Adult female ***Pseudocalanus*** abundance, size, and egg production during the winter in Glacier Bay, Alaska

Christine Sislak

Abstract

Zooplankton samples were collected by vertical net tows from six stations in Glacier Bay, Alaska in mid-March 2008 just before the onset of the spring phytoplankton bloom. Four species of adult female *Pseudocalanus* were identified throughout the Bay and species composition, size, and egg production rates were measured. *P. acuspes*, *P. newmani* and *P. mimus* were found in every sample while *P. minutus* was only found in one sample but was the dominant species. Abundances ranged from 1194 adult female *Pseudocalanus* m^{-2} in the Lower Bay to 2245 adult female *Pseudocalanus* m^{-2} in the Central Bay. Vertical distribution of *Pseudocalanus* spp may have been different throughout Glacier Bay resulting in the absence of *P. minutus* collected in the upper 30m. Egg production rates of approximately 0.1 eggs $f^{-1}d^{-1}$ were measured at the stations with the highest and lowest levels of chlorophyll. No difference in egg production in areas with different chlorophyll levels is an indication that reproduction had not fully begun during the sampling period.

Introduction

Copepods are a key link between lower and higher trophic levels in marine environments. Commercially important juvenile fish such as salmon feed on copepods in the spring (Godin 1981, Paul and Paul 1996), which in turn provide food and energy for larger marine animals and humans. Copepods must survive the overwintering processes until the spring bloom when food is readily available therefore, it is important to measure copepod abundance during the winter to spring transition. Copepods are crustaceans, which lay eggs and go through many life cycle stages before becoming viable adults. *Pseudocalanus* spp carry egg sacs (Fig 1) until the eggs are ready to hatch and may produce several egg sacs in their lifetime as long as food is available (Corkett 1978). Coastal environments are highly productive because of the available nutrients, and copepods are abundant in these areas. Research by Paul & Coyle (1993) examined the zooplankton community in the spring months of April through June in Auke Bay, Alaska, a shallow coastal environment, and found *Pseudocalanus* to be the dominant copepod genus. Similar studies are missing in other coastal areas of Alaska including Glacier Bay.

Glacier Bay is a highly productive fjord, which supports many species of mammals, seabirds, and commercially valuable fish and shellfish (Etherington et al. 2007, Park 2004). It is a US National Park important for the tourist industry of Alaska. Since Glacier Bay is such a productive and economically important area, it is important to study zooplankton pop-

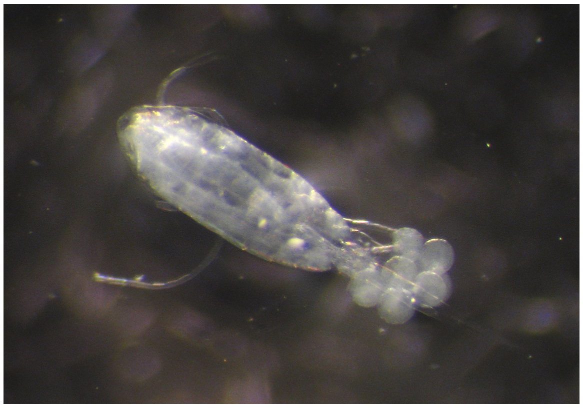

Figure 1: An adult female *Pseudocalanus* taken from Station 22. This female has an egg sac with six eggs.

ulations, specifically the community structure of adult female *Pseudocalanus* because of their dominance in the surrounding areas. Adult females collected during this study represent the population of *Pseudocalanus* that have survived the winter months and their egg sacs are the future population of copepods in Glacier Bay. This study provides quantitative measurements of adult female *Pseudocalanus* abundance, size, and egg production in the transition period between the winter and spring in Glacier Bay, Alaska.

Methods

Samples were collected at six historical stations (Hooge and Hooge 2002) from Glacier Bay, Alaska (Table 1) during 18-22 March 2008. Glacier Bay was divided into the same four regions as described by Etherington et al. (2007) and stations from the Lower Bay, Central Bay and West Arm are represented (Fig 2). All zooplankton samples were collected at nighttime using a 63µm mesh and a 0.5m diameter net. Samples were taken at night to catch the highest abundance of zooplankton in the upper 30m (Paul and Coyle 1993). Vertical tows were taken at a rate of 10m min^{-1} from 30m to the surface. All samples except station 15 were re-

