Marine Respiration: The Effects of Temperature, Light, and Body Size on Pacific

Zooplankton and Reef Goby Collected 2-10ºN Latitude

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SEA Cruise 211

Abstract

Methodology for conducting respiration studies on marine zooplankton and a small goby fish were established and implemented using a Unisef microrespirometer on the open ocean. Specimens were collected from 2-10ºN latitude. Oxygen consumption for all animals at ambient temperatures ranging from 26-28ºC in both light and dark conditions were measured. Although the amount of testing depended on the availability of animals and their survival, temperature change was stimulated on a goby and hyperiid amphipod. Euphausiids and phronemids collected from 26-28ºC were also measured. Rates of oxygen consumption were calculated using Excel and analyzed with Anova statical programming. An increase in temperature, both through stimulation on an individual level and with increasing ambient temperature resulted in an increasing rate of oxygen consumption. Light conditions significantly increased euphausiid respiration. These two factors provide insight into the metabolic effects of diel migration and changing ocean temperatures. Additionally, the zooplankton follows the trend of larger size having a lower metabolic rate. Using the methodology introduced and tested in this experiment, future studies will be able to replicate and expand the implications of this study to better understand the physiology of marine animals, diel migration, community respiration, and the impact of the ocean on the global carbon cycle.

Introduction

Oceanic respiration plays a major role in the global carbon cycle and contributes to the ongoing debate of whether the oceans function as a source or sink of carbon.. Understanding of respiration at the community level is extremely limited and much less is known about the physiology of individual organisms and how they are effected by environmental conditions. Within the pelagic food web, zooplankton are a key intermediate between lower primary producers and higher trophic levels. In the oceans, zooplankton biomass is predicted to be over 21.5 x 10^9 pounds, greater than that of other consumers (Ikeda, 1985). Contributing to both top-down and bottom-up models of the food web, zooplankton are important in controlling phytoplankton growth (Harris, 2000) and organic particulate flux from their grazing provides fuel for benthic communities and contributes to the sink of CO_2 (Harris, 2000). The balance between primary production and respiration has recently been challenged based on surface level measurements of microplankton oxygen consumption (Giorgio et al., 2002). Results have indicated that respiration may exceed levels of production in oligatrophic areas of the ocean (Giorgio et al., 2002). Current estimates of photic level respiration stem from only the most productive and metabolically active areas, leading to over-estimates of approximately 1.2gCm^2/d or on a global level, 143GtC/yr (Giorgio et al., 2002).

In zooplankton and fish metabolism, the conversion of food to energy requires oxygen. Oxygen consumption, referred to as respiration, can therefore be used to estimate metabolic rate. Since laboratory studies have shown that 42-72% of food ingested is converted through metabolism, understanding metabolic rates can be used to understand the total energy required and expelled by zooplankton (Ikeda, 1985). The extent of these implications are limited however, since Lampitt et al. found that *Oithona nana* consumes more than double the amount of food it needs to maintain its metabolism (1982).

Zooplankton occupy a variety of lifestyles and possess a great diversity of body sizes, eating behaviors, and lifecycles. Zooplankton range in size from 2-20 um. Zooplankton are detrivores, herbivores, omnivores, carnivores, and mixovores (combination of autotrophy and heterotrophy). They move and obtain their food through a variety of mechanisms, such as flagella, ion transport, peristaltic contractions, and swimming appendages (Harris, 2000). Such diversity in trophic position, feeding mode, swimming variety, and diel migration behavior implies a wide range of respiration levels among zooplankton taxa.

Prior research has indicated that body size, temperature tolerance, developmental stage, and physiological state such as feeding or swimming play a role in the level of respiration. Other factors include food availability, temperature, salinity, and oxygen saturation (Harris, 2000). Another factor could be seasonal variations in respiration that have been attributed to the amount of food available, with respiration rates being lowest during periods of oligatrophy (Lampitt et al., 1982). Also, densities of animals or crowding in experimental chambers is thought to play a role in respiration of animals that experience high population densities at certain parts of the year (Zeiss, 1963). Likewise, the overall energetics of diel migration are not well understood. The energy expended depends on the amount of activity involved as well as the environmental conditions of temperature and pressure experienced (Torres et al., 1983).

Oxygen consumption by marine zooplankton and small fish has been difficult to record due to both the small size of the individuals and distance from shore laboratories. Moreover, the environmental conditions associated with tropical climates has been understudied, especially in the Pacific Ocean. Although temperature has been seen to be a major component to respiration rates, few studies have explored marine respiration above 20ºC. In tropical areas, sea surface temperatures range approximately 16 degrees from the surface to a depth of 500 m (Scripps Institute of Oceanography, 1963). Based on CTD data from our cruise track, animals that migrate vertically, usually within the first 200 m, may experience temperature fluctuations from

28-7.5ºC degrees. Likewise, as climate conditions vary seasonally with El Nino events and continue to gradually warm, animals are subjected to a greater range of temperatures.

