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UNIVERSIDAD DE LAS PALMAS DE GRAN CANARIA

Testing zooplankton secondary production against growth in the marine mysid, *Leptomysis lingvura* (G.O. Sars, 1866)

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Testing zooplankton secondary production against growth in the marine mysid, *Leptomysis lingvura* (G.O. Sars, 1866)

Trabajo presentado por Alejandro Jesús Marrero Benítez para la obtención del título de graduado en Ciencias del Mar en la Universidad de Las Palmas de Gran Canaria y dirigida por la Doctora Doña May Gómez Cabrera, grupo de investigación Ecofisiología de los Organismos Marinos (EOMAR).

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Abstract

Zooplankton growth and secondary production are key input parameters in marine ecosystem modelling, but their direct measurement is difficult to make. Accordingly, zooplanktologists have developed several statistical-based secondary production models. Here, three of these secondary production models are tested in *Leptomysis lingvura* (Mysidacea, Crustacea). Mysid length was measured in two cultures grown on two different food concentrations (90 and 240 *Artemia* nauplii per mysid, twice a day). The relationship between length and dry-mass was determined in a pilot study and used to calculate dry-mass from the experimental length data. Growth rates ranged from 0.11 to 0.64 day^{-1}, while secondary production rates ranged from 1.77 to 12.23 mg dry-mass day^{-1}. None of the three selected models were good predictors of growth and secondary production in this species of mysid.

Introduction

Mysids are peracarida, crustaceans that inhabit many varied aquatic habitats (Tattersall and Tattersall, 1951; Mauchline and Murano, 1977). They are omnivorous and eat small planktonic organisms as well as organic detritus (Tattersall and Tattersall, 1951; Mauchline, 1980; Murano, 1999). Morphologically, they are characterized by having a thorax covered by a shell (not attached to the last four thoracic segments, unlike euphausiids), having a pouch on the ventral side of the body, and by having the first three thoracic appendages modified like maxilipeds;(the others thoracic appendages are left unmodified and similar to each other (Gómez, 2000)). In mysids identification, the most important morphological features are the telson, carapace, rostrum, eyes, antennal scale, pereopods and uropods (Fig.1). The taxonomy is difficult because the difference between two species of the same genre may be due to small morphological differences (Herrera, 2013).

Mysids are abundant in different habitats such as the oceanic water column, seagrass meadows, the seafloor, caves, etc. (Herrera, 2009). Studies on the relationship between mysids and fish suggest that mysids are one of the most valuable fish-foods, especially in coastal regions (Murano, 1999).

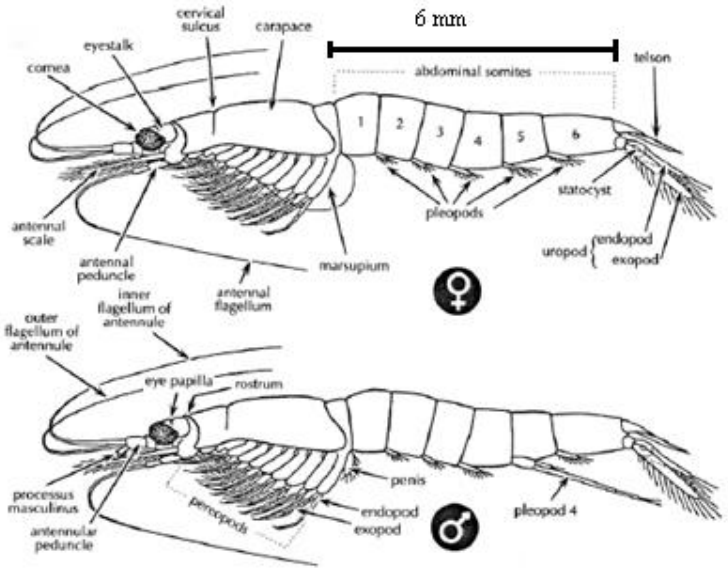

Fig. 1. Typical mysid in side view (Murano, 1999).