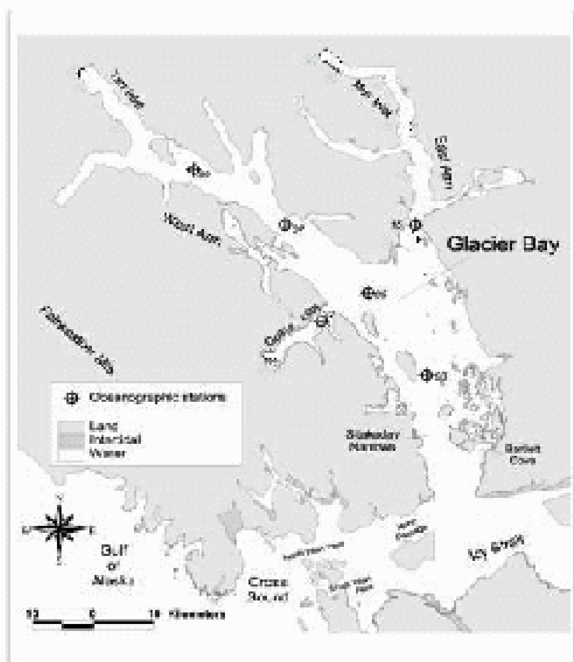

Figure 2: Glacier Bay, Alaska. The six sample sites are labeled according to the Hooge and Hooge (2002). Station 3 is part of the Lower Bay, Stations 5 and 15 are a part of the Central Bay, and Stations 22, 7, and 9/10b are a part of the West Arm.

filtered with the 63µm mesh to remove more phytoplankton. Samples were split using a plankton splitter either once or twice depending on the volume of water collected in the net tow. Samples were fixed with a 10% Formalin solution in 16 oz glass jars and brought back to the University of Washington for analysis. Water samples for chlorophyll analysis were taken at the same stations and times as zooplankton samples. Water was collected in Niskin bottles on the CTD rosette at three depths except station 3 where only two depths were collected. Chlorophyll analysis was done on board the ship using the Newton (2002) method.

Analysis of the zooplankton samples was done at the University of Washington Seattle campus. Samples were re-filtered with a 74µm mesh and rinsed with fresh water to remove larger diatoms and Formalin. In the freshwater, samples were split again to make counting and

Table 1: Station locations, depths and dates sampled.

Station	Lat	Long	Depth (m)	Date
3	58 39.4738	136 21.8090	153	19/03/08
22	58 39.4716	136 21.8136	155	19/03/08
5	58 43.2093	123 15.0173	392	19/03/08
7	58 48.7318	136 28.3096	425	20/03/08
9/10b	58 53.8761	136 44.1188	371	21/03/08
15	58 48.8810	136 06.1374	94	22/03/08

identifying easier. Adult female *Pseudocalanus* were identified according to Frost (1987) and one-half the sample was counted to estimate total abundance per station. From each sample a random selection of 50 adult female *Pseudocalanus* were removed for size measurements and species identification. Prosome length was measured under a dissecting scope at 50x using an ocular micrometer. Species were identified according to Frost (1989). Dilute sub-samples from stations 7 and 15 were examined for loose eggs. *Pseudocalanus* eggs were identified according to size and morphology by Dr. B.W. Frost.

Egg production rates at Stations 7 and 15 were calculated using equations from Runge (2000). All eggs, both still attached to a female and loose, were counted to find the number of eggs in the sample. To calculate the egg development time, needed to estimate egg production rates, according to Corkett and McLaren (1978) the average temperature over the upper 30m water column was used.

Results

Low chlorophyll levels were measured throughout the bay (Fig 3). Station 15 in the central Bay had the lowest integrated chlorophyll *a* levels, 14 mg m^{-2}, of any sampled station and Station 7 in the West Arm had the highest levels at 62 mg m^{-2}. Low abundance of *Pseudocalanus* was found at all six sampling stations and was composed of four species: *P. acuspes, P. newmani, P. mimus and P. minutus.* The total number of adult female *Pseudocalanus* was lowest at Station 3 in the lower Bay, 16 ind m^{-3}, and highest at Station 5 in the central Bay, 75 ind m^{-3} (Fig 4). Integrated over the 30m water column this is equal to 1194 ind m^{-2} in Station 3 and 2245 ind m^{-2} in Station 5. There is not a statistically significant correlation between levels of chlorophyll *a* and adult female *Pseudocalanus* abundance.

