiids	0.0	0.0	0.0	0.0	4.4	3.6
Nauplius larvae	0.0	0.0	0.0	0.0	2.7	4.7
Calyptopis larvae	0.0	0.0	0.0	0.0	0.0	0.0
Furcilia larvae	0.0	0.0	0.0	0.0	1.5	2.2
Juvenile, general	0.0	0.0	0.0	0.0	0.2	0.3
Gammarid amphipods						
Unidentified, 2–7 mm	0.1	0.1	0.0	0.0	0.0	0.0
Gastropods	456.3	195.6	812.2	1,106.6	129.0	65.9
Snail 1, black juvenile	65.2	112.9	315.1	545.7	20.4	31.8
Snail 2, general juvenile	0.0	0.0	32.6	56.5	0.0	0.0
Limacina helicina >1 mm	0.0	0.0	10.9	18.8	19.0	32.9
L. helicina < 1 mm	391.1	112.9	453.6	568.1	89.6	45.9
Hyperiid amphipods	0.1	0.1	0.0	0.0	0.2	0.3
Unidentified, < 2 mm	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified, 2–7 mm	0.0	0.0	0.0	0.0	0.2	0.3
Themisto sp. 2–7 mm	0.0	0.0	0.0	0.0	0.2	0.3
Cnidaria	0.3	0.3	0.9	0.5	0.9	0.9
Medusa, >2 mm	0.3	0.3	0.9	0.5	0.8	0.8
Siphonophore "larva"	0.0	0.0	0.0	0.0	0.1	0.1
Larvacea						
Oikopleura sp.	738.8	804.6	668.2	779.7	118.2	46.3
Other	2,759.7	2,747.5	396.6	562.8	27.2	26.2
Bivalve, larvae	108.6	99.6	260.8	396.5	1.4	2.4
Unident. invert. egg, < 0.2 mm	2,629.3	2,776.8	70.6	80.4	0.0	0.0
Unident. invert. egg, > 0.2 mm	21.7	37.6	43.5	49.8	24.4	25.4
Isopod, general	0.0	0.0	0.0	0.0	1.4	2.4
Unidentified	0.0	0.0	10.9	18.8	0.0	0.0
Unidentified nauplius	0.0	0.0	10.9	18.8	0.0	0.0
Total	40,939.9	6,764.4	12,233.9	10,172.1	1,412.6	201.5

Large calanoids comprised ≤1.5% of total zooplankton abundance, with no significant differences among mesh sizes (ANOVA, square root transformation, $P = 0.077$). The mean percentage compositions of cladocerans, gastropods, and larvaceans (maximum 9% abundance) differed with mesh size (ANOVA; $P = 0.026$, $P = 0.021$, and $P = 0.019$, respectively); all were significantly greater (SNK, $P < 0.05$) by a few percentage points in the 303-µm mesh net than in the 105-µm mesh net. The percentage of the "other" group was also low, and did not differ significantly among meshes (ANOVA, $P = 0.273$). The coefficient of variation (CV) for percentage of small calanoids was much lower than for other taxa. The CV ranged from 7–10% for the percentage of small calanoids by mesh size, 19–100% for other principal taxa, and up to 175% for the minor taxa.

Although small calanoids were the dominant organism caught by all mesh sizes, the species and life stages differed with mesh size (Figure 4; Table 1). The smallest of the small calanoids were not well represented in the 243-µm and 303-µm mesh nets. *Pseudocalanus* spp. predominated (>90%) in these larger mesh samples, particularly mature females; the proportion of smaller species and younger life history stages of small calanoids that were retained increased with decreasing mesh size. In the smallest mesh samples, *Pseudocalanus* spp., *Oithona similis*, and unidentified calanoid nauplii each comprised about one-third of the organisms present (10,000·m^{-3}); unidentified small copepodites were also abundant, contributing about 4,500 organisms·m^{-3} to the 105-µm samples. Unidentified small copepodites and nauplii were less abundant in the 243-µm samples and were absent from the 303-µm samples (Table 1). Differences in retention by pairs of meshes were also specific to calanoid taxa. The abundances of *Pseudocalanus, Oithona, Acartia*, and unidentified nauplii were all significantly greater in the 105-µm net than in the 303-µm net (ANOVA; $P = 0.003$, $P = 0.001$, $P = 0.018$, and $P = 0.001$, respectively; SNK, $P < 0.05$); only *Pseudocalanus* and *Oithona* abundances were significantly greater in the 243-µm net compared to the 303-µm net (SNK, $P < 0.05$). For the 105-µm mesh net compared to the 243-µm, only *Oithona* and nauplii abundances were significantly greater in the smallest mesh (SNK, $P < 0.05$). Finally, for all mesh pairs, only the abundances

