

Anti-Predator Defense of Marine Copepod in the Equatorial Pacific: Diel Vertical Migration in Relation to Size and Color

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Project Summary

Diel vertical migration by zooplankton to deep and dark habitats during the day is thought to be a strategy to avoid visual predators. Based on the relationships between visibility, predation, and vertical migration, I predict that the migration pattern of zooplankton is related to their body size and color. The diel vertical migration pattern of the marine copepods will be studied in the high productivity area on the western region of the Galapagos Islands.

Zooplankton samples will be collected from *R/V Thomas G. Thompson* by open/closing net at two fixed stations at three discrete depths for two days and two nights during 12-20 January 2006. Copepods would be identified; abundance, size, and color would be determined. The specific goals of this study are to describe the relationships between vertical migration patterns of the marine copepod and their visibility in term of body size and body coloration, and to address the role of being big and visible in increasing vulnerability to predation.

Introduction

Diel vertical migration (DVM) is an extremely common behavioural phenomenon that occurs in both freshwater and marine zooplankton, particularly the copepods (Cohen and Forward 2002). Among the hypotheses that have been proposed to explain DVM of zooplankton, the one that have received the most attention is the “predator- avoidance hypothesis”, which suggests that zooplankton descend to darker subsurface waters to avoid visual predators during daytime, and then return to surface waters at night to feed. The lower ambient light levels near the surface at night make it harder for visual predators to perceive their prey, and lower the risk of predation.

Visibility is related to DVM by many reports, the largest and most visible zooplankton are more vulnerable to visual predators. As zooplankton forms all or a major part of the diets of

diverse marine organisms, predation-prey interaction is inevitable. The success of zooplankton in the predator-prey interactions depends critically upon their visibility and the anti-predator strategy that they adapt to avoid their predators. To explain the success of copepods in the predator-prey interaction, we must first understand the factors that determine the predator-prey interactions.

Copepods are well-known vertical migrant in both fresh and marine water. Many studies have been done on the vertical distributions and susceptibilities to predation of the marine copepods in relation of their size. Hays et al. (1994) observed that the marine copepods most susceptible to visual predation due to conspicuous coloration and large body size exhibited a greater vertical migration response. Pearre (2003) reported that the depths which copepod descends during daytime were directly related to size, and the study of Suchman and Sullivan (2000) demonstrated that the sizes of copepod has a significant influence on their vulnerability to predation. These previous findings led me to test the hypothesis that the diel vertical migration as an anti-predator defense is performed by the marine copepod according to their visibility to the predators. Since the prey body size and color influences visibility to predators (Zaret and Suffern 1976), I suppose that difference in body size and body color cause difference in migration behavior; diel vertical migration should be more pronounced for the copepods that are large in size and/or highly pigmented. I expect copepods with larger body size and/or with more pigment exhibit stronger migrations to deeper, darker depths during the day than the smaller and less pigmented copepods.

The Galapagos would be one of the ideal areas to carry out this study, zooplanktons in the Galapagos regions showed a high degree of diversity, and the copepods have been the most abundant organisms there, according to Figueroa et al. (2005). Studying the migration behavior

of the copepods in the Galapagos regions will not only provide better understanding on the biological interaction of the lower trophic levels there, but it will also give insight on the role of visibility in diel vertical migration and the effects of predators on the zooplankton community.