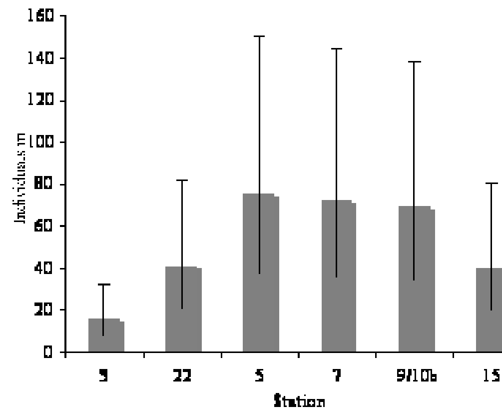

Figure 4: Adult female *Pseudocalanus* were counted in one half of the total sample collected at each station. The counted value was doubled and used as the total abundance of the sample. Standard error bars from 50-200% of the counted number are used because only one net tow was taken per station.

Size distribution varied throughout the bay (Fig 5). The largest mean prosome length was measured at Station 9/10b, 1.2 mm, and the smallest was at Station 3, 0.9 mm. Sizes of females varied more between stations than within

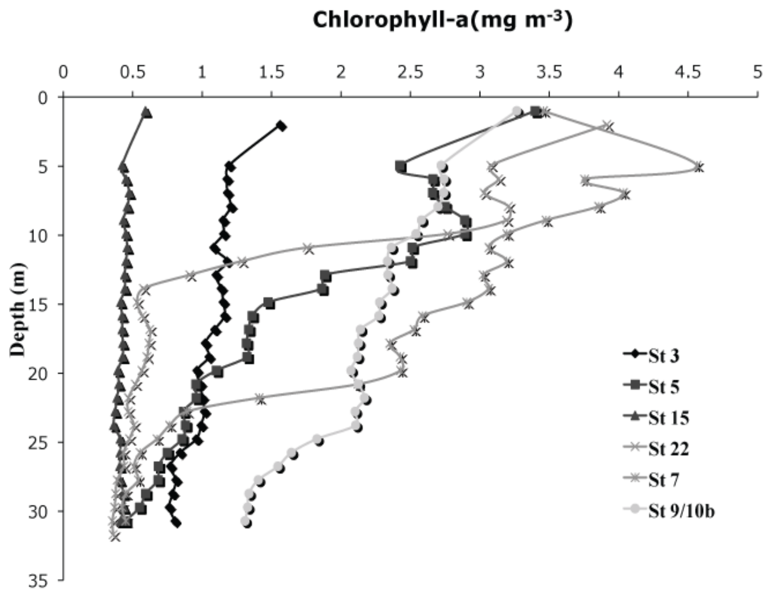

Figure 3: Chlorophyll *a* profiles at sampled stations.

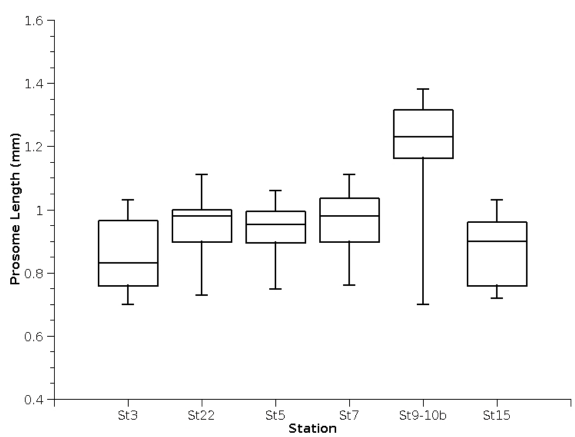

Figure 5: Prosome lengths of randomly selected adult female *Pseudocalanus.* Bars show between 25-75% of measured individuals and mean sizes are marked within the box. For all stations n=50 except Station 3 where n=36.

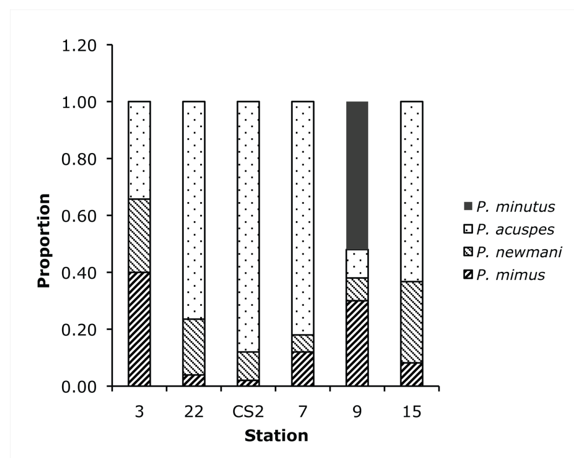

Figure 6: Percent species composition of *Pseudocalanus* at sampled stations.

a sample. Station 9/10b was distinguished from other stations sampled because of its larger females. The other two stations in the West Arm closer to the Central Bay have similar sized individuals. In the Central Bay, Station 15 had a smaller sized population than Station 5.