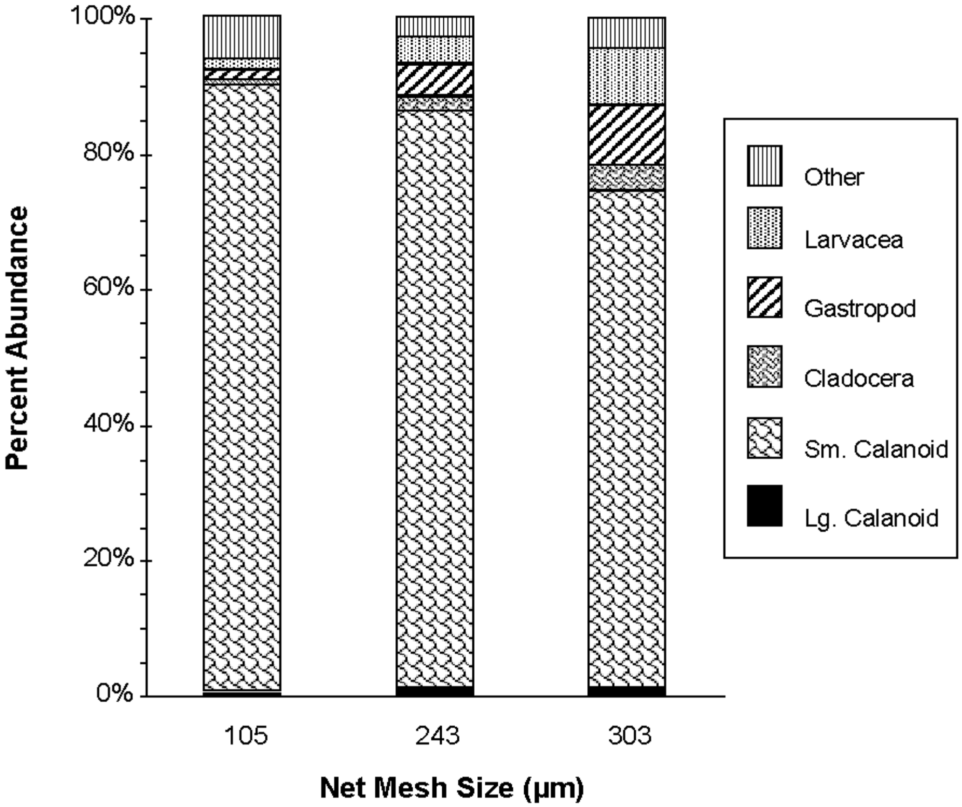

Figure 3. Numerical percentage composition of zooplankton by mesh size from pooled stations in northeastern Prince William Sound, Alaska, July–August, 1995. Taxa representing less than 2% of the total are not shown.

of the smallest taxa (unidentified small copepodites and nauplii combined, and *Oithona*) differed significantly (ANOVA, $P = 0.001$; SNK, $P < 0.05$).

DISCUSSION

Zooplankton nets of 3 different mesh sizes had significantly different retention of mesozooplankters in northeastern PWS in summer. Of the 3 meshes tested, the 105-µm mesh best represented daytime surface abundance of mesozooplankton important in summer forage fish diets. The 303-µm mesh undersampled important plankters, retaining only the largest of the small calanoids, adult female *Pseudocalanus* spp. The intermediate mesh net retained some of all taxa encountered, but it undersampled *Acartia*, *Oithona*, and small copepodites (including *Pseudocalanus* spp.) compared to the 105-µm net. Although relatively few samples were collected for this study, the results are consistent with trends suggested by the plankton literature.