Also, mysids are valuable food-chain components for other predators, especially those living in coastal and in seagrass areas. Mysids are found, in high abundance in *Cymodocea nodosa* seagrass meadows around the Canary Islands, as seen in the work

of Herrera (2013). They are the most abundant animal in this ecosystem, comprising at least 65% of all organisms that inhabit in this ecosystem (Herrera et al., 2014). In spring, seagrass meadows have a high shoot density and plant biomass (Tuya et al., 2006) that serves as a rich habitat and nursery for many organisms, including mysids. Accordingly, the combination of *Cymodocea nodosa* seagrass meadows and mysids likely play an important role in maintaining coastal productivity (Herrera, 2013).

For this reason, it is essential to understand the growth (secondary production) of these crustaceans to quantitatively predict their impact on the productivity of coastal ecosystems.

Secondary production reflects the net balance between metabolic gains and the integral of all metabolic losses (Gómez et al., 2012). Measurements of secondary production in the laboratory on one species are not the same as secondary production of a mixed zooplankton community in the ocean. Nevertheless, laboratory experimentation is a vital starting point, modelling is another one (Gómez et al., 2012).

The first investigators to use modelling to predict secondary production in zooplankton were Huntley and López (1992). They used only temperature as their key variable. Later, other models were developed. Hirst and Sheader (1997) constructed their model from samples from the Arabian Sea. Huntley and Boyd (1984), based their model on temperature and body mass. The Hirst and Sheader (1997) model gave higher growth rates, but Peterson et al. (2002) had concluded that it was the best predictor of secondary production, even better than the Hirst and Lampitt (1998) model. Later, Miyashita et al. (2009), researching copepods in subtropical coastal seawater, confirmed that the Huntley and López (1992) model overestimates secondary production compared with the Hirst and Lampitt (1998) model. However, it has been shown that the Huntley and López model seems effective when food is not-limiting. For example, in areas such as estuaries and upwelling areas it seems to work (Peterson et al., 2002). Afterwards, Gómez et al. (2012) compared five models, including Huntley and López (1992), Hirst and Lampitt (1998), Hirst and Sheader (1997), Stockwell and Johannsson (1997) and Shuter and Ing (1997) models, with *Daphnia magna* laboratory data and; conclude that the best secondary production model for this organism was the Stockwell and Johannsson (1997) model. They noted that the Huntley and López (1992) model overestimates secondary production, as confirmed by previous studies and suggests

future avenues of research in which new models, would predict secondary production in other zooplankton species such as euphausiids or mysids.

In this experiment, with the aim of understanding secondary production in natural mysids populations, growth and secondary production of the mysids *Leptomysis lingvura* (Wittman, 1981) were measured in cultures grown on different concentration of food.

Leptomysis lingvura is one of the three mysid species found along the coast of Gran Canaria (Canary Islands, Spain). It is characterized for having a short carapace with a triangular face and a small, wide telson (Herrera, 2013).This species was chosen because of its important role in the Gran Canaria coastal ecosystem and because it grows well in the laboratory. In fact, it can complete its life cycle in captivity (Herrera, 2009; Herrera et al., 2011). This capacity to grow well in captivity greatly improves the facility to study growth and secondary production in the laboratory. Accordingly we grew this mysid in aquaria on different food concentrations and compared its growth with that predicted by the current models of secondary production in marine zooplankton.

Material and methods

Samples were taken at Risco Verde, on the east coast of Gran Canaria, Canary Islands (Fig. 2), on March 7th 2015, at depths between 15 and 20 meters using SCUBA equipment and a hand net.