Proposed Research

In order to determine the relationships between vertical migration patterns of the marine copepod and their visibility in term of body size and body coloration, study will be carried out during 12-20 January 2006 aboard the *R/V Thomas G. Thompson* in the western regions of the Galapagos Islands. Sampling for zooplankton will be taken place at two different sites at the west of Isabela where the productivity is reported high: Station 1 ($0^{\circ} 10' S, 91^{\circ} 36' W$) will be at the deep-water area where the water depth is ~ 1200 m, and Station 2 ($0^{\circ} 35' S, 91^{\circ} 21' W$) will be at the shallow-water area where the water depth is ~ 200 m (Fig. 1). Those two sites are fixed for sampling; each site will be visited twice for both day and night to get duplicate samples, however, two day samples and two night samples may have to be performed on different dates due to the tight schedule of the cruise. Ideally, each sampling event will have to occur at roughly the same time for each day and each night, around 1200 h and 0000 h respectively, but three-hour leeway is allowable. At each site, 0-180 m profile of temperature, fluorescence, and light intensity will be recorded with SeaBird SBE9/11 CTD before net sampling. Zooplankton samples will be collected from three discrete depths (0-30 m, 30-100 m, and 100-180 m) using a vertically deployed opening/closing net (mouth diameter 1 m, mesh size $300 \mu\text{m}$). Each haul will be lowered and retrieved at roughly 30 m/s, approximately 1.5 hour will be required to for each sampling, if necessary, additional time may be needed.

From these samples, I'll examine the abundance, body size, and the coloration of the copepod to address the role of individual visibility in DVM. Samples will be preserved in the

labeled glass jars with 4% formaldehyde solution for subsequent analysis (Rollwagen Bollens and Landry 2000; Sims et al. 2005; Vestheim et al. 2005). In the laboratory, zooplankton samples will be divided into two "equal" portions using a Folsom plankton splitter. All the samples collected will be shared with Jen Nomura for her DVM study of zooplankton. Copepods in the zooplankton samples will be identified, measured, photographed, and counted under a dissecting microscope immediately after being collected. Copepod identification will be made according to McKinnon et al. (2003) and hopefully under the assistance of the zooplankton experts on the ship. To examine the coloration, copepods that placed on a colorless or white background will be photographed through the eyepiece of the Nikon dissecting scope using Canon PowerShot A95 camera (5.0 megapixels). No flash or other artificial light sources will be used (Vestheim et al. 2005). To determine the size of the copepod samples, the prosome length (Fig. 2) of 50 individual copepods from each haul will be measured with ruler, from the tip of the head to the insertion of spines into the caudal ramus. To estimate the total abundance, 10% of the entire sample will be counted; levels of abundance in the different depth strata are quantified in terms of numbers per m^3 (Hays et al. 2001). Copepods samples will be then separated into two size fractions depends on the samples collected, the entire size-fractioned samples are counted for abundance. All zooplankton samples will be discarded after they have been analyzed.

Project Budget

Funding for this project is provided entirely by the School of Oceanography at Univeristy of Washington. Research vessel, *R/V Thomas G. Thompson*, shipboard equipments, and other laboratory supplies needed for this study will be provided at no charge to the project budget. I will provide my own laptop for storing the data and copepod pictures. A tabular summary of all costs associated with this study are listed in Table 3.