The three species *P. acuspes, P. newmani* and *P. mimus* were found in all six samples but only Station 9 contained *P. minutus* in addition to the three other species (Fig 6). Species abundance varied throughout the Bay with different species dominating at different stations. In the lower Bay *P. mimus* was dominant and in the Central Bay and West Arm *P. acuspes* was dominant.

Egg production rates calculated at Stations

7 and 15 were calculated to 0.09 eggs f^{-1} day^{-1} and 0.1 eggs f^{-1} day^{-1} respectively. Only these two representative stations were chosen because of the difficulty of identifying free-floating *Pseudocalanus* eggs in samples. Both stations were chosen because they represent the full range of chlorophyll concentrations encountered in Glacier Bay.

Discussion

Chlorophyll *a* levels were lower than expected but followed similar trends in the different regions of the bay (Etherington et al. 2007). The highest levels were in the West Arm followed by the Central then Lower Bay. The low levels are an indication that the spring phytoplankton bloom had not begun when sampling occurred in mid-March. Total abundances of adult female *Pseudocalanus* in Glacier Bay were low which is also due to the pre-bloom conditions. The levels of adult female *Pseudocalanus* in Glacier Bay were comparable to Gulf of Alaska levels measured during the same time of year (Napp et al. 2005).

Pseudocalanus species were found throughout Glacier Bay. Three of the four species found, *P. minutus, P, mimus* and *P. newmani*, have been documented near Glacier Bay (Frost 1987, Siefert 1994, Napp et al. 2005) but no other published research has documented *P. acuspes* in the Southeast Alaska region. *Pseudocalanus acuspes* is predominantly found in Arctic coastal environments (Frost 1987, Liscka et al. 2005) but was measured in all samples and was dominant in the Central Bay. *Pseudocalanus minutus* was only collected at Station 9/10b in the West Arm where it was the dominant species. This species of *Pseudocalanus* is an oceanic species more commonly found in areas of water mixing (Lischka and Hagen 2005).

One possible explanation of the occurrence of these species could be influenced by a temporal cycle. Previous work described areas where *P. mimus* became the most abundant species and *P. minutus* became the least abundant species in the overall percent species composition of *Pseudocalanus* between late spring to summer (Siefert 1994, Napp et al. 2005). During our sampling period *Pseudocalanus minutus* in Glacier Bay may have already reached its lowest abundances. *Pseudocalanus acuspes* may be present at this time in the bay because water was still at its coldest temperatures (Etherington 2007) and therefore, most like an Arctic environment than any other time. To support or reject this idea sampling at monthly time intervals throughout a year could be done.

Vertical distribution of species is also important to consider when evaluating species composition. Since net tows were only taken in the upper 30m there is potential to not collect a species because it has not migrated toward the surface. *Pseudocalanus minutus* may have been present in other areas of the bay but at deeper depths than 30m. Temperature profiles of the upper 75m at sampled stations show Station 9/10b to have a slightly lower temperature between 20-30m than other stations. Colder epipelagic waters at Station 9/10b could have influenced *P. minutus* to migrate higher in the water column.

Following the trends of low abundances and chlorophyll, *Pseudocalanus* eggs were in low abundances. Low egg counts are an indication that *Pseudocalanus* were not ready to reproduce, possibly because of the low food supply before the spring bloom. The egg production rate (EPR) of *Pseudocalanus* spp was calculated to test if chlorophyll levels were influencing reproduction. Egg production rate is the number of eggs a female lays in one day. In order to calculate the EPR it was estimated that all adult female *Pseudocalanus* were fertile, the age distribution of eggs is uniform, and all eggs counted are viable (Runge 2004). Assuming all of these factors are true, the EPR estimate did not differ between the highest chlorophyll station, 7, and the lowest, 15.

Calculated EPR of 0.1 eggs f^{-1} day^{-1} are similar to other measured *Pseudocalanus* EPR during winter (Napp et al. 2005, Renz et al. 2007). Although there were more than twice as many individuals in Station 7 as Station 15 there were also almost twice as many eggs in Station 7, 2020 eggs m^{-2}, as Station 15, 1265 eggs m^{-2}. Early in the month of April, the lowest EPR measured in Auke Bay, Alaska was 0.3 eggs f^{-1} day^{-1} (Paul and Coyle 1990). It was not until late April and early May, a little over one month after the recorded phytoplankton bloom that egg production began to climb. Similarly, reproduction had not yet begun in Glacier Bay in mid-March and is not expected to peak until late summer.