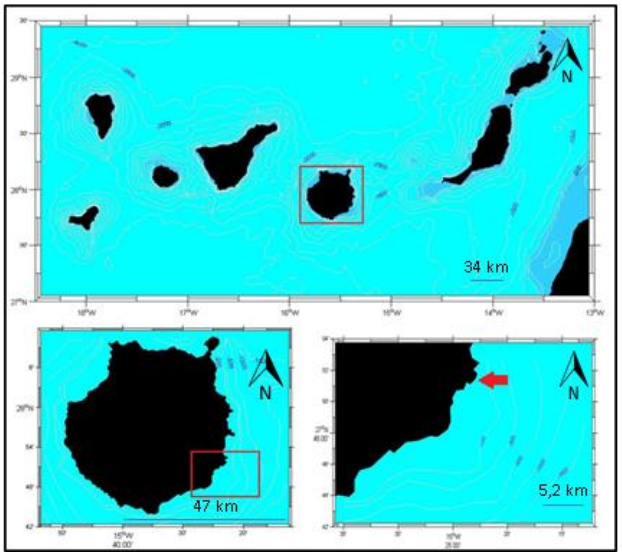

Fig. 2. Location of the sampling area. Distances obtained from IDE Canarias, visor Grafcan.

During the 10 days of acclimatization, mysids were placed on two plastic tanks of 40 L and were fed twice daily with 100 or 150 *Artemia* nauplii per mysid (the concentration of *Artemia* nauplii depended on the number of eggs that hatched). The seawater temperature, pH, NH_4^+, NO_3^- and NO_2^- concentrations were monitored from the acclimatization period until the end of the experiment. The photoperiod was 14h:10h light and dark throughout the experiment.

After this acclimatization, mysids were identified by species using a binocular microscope and following the works of Tattersall and Tattersall (1951), Wittman (1981), Murano (1999) and Herrera (2013). Then, *Leptomysis lingvura* were placed in 2 aquaria of 35 L, for adult breeders (Fig. 3) and 4 aquaria of 16 L for growing the juveniles. The water recirculation system of these aquaria was based on the system described in Lussier et al. (1988), with a 2 mm mesh siphon that transfers the juveniles to a 0.5 mm mesh collector, allowing adults and juveniles to be separated. Water flowed from aquaria to a biofilter, a tank where nitrifying bacteria oxidized NH_4^+ to NO_2^- and then to NO_3^-. After that, the water passed through a skimmer to remove proteins from the organic material produced during nitrification. Finally, water was pumped back to the aquaria. During this experiment, the seawater temperature was maintained at 18.68±0.22ºC, the pH was maintained at 7.99±0.04, and the NH_4^+, NO_3^- and NO_2^-, at concentrations below 0.05±0.01, 4±1.67 and 0.01±0.02 respectively.

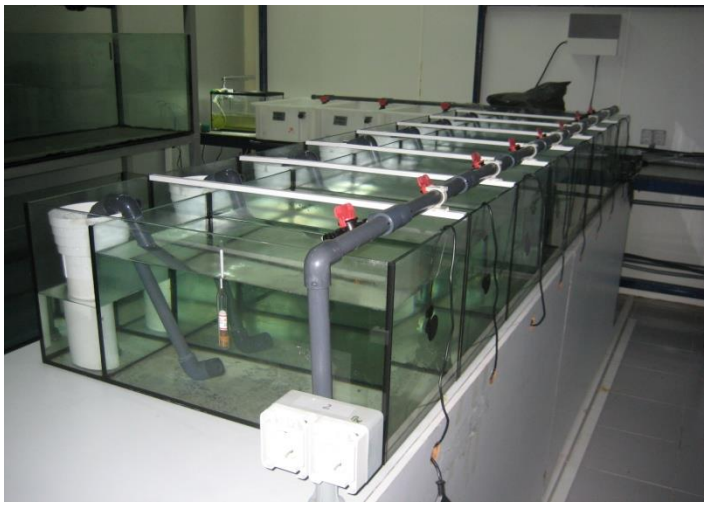

Fig. 3. Mysids aquaria.

Mysids were counted daily and fed with various concentrations of 48 h (2 day-old) *Artemia* nauplii. Some of them were given twice daily 90 *Artemia* nauplii per mysid (first experiment), and the others were given twice daily 240 *Artemia* nauplii per mysid

(second experiment). The *Artemia* were enriched with Easy-DHA $Selco^{®}$ (INVE, Belgium).Then mysid growth was monitored.