The main goal of this study was to explore the utility of using a microrespirometer to obtain accurate measurements of metabolic rates of zooplankton and small fish on a moving ocean vessel. The purpose of this study was to explore the respiration of different zooplankton groups in varying conditions along a cruise track of 18 degrees to 4 degrees north. This paper aims to 1. establish a method for measuring the oxygen consumption of marine zooplankton and small fish, 2. evaluate the effects of temperature and light and dark conditions on the rate of oxygen consumption, 3.measure rate of oxygen consumption differences on an individual level. This analysis can begin an understanding of how animals will cope with varying climatic conditions.

Based on prior knowledge, this experiment was expected to show animals respiring at a higher rate with increases in temperature and activity level. Regardless of latitude and temperature conditions at the site of conditions, animals of the same species were expected to respire at the same rate. Additionally, animals that migrate vertically were predicted to have different rates of oxygen consumption in light or dark conditions. Metabolism was also expected to decrease with increase in overall size.

Methods

Collection

Individuals were recovered from 6 sites along a cruise track traveling from approximately 10-2ºN. Figure 1. Surface temperatures were recorded using a flow-through system onboard the R.C. Seamans and relative abundances of zooplankton were estimated using 100 counts. Table 1. Individuals were collected by two meter nets, bongo nets, nueston tows, and field collection at a Christmas Island reef.

Animal Husbandry

Collected animals were placed in an aquarium and maintained at ambient temperatures until experimentation. Animals were held in screened glass jars to allow water circulation and constant oxygen flow. Survival rates varied depending on individual. In general, the goby was able to survive for a period of a few days. Phronemid amphipods survived for a maximum of two days, with measureable rates for 1 day. Hyperiid amphipods and euphausiids lasted only one day, with significant data only being able to be collected in the first 6 hours. Data on copepods were extremely variable and survival rates limited accurate measurements because many died during experimentation.

Calibration

Prior to collection, computer equipment was installed and equipment secured with twine and electrical tape. A 50 mL calibration solution of 50 mL diionized water, .991g Sodium Ascorbate (198.11g/mole), and .20g NaOH (39.9971 g/mole) was combined and left to mix. Following preparation of calibration solution, the oxygen probe was prepolarized for approximately one hour. Prior to each experiment, calibration was performed to account for the temperature and salinity of the ambient water sampled. Values were around 500 mg/mL for seawater and 0-100 mg/mL for the calibration solution. The sodium ascorbate solution set the probe to a level of zero and seawater set the 100% level. Each time, the calibration screen indicated a steady drop, with concentrations being approximately equal between samples.

Experiments

The waterbath was filled with flow-through water and monitored to maintain ambient temperatures. Animals were placed into chambers ranging in volume from 3883 to 6765 mL.

Volumes were calculated according to the equation: (Volume=Volume of Chamber-Volume of Lid). Filtered seawater was used to prevent other organisms from contributing to the oxygen consumption within the chambers. Between runs, the chambers were flushed with fresh oxygenated water. The use of a Unisense oxygen probe allowed continual recording of oxygen concentrations every second for the run of the experiment. The oxygen consumption of each animal was first tested under ambient temperature conditions in both light and dark conditions. The lengths of experiments were monitored and adjusted according to amount of oxygen in the chamber until a standard run time could be established per individual. The number of runs was dependent on animal survival and condition limitations. As a result, more data was able to be collected from certain species. A minimum of 2 runs for each condition, light and dark, were completed for each temperature. If possible, there were more runs, depending on the longevity of the animal. The ideal run time was six minutes in light conditions and four minutes in dark with at least three runs at a given ambient temperature. Table 2.

Before transfer to the next chamber, the probe was rinsed with deionized water. Following the experiment, each chamber was rinsed and scrubbed using a wire brush and soap. Individuals were preserved in formalin and dry mass weighed on a mass balance on land. Some mass was lost from each individual due to decomposition after experimentation and average mass of individuals were estimated. Table 2.

Standardization

Since all of the animals actively circulated water in the chamber, stirrers were not used. In one copepod experiment, stirrers to circulate oxygen were compared to runs without stirrers and found to have no effect in measurement. There was also not a measurable difference in the rate depending on whether light or dark conditions were ran first or second. Additionally, the slope did not change considerably depending on number of runs or length of experimentation.

However, further exploration of the effects of length of time each experiment can be run for individual species is warranted.

Temperature

Waterbath temperature was altered from ambient and oxygen consumption was tested for the goby and hyperiid amphipod. Standardization tests showed that within four hours, the amount of time in a given temperature did not change the oxygen consumption. From a starting temperature of 27ºC, temperature was decreased 5ºC to 22ºC and the goby was tested. The temperature was then increased to ambient for approximately four hours before being raised to 30ºC. The goby was tested immediately. The hyperiid amphipod started at an ambient temperature of 28ºC and was decreased to 25ºC. The hyperiid was tested once immediately after the temperature was altered and again four hours after the change.

CTD data was collected during the course of the cruise using surface water measurements and CTD casts. Data was extrapolated using OceanView software. Figure 3.

Light and Dark

At each temperature, animals were tested in both light and dark conditions. Dark conditions were simulated with the use of a black cloth that covered the entire waterbath. In comparison to light experiments, dark runs were shorter, approximately 4 minutes in duration.