I tabulated abundance estimates from Alaskan studies that used nets with mesh sizes similar to mine to show the general decline in abundance with mesh size (Table 2). Data were collected in different years and locations, but trends in abundance were consistent with my results and indicate net selectivity for zooplankton size fractions. This is not surprising given the size range of small taxa. The TLs (and widths) of adult small calanoids differ by more than a factor of 2, with *Oithona* the smallest common genus and *Pseudocalanus* the largest. Female *O. similis* are 1.0 mm in TL, *Acartia longiremis* and *A. clausi* are 1.3 and 1.4 mm, *Centropages abdominalis* males and females are 1.5–2.1 mm, and *Pseudocalanus* spp. are up to 2.0 mm. The copepodites (C1–C5 stages) of these genera range from 0.5–1.4 mm in TL (Gardner and Szabo 1982) but can be difficult to identify.

I found only 2 studies published from Alaska that compared the abundance and size selectivity of different mesh nets (Siefert 1994; Incze et al. 1997), both in Shelikof Strait. Siefert (1994) showed that adult female *Pseudocalanus* spp. retention varied not only between 2 mesh sizes (150 and 333 µm), but the retention ratio of the meshes varied seasonally; variation in size and species composition of *Pseudocalanus* spp. from May to October accounted for these differences.