To measure the standard length, the distance from the rostrum between the eye stalks to the end of the last abdominal segment (Herrera et al., 2011) a binocular microscope with a Canon EOS 1000D 10-megapixel camera was used. The image was then measured with ImageJ 1.40g (National Institutes of Health, USA).

Once all measurements were obtained, averages and standard deviations required to do the growth curves were calculated. From the initial measurement, the length increased per time in both cultures. The culture of 90 *Artemia* nauplii per mysid was followed for 35 days, but in the culture grown on 240 *Artemia* nauplii per mysid, the mysids died after 22 days. That tragedy limited the length of the second experiment to 22 days. Still, it was sufficiently long to achieve the experimental objectives.

To obtain the relationship between length and dry-mass, some mysids (randomly selected for different size classes) were dried at 60ºC in a drying oven for 24 h. Then they were weighted on a Cobos balance with an ultramicroscale (+0.1 mg), according to Lovegrove (1966).The dry-mass data were plotted against the length (Fig. 4). The regression line was calculated to obtain the relationship between length and dry-mass. This was used to obtain the dry mass per time for both cultures.

Lastly, growth rates were calculated from an exponential function fitted to the data (as shown in Gómez et al., 2012):

$$W_t = W_0 e^{gt} \quad (1)$$

Where W_t is the dry-mass at time *t*, W_0 is the dry-mass at time zero, *t* is the time (days), and g is the daily (24 hours) growth rate (Escribano and McLaren, 1992). The global rate of growth (g_g) was calculated as the slope of the regression line in a plot of the log growth vs. time (Kimmerer and McKinnon, 1987).

Using this equation, daily secondary production for both cultures, as dry-mass increase per mysid, per day, was calculated.

All statistics were run using the R statistical package (Pinheiro et al., 2009; R Development Core Team, 2010), and the Shapiro-Wilk test for estimating whether the data was normal or not. The Student´s t-test and Wilcoxon signed rank test were used to evaluate if there was significant difference between regression lines.

Three secondary production models were based on marine field studies were used to check if they could be applied to marine Mysidacea, and specifically to *Leptomysis lingvura*. These models were:

(a) Huntley and López (1992): This model describes the growth rate (g) as a function, exclusively, of temperature (t). It is represented by the equation:

$$g = 0.0445 * e^{0.111t}$$

(b) Hirst and Sheader (1997): This model assumes that the intrinsic growth rate (g) depends on the temperature (t) and the body mass (W). It is represented by the equation:

$$g = (0.0732 * 10^{0.0246t})/W^{0.2962}$$

(c) Hirst and Lampitt (1998): This model also describes the growth rate (g) as a function of temperature (t) and body mass (W), according to the equation:

$$g = (0.0723 * 10^{0.0208t})/W^{0.321}$$

In summary, these models estimate secondary production as the product of biomass and the modeled growth rate.

Results

A pilot study was made in which both length and dry-mass were measured independently. From the data a linear regression line was obtained to derive the length - dry-mass relationship (Fig. 4). The slope of the line was 0.6557 with an adjusted r^2 of 0.975.