Analyzation

Due to the decrease in oxygen consumption in a control monitor of oxygen concentration, (Figure 2), the first minute and thirty seconds of each experiment were disregarded due to oxygen probe error. Following the experiment, values from the Unisense probe were immediately exported into a Microsoft Excel document for calculation of respiratory rate and

statistical analysis. Trendlines were calculated for each run and slopes averaged for Anova double variance statistical calculations. The maximum number of comparable slopes dictated the number of runs analyzed. Metabolism was calculated according to the equation: $MO2 = ($Rate of Oxygen Consumption/Mass of Individual$)$.

Results

Temperature

Temperature extrapolations from CTD data provide an estimate of temperatures experienced within the diel migration realm of 200m where individuals were collected as seen in Figure 3. Surface temperatures fluctuated from 26º-28ºC. A transition to 25ºC and colder temperatures occurred at shallower depths as latitude decreased. This zone occurred at approximately 95m at 10ºN and 50m at 5ºN. From this zone, temperature more rapidly declined with minimum temperatures around 12ºC occurring at 200m at 2ºN.

The respiration rate of the goby increased with increasing temperature (Figure 4). This pattern was seen in both light and dark conditions. At ambient temperature of 27ºC, the average respiration rate of the goby was 25849.67 mg/mLhr (n=6). When temperature was decreased to 22ºC, the average respiration rate was 20640 mg/mLhr (n=6). An increase of 3 to a temperature of 30 resulted in the average rate of oxygen consumption being 37317.13 (n=6). The rate of oxygen consumption was significantly different at the three temperatures (p=0.01).

The respiration of the two hyperiid amphipods increased with increasing temperature (Figure 5). At ambient 28 degree temperature, the average rate of oxygen consumption was 1482.333mg/mLhr (n=6). When temperature was decreased to 25º, the average rate of oxygen consumption was 1326.833 mg/mLhr (n=6).

When comparing the three euphasids tested at ambient temperatures from different collection stops, average respiration increased from 5805.7mg/mLhr (n=6) at 25ºC degrees centigrade to 19728.8mg/mLhr at 28ºC (p= 8.4 x 10-5) (Figure 6).   Phronemid amphipods were tested at 3 ambient temperatures, 26, 27, 28ºC. At 26ºC, the average rate of oxygen consumption was 5061mg/mLhr (n=3), at 27 C, the average rate was 4243mg/mLhr (n=3), and at 28ºC, the average rate was 9610mg/mLhr (n=3) (p=0.005123).

Light and Dark

Euphasid oxygen consumption was significantly lower in light conditions than in dark (p=. 0.008535) (n=12) (Figure 8). Runs on the goby (p= 0.093677), hyperiid (p= 0.729327), and pelagic shrimp (p= 0.323098) did not show statistical significance between light and dark conditions.

Body Size

As seen in Figure 9, at 26ºC, the metabolic rate of the euphausiid, body mass 15mg, was 126.525mg/mLhr and the phronemid, body mass 40mg was 387.047mg/mLhr. At 27ºC, the metabolic rate of the goby, body mass 80mg was 323.12mg/mLhr, the phronemid 106.075mg/mLhr, and for copepods, body mass 1mg, 3212.5mg/mLhr. At 28ºC, the metabolic rate of the phronemid was 240.25mg/mLhr, hyperiid, body mass 20mg, 74.112, euphausid 1315.253, and pelagic shrimp 216.804mg/mLhr.

Discussion

Variation between species was expected to the many lifestyles that zooplankton occupy. Differences in both the amount and rate of oxygen consumed support this hypothesis. However, individual variation on a species and individual level was found throughout the runs. Individual

variation was also seen in studies on zebrafish embryos (Bang et al., 2004). The beginning of each run was marked by a rapid rate of oxygen consumption that steadied to a constant rate. After the first one to two minutes, the animals respired at a measurable and relatively uniform rate with levels of oxygen maintained over a 50% level of concentration. This pattern could have been the result of probe error (Figure 2) and could also show the transition from active to resting respiration rates. The behavior of animals could also account for some of the accuracy of the measurements. As benthic reef fish, gobies rest on the bottom and rarely swim upward, needing to exert much effort to do so. This typical behavior allowed the resting rate of gobies to be consistently measured during most runs. In contrast, individual oxygen consumption curves of hyperid amphipods fluctuated considerably. This finding could be partially attributed to the sporadic swimming behavior displayed during runs. Small variations in oxygen levels could have been the result of mixing induced by the animal swimming. Likewise, small-scale turbulence has been noted by Saiz et al. (1992) to increase metabolic rates. All of these factors could explain some of the variability in the readings.