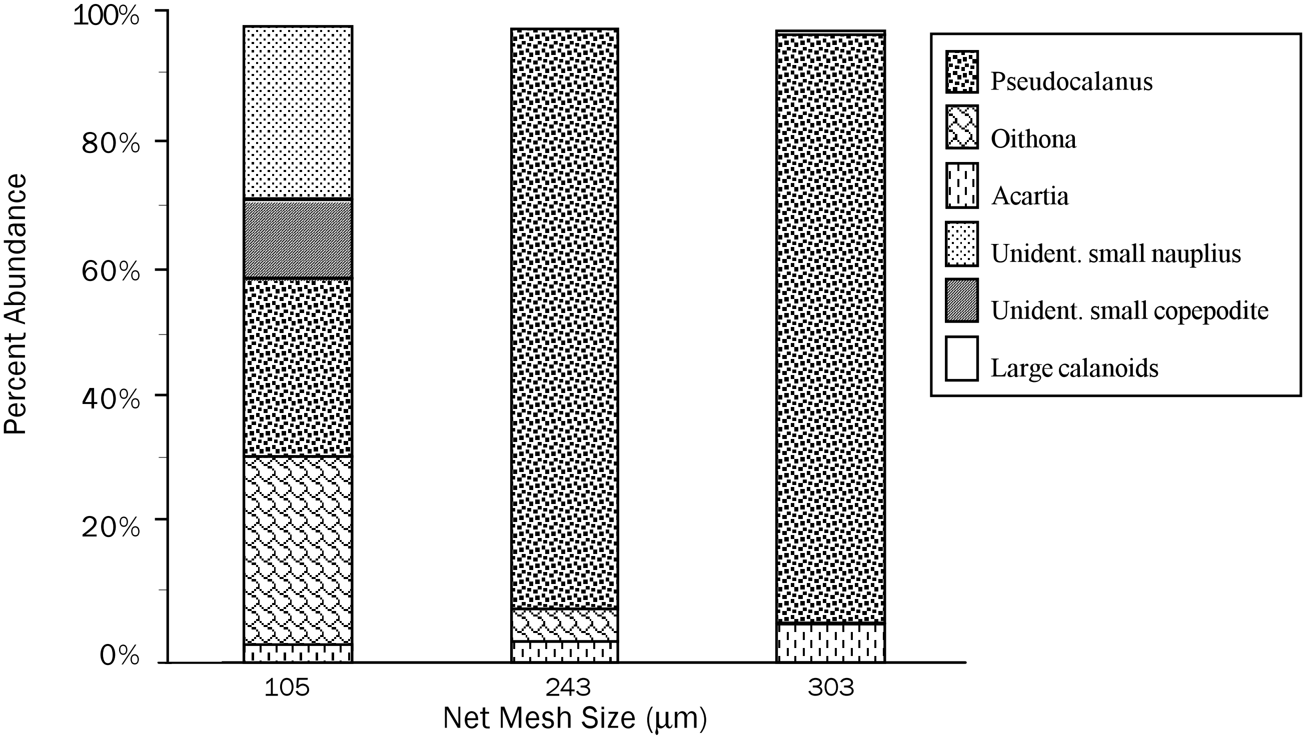

Figure 4. Taxonomic composition of calanoid copepods in zooplankton samples from pooled stations using 3 mesh sizes in northeastern in Prince William Sound, Alaska, July–August, 1995. Taxa representing less than 2% of the total are not shown. Large calanoids were principally *Neocalanus* sp. and *Calanus* sp.

Incze et al. (1997) found that copepods were 79–89% of the total zooplankters retained by 333-µm mesh but determined that only 55–67% of the copepod species and stages were quantitatively retained (Siefert 1994; Incze et al. 1997); those poorly retained included *Pseudocalanus* spp., *Acartia* spp., *Oithona* spp., and copepodite *Metridia pacifica*. The abundance of calanoids estimated from the 150-µm mesh was approximately 3 times the abundance from the 333-µm mesh, principally due to retention of *Pseudocalanus* spp. by the smaller mesh (Incze et al. 1997).

Quantitative sampling of calanoids has long been recognized to require different mesh sizes, from studies in other areas using, for example, silk mesh conical nets (Saville 1958), a high-speed multipurpose sampler (Nichols and Thompson 1991), and WP-2 vertical tows (Tremblay and Roff 1983a; McLaren et al. 1989). Numerous studies examined the filtration efficiency and performance of zooplankton nets (e.g., Jacobs and Grant 1978; Omori and Ikeda 1984). For example, the 333-µm mesh was the minimum size that maintained over 85% filtration efficiency in one study (Smith et al. 1968), but in another, its filtration efficiency was lower, 77–84% (Frank 1988). Filtration efficiency of high-speed samplers declined with mesh size, from >90% for nets of 90–270-µm mesh to 55% for 35-µm mesh. Plankton mesh 75% of the target animals' widths generally caught approximately 95% of them (Nichols and Thompson 1991). For calanoids, 250-µm mesh nets undersampled small species such as *O. similis* and *Microcalanus pusillus* (Tremblay and Roff 1983b), or *Pseudocalanus* spp. and nauplii-C2 of *Calanus* spp. (McLaren et al. 1989), and failed both in sampling zooplankton presence and in revealing temporal trends (Frank 1988). The 250-µm mesh net was thought to retain larger species, including all copepodites and adults of *Calanus* spp. (McLaren et al. 1989). Many studies requiring data on zooplankton abundance and size rely on multiple nets and do not directly compare the abundance of taxa between meshes (e.g., Springer et al. 1989; Coyle and Paul 1990). Particularly for production studies, use of multiple mesh sizes is recommended to represent all taxa and stages (Anderson and Warren 1991). Nets that retain small taxa may still not sample efficiently because of backflushing. Backflushing is less likely to occur when less water volume is filtered (as in shallow vertical tows), but it does sometimes occur during peak phytoplankton blooms or when superabundant small taxa or gelatinous slub clog the net (personal observations).

Trophic studies must also consider the appropriateness of nets used to represent prey of young fish. Several recent studies have shown that small calanoids are important in the diets of forage fish in PWS (Foy and Norcross 1999a; Sturdevant and Hulbert 1999; Sturdevant et al. 1999; Purcell and Sturdevant 2001;

Table 2. Estimates of total abundance from selected zooplankton studies in Alaska using nets with various mesh sizes.