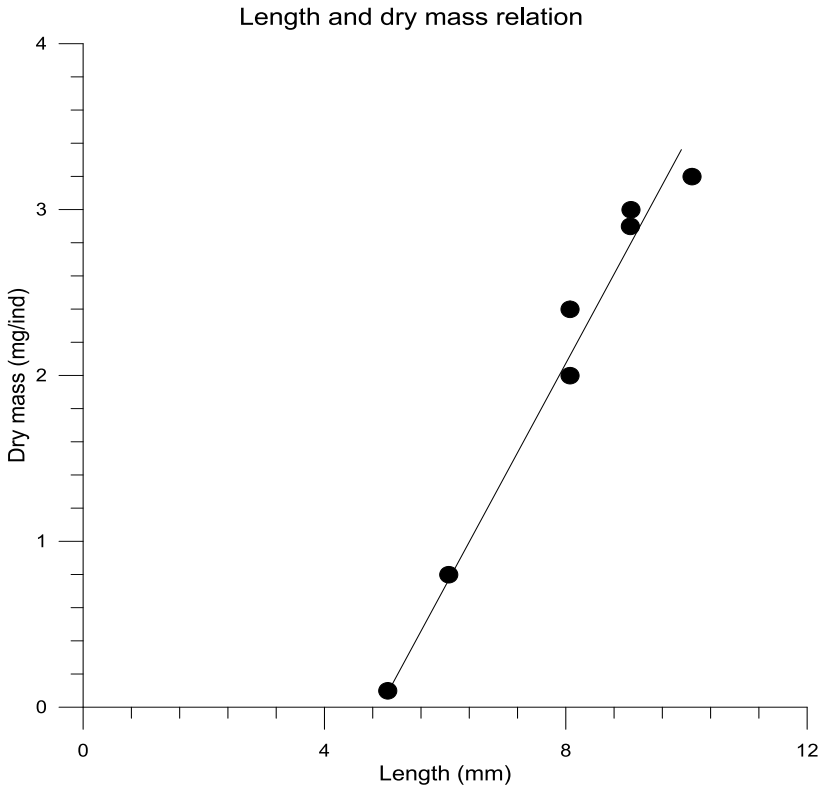

Fig. 4.*Leptomysis lingvura* length and dry mass relationship, with the equation: $y = 0.6557x + 3.1408$, $r^2 = 0.975$.

Mysid growth, as length (Fig. 5), when grown on 90 *Artemia* nauplii per mysid, twice per day, is sigmoidal curve. Length-based growth measurements plateaued on the 24th day of the first experiment.

However, in the second experiment in which the mysids were fed 240 *Artemia* nauplii per mysid, twice per day, length increased most rapidly between days 11 and 22. In the first experiment, where the mysids were fed 90 *Artemia* nauplii per mysid, twice per day, the fastest increase growth occurred between days 12 and 24 of the experiment.

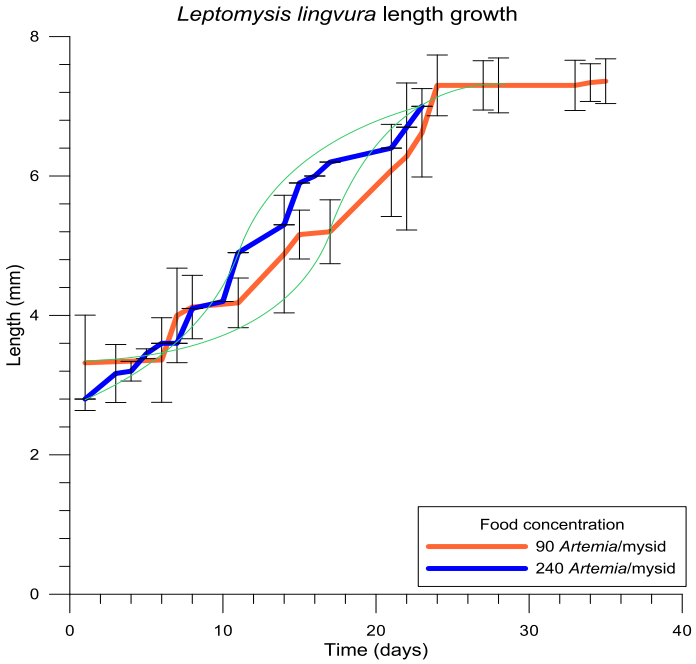

Fig. 5. Two different growth experiments showing *Leptomysis lingvura* length as a function of time in cultures grown on different food concentrations. Growth equations are: For mysids fed with 90 *Artemia* nauplii per mysid, twice a day: $y = 0.236x + 3.034, r^2 = 0.950$.For mysids fed with 240 *Artemia* nauplii per mysid, twice a day: $y = 0.207x + 2.439, r^2 = 0.968$.

The maximum length (Table 1) of the poorly-fed mysids was only 13% less than that of the better-fed mysids even though the poorly-fed mysids ate 63% less.