Temperature

As temperature increased, the respiration of animals was expected to increase with increasing metabolic activity. At lower latitudes, where animals live in warmer ambient temperatures, higher ambient temperatures were not expected to increase respiration rates since animals would be equilibriated to different conditions. Data from both the goby and hyperiid amphipod experiments supports the intial hypothesis. Increases in temperature affected the individual animals by increasing the rate of respiration. These results coincide with copepod studies in which 94% to 95% of metabolic variation was attributed to temperature and body size (Ikeda 1985). Similar temperature effects were recorded for diel migrating freshwater copepods (Bishop, 1968) . These animals were not effected by light and dark conditions, but respiration

rate increased with an increase of temperature. An increase in respiration with temperature is supported by many prior studies in which copepods noticed that an increase in 10ºC results in a 2-3 times increase in metabolic rate (Schmidt-Nielsen; 1979 Kinne 1964; Prosser, 1961,). This study did not have a wide enough temperature range to compare to these studies, but the overall trends are similar. An increase in activity with higher temperatures could also have motivated an increase in oxygen consumption. In another copepod study, Torres et al. concluded that increasing swimming speed at the surface requires more energy (1983). Therefore, increased activity in the chamber could magnify the effects of temperature. This suggests a similar physiological response to marine organisms regardless of location in response to temperature fluctuations.

Contrary to expectations, ambient temperatures also affected the rate of respiration. As latitude decreased and temperatures increased, the rate of respiration of animals within the same species increased as well. The decrease in respiration rate at 27ºC could be the result of data coming from only one animal. This data reflects observations of copepods where respiration rates have been seen to be higher at lower latitudes (Ikeda et al., 1982). The overall increase in respiration with higher ambient temperatures suggests that animals are not physiologically adapted to warmer climates.

Light and Dark

Animals that migrate vertically through the water column were expected to experience an increase in respiration when exposed to light since the animals movement revolves around staying in dark conditions. Euphausiid results support this hypothesis. These results are supported by a study in which marine zooplankton have been found to increase their respiration level proportionately to the amount of light with exact amounts dependent both on the species studied and depth of collection (Fernandez, 1977). However, this data contradicts studies on diel

migrating copepods where light and dark did not have an effect (Briggs, 1980). This may be the result of physiological differences between copepods and euphausiids. The increase in respiration may suggest that physiological limits are placed on euphausiids that prevent them from being active in the light. It may also show that since euphausiids operate in dark conditions, the shock of entering light affects their respiration rates. Statistically significant differences between light and dark conditions were not observed for any of the other animals. Due to limited literature available aboard the R.C. Seamans, the behavior of these animals in the water is not understood. If such animals do not migrate vertically, these findings may show a physiological similarity between diel migrators. If the other tested animals do migrate, the results would support the Briggs 1980 experiment and such a finding may indicate differences in activity level during migration or variation in physiological motivators for travel in the water column. For example, Duval and Geen found that euphausiids, shrimps, and fishes increase their swimming speed during migration (1976). An increase in activity level during migration by *Euphausia pacifica* results in over a three times increase in oxygen consumption (Torres et al., 1983). Along with a stronger understanding of the behavior of zooplankton, the level of activity in different levels of light is a factor that should be studied in future experimentation. Continued study may hold the potential to understand animal behavior through their metabolic responses to changes in light and dark conditions.

Body Size

Animals with larger body sizes were expected to have lower metabolic rates. Findings within the zooplankton support this hypothesis. At the same temperature, larger animals had a lower metabolic rate. In general this trend seems to apply across temperature ranges. This study supports work on copepods that shows that in relation to body size, smaller animals have a higher metabolic rate (Ikeda et al., 1982). The metabolic rate of the goby fish lies above that of

smaller zooplankton, which probably shows the inability to compare metabolism between reef fish and zooplankton. Small zooplankton have a greater metabolic rate and grow faster than large zooplankton (Harris, 2000). However, the measured respiration rate of *O. similis* was found to be approximately 8 times lower than a copepod of the same weight (Castellani, 2005). In such circumstances, lower metabolic rates can be the result of less active lifestyles. Resting zooplankton uptake oxygen at 50% the level of those actively swimming (Zuethen, 1947). Animals that spend most of their time motionless in the water column may have slower respiratory rates than active animals of the same size (Lampitt et al., 1982). Interestingly, another factor that may play a role is the feeding habit of different animals. Omnivores have a higher respiration rate than herbivores of the same size (Conover et al., 1968). Lower metabolic rate of certain species of the same body size may indicate the ability for animals to higher year-round abundances or the ability to occupy oligotrophic environments.

Future replications of this project are necessary to further understand the physiology of marine organisms. The methodology developed through the series of experimentations has the ability to be replicated and advanced to answer many larger questions.   With better measurements of body mass for individuals, metabolism on both the species and individual level can be estimated, which will contribute to understanding the general metabolic requirements of zooplankton and fish. Further understanding of species behavior in the natural environment and within the chambers can lead to insights concerning variations and trends in oxygen consumption. For instance, locomotion and level of activity in relation to the energetic demands can be observed. Understanding of the overall physiological limitations and survival advantages of specific species can also be implied. This project holds the potential to study respiration on a community level. Based on abundances of animals and respiration studies of animals on location, an understanding of the differences in overall respiration between areas of the ocean

based on temperature, productivity, as well as other factors can be analyzed. More knowledge on the physiology of animals will allow predictions as to the effects and limitations of animals in changing climate conditions and the effect on global carbon cycles.