Mesh Opening (µm)	Net Type	Tow Depth (m)	Abundance (no.·m^{-3})	Date	Authors
25	bottle	10–40	16–84,000	May–Jul 1990	McGurk et al. 1992
105	NORPAC	25	23,200	Aug–Sep 1994	Willette, Sturdevant, Jewett, and Debevec (unpublished data)
158	Clarke-Bumpus	0.5[a]	40–154,000	Jun 1965–1966	Bailey et al. 1975
165	CalVet	50	4,000–17,000	May–Jun 1987–1989	Coyle and Paul 1990
165	bongo	50	8,102	Jul 1986	Wing 1988a, 1988b
216	NORPAC	20[a]	4–6,000	Jun 1977	Cooney et al. 1981
243	NORPAC	20	11–19,000	May–Jun 1991	Sturdevant and Landingham 1993
243	NORPAC	20	2–7,000	Jun 1989–1990	Celewycz and Wertheimer 1996
243	NORPAC	1[b]	16,306	Jul 1986	Wing 1988a, 1988b
250	NORPAC	20	5,347	Jul 1993	Moulton 1997
333	bongo	250	475[c]	Jul 1985	Incze et al. 1997
335	NORPAC	20	1,000–3,500	May–Jun 1989	Cooney (unpublished data)
505	bongo	50	1,085	Jul 1986	Wing 1988a, 1988b

[a] Presumed depth.

[b] Horizontal surface tow.

[c] Abundance converted from 95,000·m^{-2} based on depth of 200 m.

Sturdevant et al. 2001). For example, small calanoids ranged from 41–94% of prey numbers in the diets of young of the year and age-1 Pacific herring, walleye pollock, capelin, sand lance, and young of the year Pacific tomcod, but they were not prominent in young of the year pink salmon or age-1 Pacific tomcod diets. Fish consumed many of the same taxa sampled by the nets used in this study. The most prevalent prey taxon in fish stomachs was unidentified small copepodites, the rarest was calanoid nauplii, and the most common genera were *Pseudocalanus* and *Oithona*. Forage species selected large calanoids when available, but large calanoids were uncommon prey in summer (Sturdevant and Hulbert 1999; Sturdevant et al. 2001) and important prey in spring (Foy and Norcross 1999b; Sturdevant et al. 1999). Thus, different nets may be required for trophic studies conducted in different seasons. The seasonality, diel vertical migration (Cooney 1987; Bollens et al. 1993) and life history of prey (Cooney et al. 1981; Coyle et al. 1990; Anderson and Warren 1991; Incze et al. 1997; Foy and Norcross 1999b), as well as sampling conditions, must be considered in choosing sampling gear for trophic studies.

Estimations of prey species preference can also vary depending on how zooplankton is sampled because of the differences in species proportions caught by different meshes. This study shows that coarse-mesh nets underrepresent the small calanoid taxa most abundant in zooplankton (Figure 3), which are also those most consumed by young of the year and age-1 fish in summer (e.g., Sturdevant et al. 2001). For example, comparing the percentage composition of calanoid taxa in fish diets to their percentage composition in net samples would indicate avoidance of *Pseudocalanus* and small taxa based on the 243-µm and 303-µm mesh nets, but would indicate selection for these taxa based on the 105-µm net. The calanoid nauplii that passed through mesh ≥243 µm were avoided by most juvenile fish, but the equally small invertebrate eggs and veligers often made up substantial percentages of prey numbers in juvenile walleye pollock and Pacific herring diets (Sturdevant and Hulbert 1999), known filter feeders (Gibson and Ezzi 1990; Grover 1991). Successful feeding depends on both prey size and abundance (Parsons and LeBrasseur 1970; Gibson and Ezzi 1990; McGurk et al. 1992, 1993). Only the 105-µm mesh measured abundances high enough to support the daily ration of certain juvenile fish (Parsons and LeBrasseur 1970).

Although the zooplankton abundances and the species and sizes of calanoids retained by each mesh in this study were significantly different, the proportions of pooled large or small calanoid groups retained were similar. Each mesh would thus produce similar estimates of prey selection from these pooled taxonomic categories. At the species level, however, they would produce very different characterizations of selection from the prey environment. Such differences are important in bioenergetic, secondary production, or carrying capacity studies. The abundance and composition of small zooplankton prey of many young of the year fish species may not be adequately represented by nets with ≥ 243-µm mesh. A study comparing abundances from different meshes at different times of year would provide additional useful information.

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