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Figures and Tables

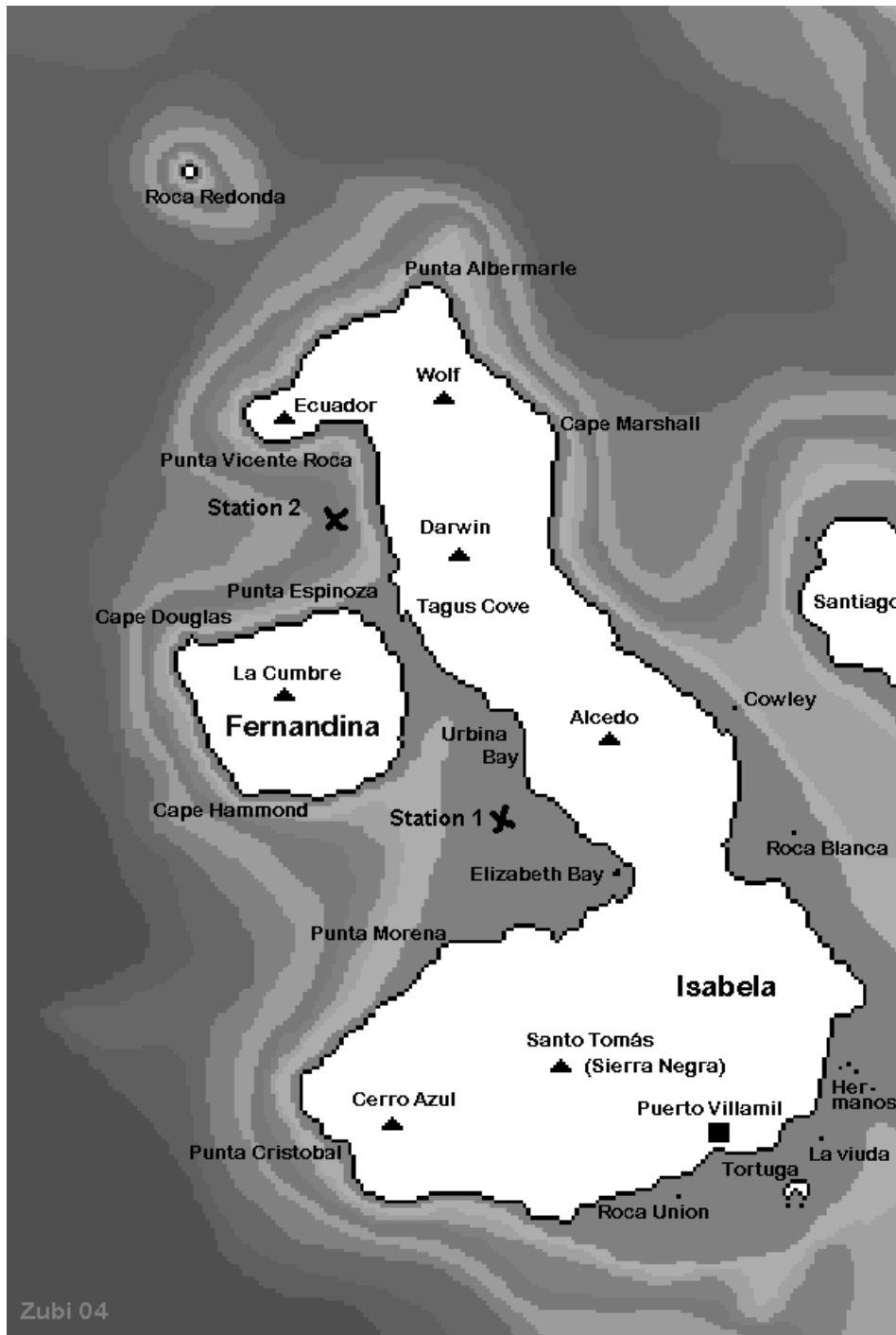


Figure 1. A map of the western region of the Galapagos includes two sampling sites, Station 1 and Station 2. Sampling locations are indicated by a “x” on the map.