Conclusion

Marine respiration is variable both on the species level and within individuals. Individuals experience an increase in oxygen consumption with temperature increase which suggests variability in respiration due to migration and seasonal climate changes. With increasing ambient temperatures along the cruise track, respiration also increased, portraying that animals may not be adapted toward higher temperatures experienced at specific latitudes. Light was seen to affect euphasiid respiration, which could be the result or cause of diel migration. A decrease in metabolic rate was seen to decrease metabolic rate. Overall, with continued study of the behavior and physiology of zooplankton and fish communities, a better understanding of community respiration can lead to stronger estimates of overall marine respiration and the role of ocean processes on the global carbon cycle.

Appendix A: Figures

Figure 1. Map of collection sites along S211 cruise track from 10-2ºN. May 2007, S211.
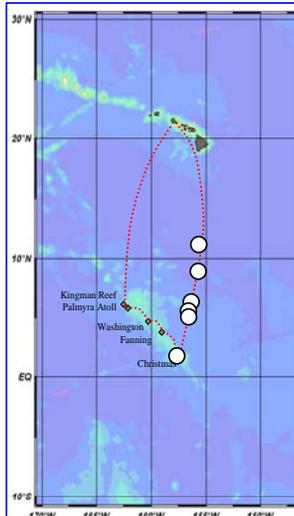
Figure 2. Oxygen concentration level vs. hours in seawater control run. N=1. May 2007, S211.
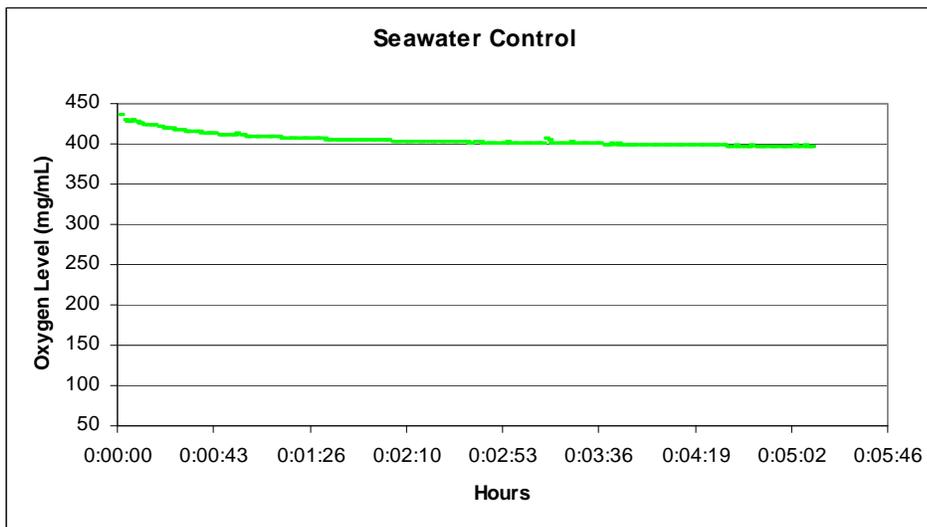
Figure 3. Depth vs. latitude temperature data from CTD casts and sea-surface temperature recordings from 2º-10ºN. May 2007, S211.
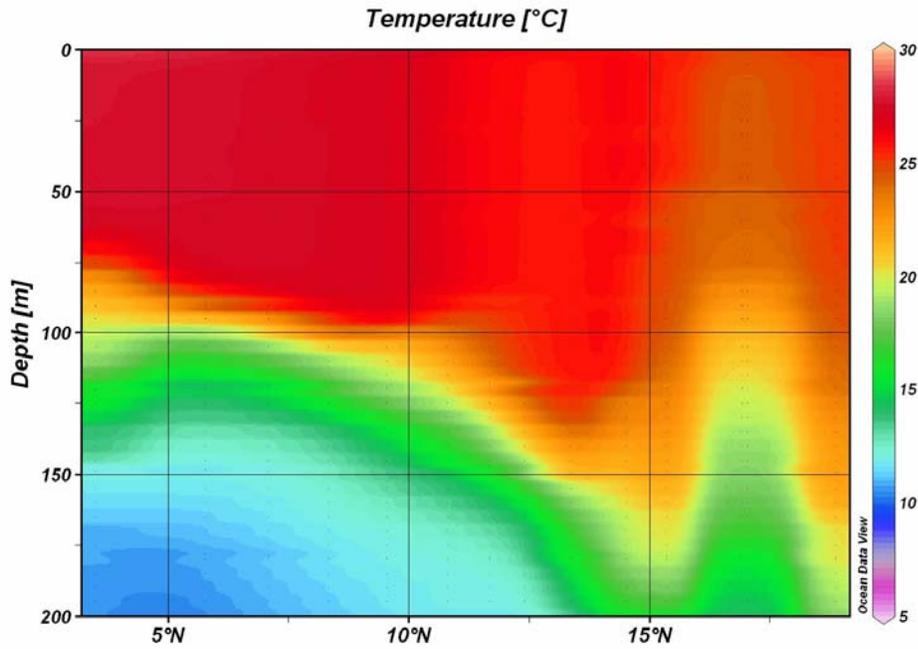
Figure 4. Rate of oxygen consumption for goby fish vs. temperature at ambient 27ºC (n=6) and altered temperatures of 22ºC (n=6) and 30ºC (n=6). May 2007, S211.
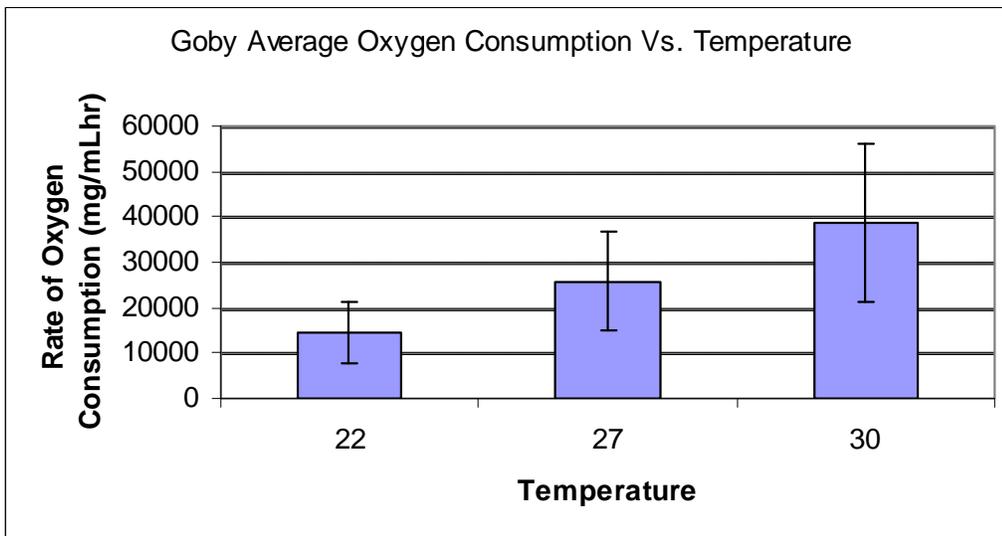
Figure 5. Oxygen consumption of hyperiid amphipods vs. temperature under ambient 28ºC (n=6) and altered 25º(n=6) conditions. May 2007, S211.