Food concentration (*Artemia*/mysid)	Length at 21 days L_{max}(mm)	Dry mass at 21 days W_{max} (mg/ind)	Temperature (ºC)	Dry mass regression line equation	Dry mass equations r^2
90	6.08	5.42	18.3	: $y = 0.237x + 0.691$	0.946
240	7.00	6.07	18.6	$y = 0.267x + 0.110$	0.953

Table 1. Maximum length, maximum dry-mass and water temperature at day 21 in the two of *Leptomysis lingvura* culture.

Initially, *Leptomysis* fed with 90 *Artemia* nauplii had the same length and dry-mass increase, on average, than those fed with 240 *Artemia*. However, from the 10th day of experiment the master variable, length, increased more in the mysids fed with 240 *Artemia* nauplii. The increase demonstrated that the difference in food concentration affected mysid growth significantly. In other words, for every passing day, *Leptomysis lingvura* fed with 240 *Artemia* nauplii grew 0.054 mg more than those fed with 90 *Artemia* nauplii.

There was a significant difference between both regression lines, with a p-value of 0.0201. The estimate of the residual standard error for the length-based time courses was 0.3279, with an adjusted r^2 of 0.9566. The F-statistics for testing the significance of the measurements gave a value of 198.5 on 3 and 27 degrees of freedom (p-value=$2.2 * 10^{-16}$; it is significant when p-value<0.05).

Specific daily growth rates (Fig. 6), measured in day^{-1}, decreased continuously throughout the experiment, with the steepest decline in *Leptomysis* fed with 90 *Artemia* nauplii per mysid.

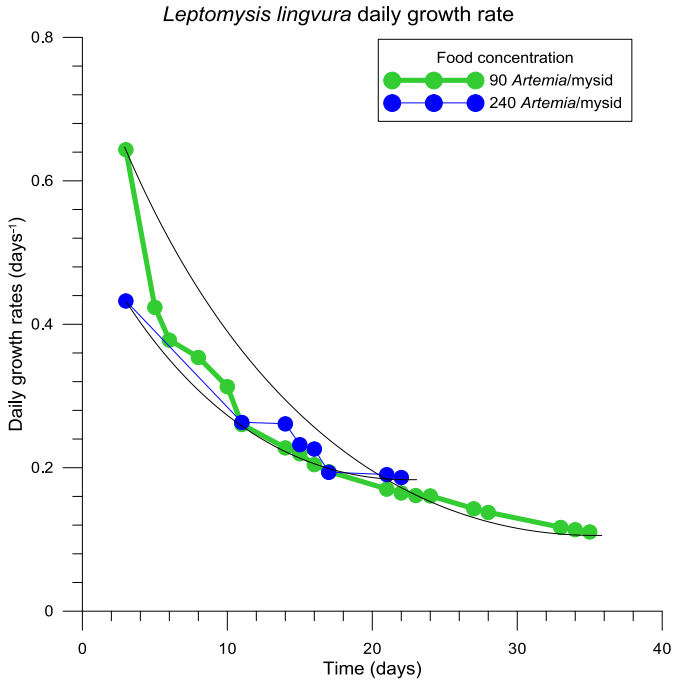

Fig. 6. Decrease in the daily growth rate, g, as calculated from the two growth equations for dry-mass, as given in the caption of Fig. 4 and from Equation (1), for *Leptomysis lingvura* in two concentrations of food.

The daily growth rate equations were: For mysids fed with 90 *Artemia* nauplii: $y = -0.231\ln(x) + 0.8913, r^2 = 0.917$. For mysids fed with 240 *Artemia* nauplii: $y = -0.124\ln(x) + 0.5775, r^2 = 0.9459$. With a p-value of 0.05 (It is significant when p-value≤0.05).

However, the fastest global growth rate during the first 20 days of experiment was in the culture of 240 *Artemia* nauplii per mysid (0.61 day^{-1}), and the slowest growth rates were in mysids grown with 90 *Artemia* nauplii (0.49 day^{-1}).