Conclusions

- Numbers of adult female Pseudocalanus were very low at sampled sites because it was early in the season.
- Egg production did not differ at sites with the lowest and highest chlorophyll because reproduction had not begun.
- P. acuspes was found at all sampled stations of Glacier Bay but documentation of this species in the area has previously been unpublished.
- P. minutus was found only at one station in the upper 30m which may be because of vertical distribution within the water column or temporal cycle species abundances.

Acknowledgements

This project was financially supported by the University of Washington School of Oceanography as a part of the Senior Research Thesis to Glacier Bay, Alaska, Spring 2008.

I would like to thank Dr. Bruce Frost for all of his time and effort put into teaching me about the wonderful world of copepods and for providing all species identification and egg counts. Thank you to the entire teaching staff of Ocean 444 especially Dr. Christopher Krembs and Eric Collins whose support and patience during the development of this project has been greatly appreciated. Thank you to Kathy Newell for all her help in my planning and photography of the *Pseudocalanus*. Thanks to the crew of the R/V Thomas G Thompson and fellow students for all their help in sampling. Thanks also to Jasper Boas for providing chlorophyll data.

References

Corkett, C. J. and Ian A. McLaren. 1978. The Biology of Pseudocalanus. Adv. Mar. Biol. **15**: 1-231.

Etherington, L. L., P. N. Hooge, E. R. Hooge, and D. F. Hill. 2007. Onceanography of Glacier Bay, Alaska: Implications for biological patterns in a glacial fjord estuary. Estuaries and Coasts **30**: 927-944.

Frost, B.W. 1987. A taxonomy of the marine calanoid copepod genus *Pseudocalanus*. Can. J. Zool. **67**: 525-551.

Godin, J.-G. J. 1981. Effect of hunger on the daily pattern of feeding in juvenile pink salmon, *Oncorhynchus gorbuscha* Walbaum. J. Fish Biol. **19**: 63-71.

Hooge, P. N. and E. R. Hooge. 2002. Fjord Oceanographic Processes in Glacier Bay, Alaska. USGS Alaska Science Center.

Lischka, S. and W. Hagen. 2005. Life histories of the copepods *Pseudocalanus minutus*, *P. acuspes* (Calanoida) and *Oithona similis* (Cyclopoida) in the Arctic Kongsfjorden (Svalbard). Polar Biol **28**: 910-921.

Napp, J.A., R. R. Hopcroft, C.T. Baier and C. Clarke. 2005. Distribution and species=specific egg production of Pseudocalanus in the Gulf of Alaska. J. Plankton Res. **27**: 415-426.

Park, W., M. Sturdevant, J. Orsi, A. Wertheimer, E. Fergusson, W. Heard, and T. Shirley. 2004. Interannual abundance patterns of copepod during an ENSO event in Icy Strait, southeastern Alaska. J. Mar. Sci. **61**: 464-477.

Paul, A. J., and J. M. Paul. 1996. Microscale abundance of copepod nauplii prey of larval fishes in a glaciated fjord measured with a 50-mL sampler. Alaska Fishery Science Bulletin **3**: 54-58.

Paul, A.J. and K. O. Coyle. 1990. Egg Production in *Pseudocalanus* spp. Copepods, p. 229-242 *In* Ziemann, D.A. and K. W. Fulton-Bennett [eds.], APPRISE – Interannual Variability and Fisheries Recruitment.

Paul A.J. and K. O. Coyle. 1993. Taxa composition and biomassof the surface- dwelling crustaceans during spring pycnocline formation in Auke Bay, Southern Alaska. J. Crustacean Biol. **13**: 594-600.

Renz, J., J. Peters and H. Hirche. 2007. Life cycle of Pseudocalanus acuspes Giesbrech (Copepoda, Calanoida) in the Central Baltic Sea: II. Reproduction, growth and secondary production. Mar Bio **151**: 515-527.

Runge, J.A. and J.C. Roff 2000. The measurement of growth and reproductive rates, p. 401-454. *In* R.P. Harris, P.H. Wiebe, J. Lenz, H.R. Skjoldal and M. Huntley [eds.], Zooplankton Methodology Manual. Academic Press.

Siefert, D. L. W. 1994. The importance of sampler mesh when estimating total daily egg production by *Pseudocalanus* spp. In Shelikof Strait, Alaska. J. Plankton Res. **16**: 1489-1498.