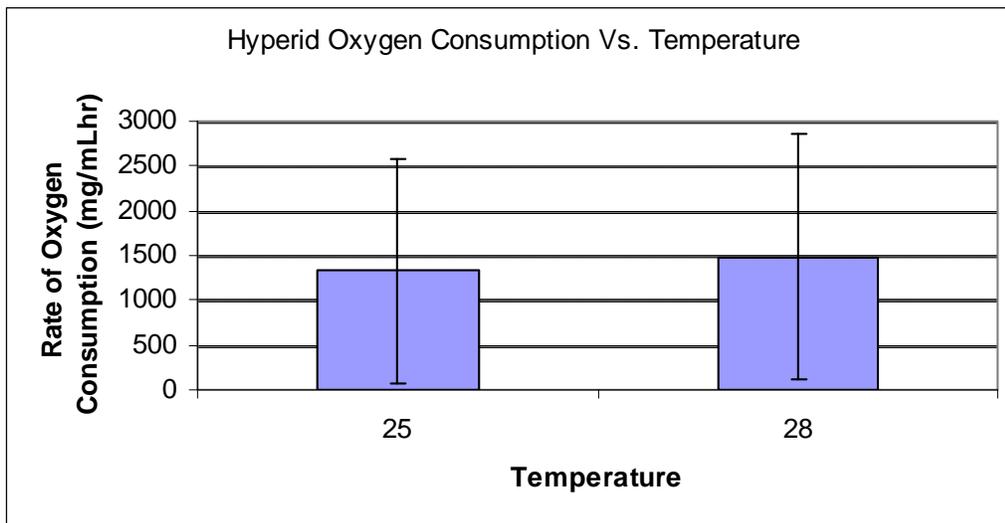
Figure 6. Euphasiid respiration vs. temperature at ambient temperatures of 26ºC (n=6) and 28ºC (n=6). May 2007, S211.
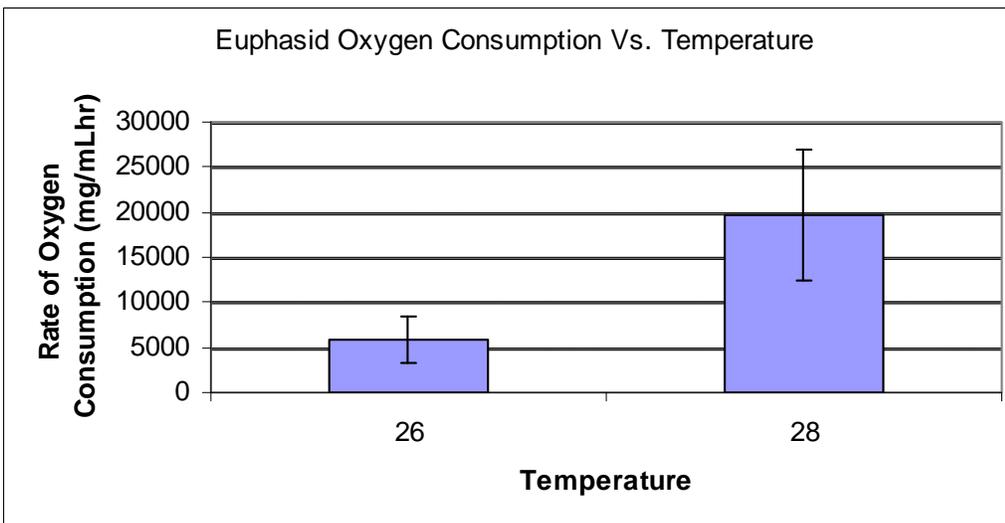
Figure 7. Phronemid respiration vs. temperature at ambient temperatures of 26ºC (n=3), 27ºC (n=3) and 28ºC (n=3). May 2007, S211.
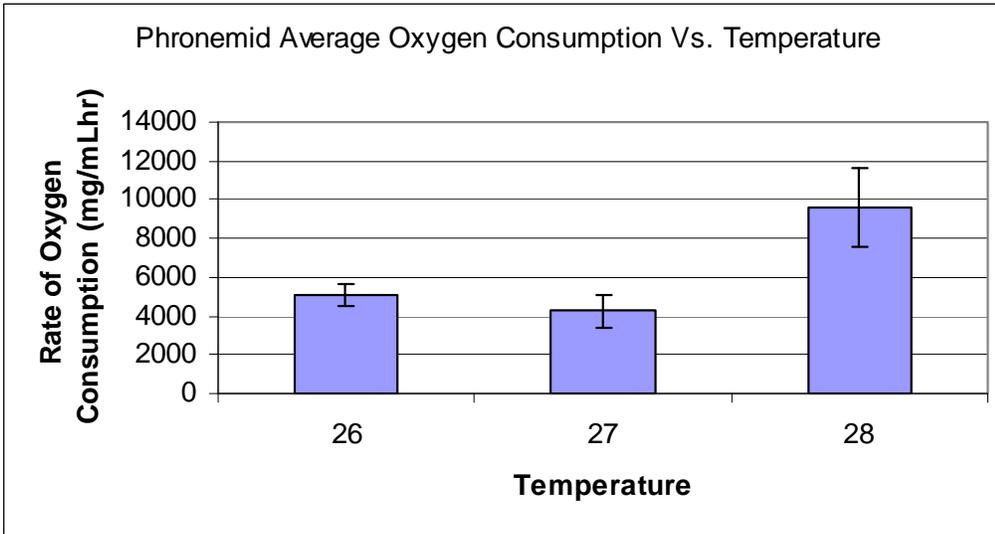
Figure 8. Euphasid oxygen consumption vs. light and dark conditions. Light (n=6), dark (n=6). May 2007, S211.
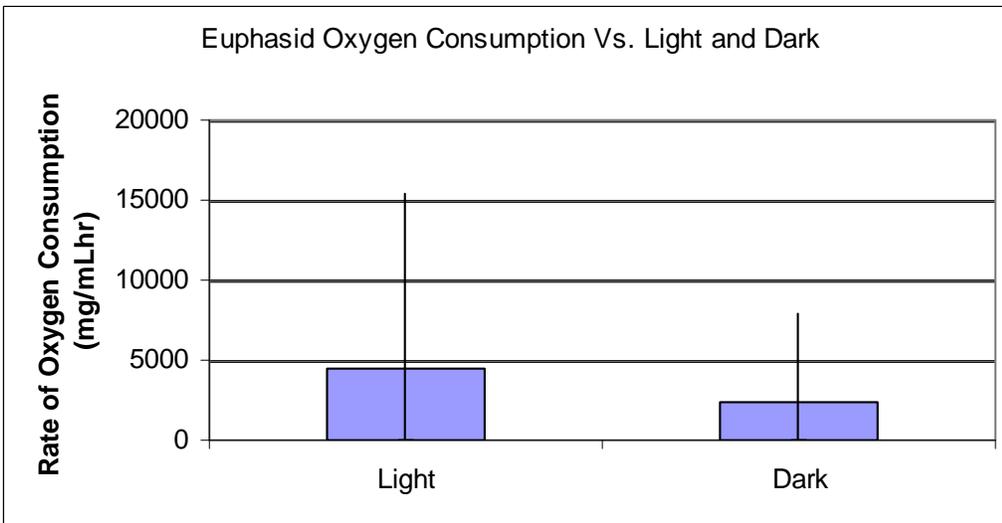
Figure 9. Metabolic rate of species based on rate of oxygen consumption/mass of animal vs. temperature. Estimated body sizes in mg: goby (80mg), phronemid (40mg), hyperiid (20mg), euphausid (15mg), copepod (1mg), and pelagic shrimp (70mg). May 2007, S211.