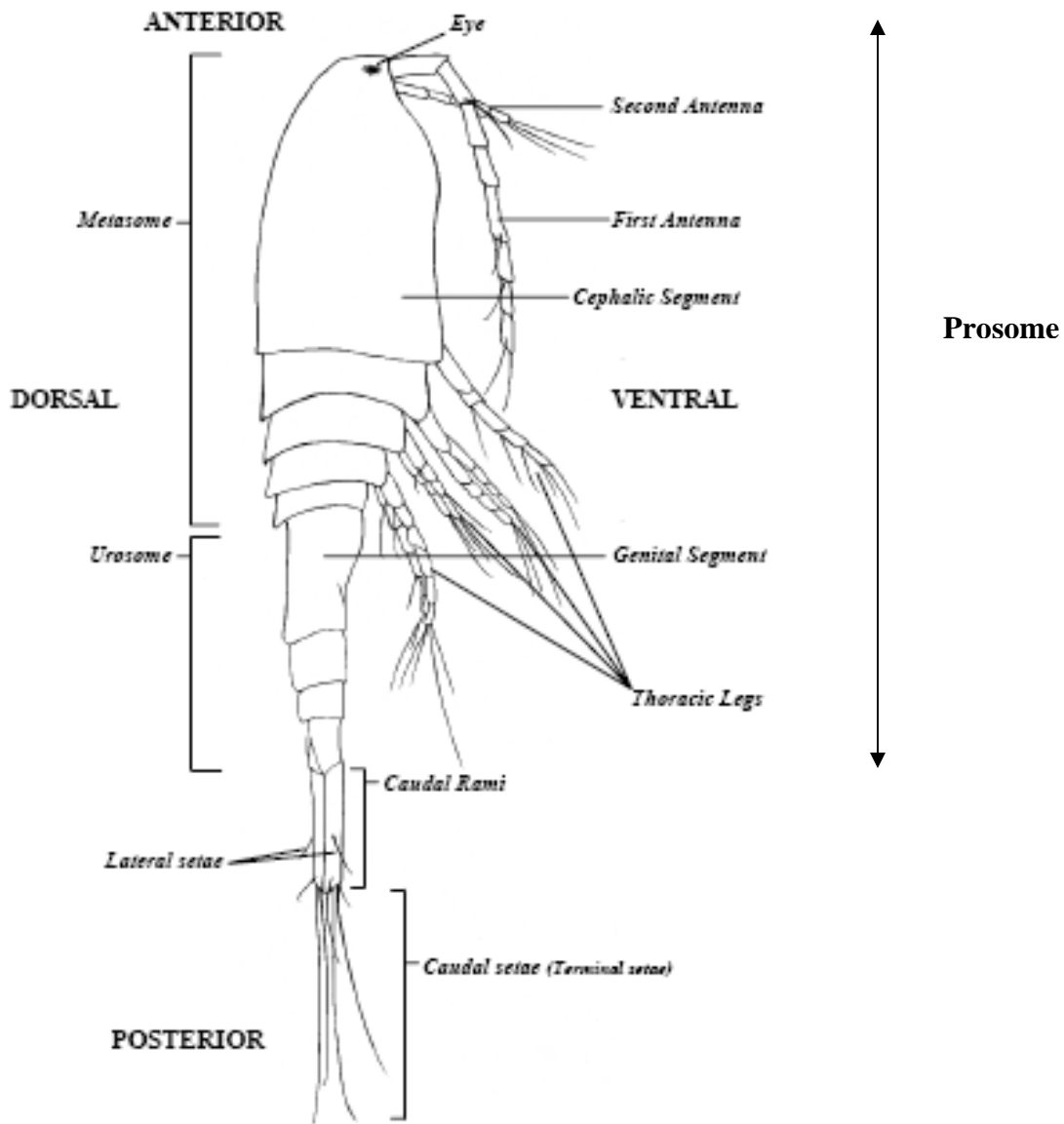


Figure 2 General morphology of Copepoda

Figure 2. General morphology of Copepoda (Carling et al. 2004).

Table 3. Summary of all costs associated with this study.

	Unit Cost	Quatity	Time (days)	Total Cost	Actual Cost	
Platform						
R/V Thomas G. Thompson	\$28,000.00 /day	1	9	\$252,000	\$0	
Shipboard Equipments						
CTD System	\$135.00 /day	1	2	\$270	\$0	
Plankton Net, 1m, 300 um mesh	\$6.00 /day	1	2	\$12	\$0	
Transmissometer	\$45.00 /day	1	2	\$90	\$0	
Kevlar line	? /day	1	2	?	\$0	
Lab Equipments/Supplies						
Dissecting microscope	? /day	1	8	----	\$0	
Sieve (64-micron)	? /day	1	8	----	\$0	
Sieve (200-micron)	? /day	1	8	----	\$0	
Plankton splitter	? /day	1	8	----	\$0	
Canon PowerShot A95 camera		1	8	----	\$0	
Glass jars	? /day	24	8	----	\$0	
Laptop	----	1	8	----	\$0	
Chemicals						
Formaldehyde solution, 500 mL	\$7.49 /bottle	1	----	\$7.49	\$0	
				Total	\$252,379.49	\$0