Metabolic Rate vs. Temperature

Legend:
- Goby
- Phronemid
- Hyperid
- Euphausid
- Copepods
- Pelagic Shrimp

Y-axis: Rate of Oxygen Consumption/Mass of Individual

X-axis: Temperature (C)
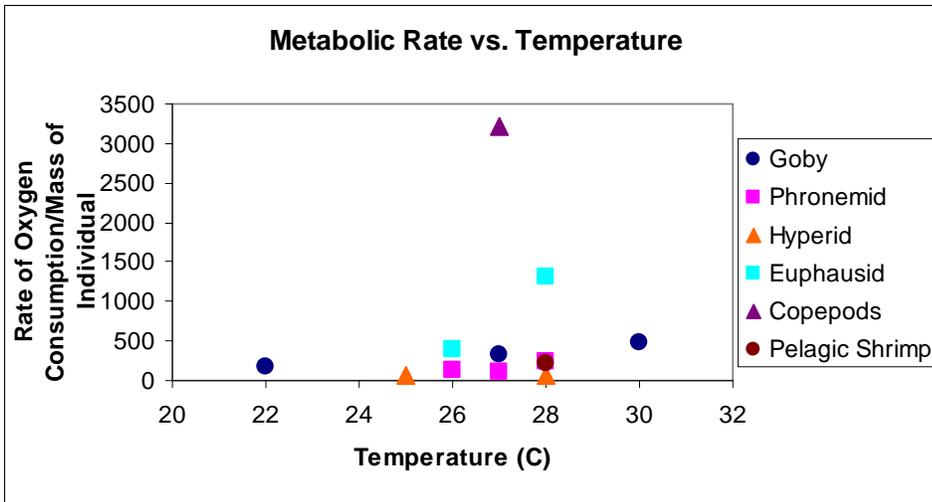
Appendix B: Tables

Table 1. Individuals collected, latitude and longitude of sample locations, sea surface temperatures, and relative abundances of collected individuals from 100-count data. May 2007, S211.

Individuals	Location	Lat, Longitude	Temperature	% Abundances
Phronemid Amphipod A; Euphasid Shrimp A, B	S211-011 Front Boundary	10 46.1 N x 156 35.9 W	27.2	Hyperiid 3%; Euphasid 0-9%
Phronemid Amphipod B; Blue Copepods; Euphasid Shrimp C	S211-013 S. Tropical Convergence Front	8 18.6 N x 156 28.4 W	27.6	Hyperiid 0-3%; Copepods 44-63%; Euphasid 8-32%
Phronemid Amphipod C	S211-016 North Equitorial Countercurrent	6 28.4 N x 156 27.6 W	28.0	Hyperiid 1%
Hyperiid Amphipod A, B	S211-018-BN South Equitorial Current	4 58.8 N x 156 29.3 W	27.2-28.1	Hyperiid 5%
Red Copepods; Euphasid Shrimp D	S211-020-BN 20 miles north of Fanning	4 4.8 N x 159 40.7 W	28.4	Copepods 42%; Euphasids <1%
Goby	Christmas Island	1 50.33 N x 157 21.1 W	27.0	

Table 2. Number of runs by individual in temperature and light=L/dark=D conditions and their measured length and mass, and estimated measurements=Est. Mass. May 2007, S211.

	Length (cm)	Mass (g)	Est. Mass (g)	22 L	22 D	25 L	25 D	26 L	26 D	27 L	27 D	28 L	28 D	30 L	30 D	Control
Goby	2.2	<.01	0.08	6	7					6	6			5	4	1
Hyperiid Amphipod			0.02													
A	0.72	0				1	1					3	3			
B	n/a	n/a				3	3					3	3			
Phronimid Amphipod			0.04													
A	1	<.01						2	1			2	2			
B	1.3	0								2	2	1				
C	1.92	0.1										3	3			
Euphasid Shrimp			0.015													
A	1.12	0						2	1							
B	1.4	<.01						1	1							
C	1.5	0						1	1							
D	n/a	n/a										4	3			
Copepods			0.001													
Blue	0.1									2						
Red	0.1									2	1					
Pelagic Shrimp																
A	2.15	0.07										2	2			

Appendix C: Equipment List

<u>Collection</u>
neuston net tows
aquarium
microscope
identification guide for fish larvae
ependorf Flask (for volume displacement measurement)
smaller net/pipets for fish larvae

<u>Respiration Experimentation</u>
Computer with Windows: Installed Unisense Software
USB or way to save data
waterbath
seapointflow-through thermosalinograph
thermometer for waterbath
Unisense Equipment:
      4 mL chambers
      1mL chambers
      chamber rack
      stirring magnets
      nylon protection covers
      Box
      Cables
      Power Supply
      2 oxygen sensors
      Manual
      Oxygen Concentration Table
distilled water
calibration salt solution
pipets
ethanol
soap
water
brush
tin foil
small pocket calculator
twine
electrical tape

50 mL calibration solution the following will be combined (do not shake):
      50mL diionized water:
      .991g Sodium Ascorbate (198.11g/mole)
      .20g NaOH (39.9971 g/mol

      For calibration, using Unisense guide for temperature and salinity, find standardization number and in order to convert umol/l to mg/mL, multiply value by 1.426mg/mL.

Chambers	Volume (mm^3)
A	3883.4
B	4248.8
C	3982.8
D	6154.9
E	6348.6
F	6765.2
G	3834.6

Lids	Volume (mm^3)
a	1455.8
b	1701.6
c	1649.7
d	1586.2
e	1556.1
f	1604.8
g	1838.9
h	1777.0
i	1684.3
j	1518.1
k	1791.7
l	1416.6

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