The daily secondary production trend (Fig. 7) seems to be regular for mysids fed with 90 *Artemia* nauplii. There was an increase on the 14th day of experiment and an uneven distribution for mysids fed with 240 *Artemia* nauplii. A notable increase had already occurred on the 10th day of experiment for mysids fed with 90 *Artemia* nauplii,

denoting that the secondary production would be much higher with the higher food concentration. Both trends were significantly different, showing a p-value of 0.00107 (It is significant when p-value<0,05).

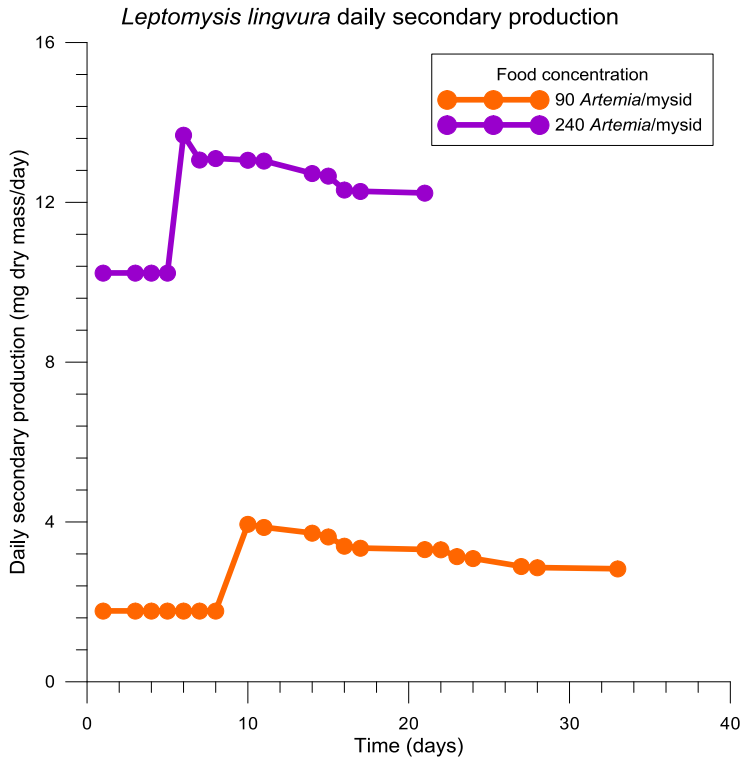

Fig. 7. The secondary production trend in *Leptomysis lingvura* grown on two different food concentrations, calculated from the daily growth rates shown in Fig. 6 and the dry-mass functions of Fig. 5. Secondary production equations are: For mysids fed with 90 *Artemia* nauplii per mysid: $y = 0.0439x + 2.005, r^2 = 0.3021$. For mysids fed with 240 *Artemia* nauplii per mysid: $y = 0.1031x + 10.825, r^2 = 0.3507$.

Discussion

When the results of this study are compared with others from the literature, it can be seen that mysids have similar growth rates and secondary production rates to those of copepods (Table 2). On the other hand, mysids had higher secondary production rates than other organisms such as cladocerans and polychaetes (Table 2). These variations or similarities can be attributed to differences in taxonomy, physiology and habitat, and way of life. We would also like to say that if 65% of the seagrass community is comprised of mysids (Herrera, et al., 2014), then these crustaceans are sustaining the secondary production of these seagrass meadows as the copepods do in the oceanic water column.

Organism	Growth rate (d^{-1})	Secondary production (mg dr- mass/day)	References
Mysidacea	0.19-0.25	2.69-12.07	This study
Copepods	0.01-0.28		Liu et al. (2013)
	0.01-0.27		Calbet et al. (2000)
	0.01-0.30		Kimmerer et al. (2007)
	0.22		Kimmerer (1987)
		2.52-15.73	Lin et al. (2013)
Cladocerans	0.11-0.33	0.35-0.64	Gómez et al. (2012)
Polychaetes		1.56-2.39	Chu et al. (2014)

Table 2. Comparison between *Leptomysis lingvura* secondary production parameters and other organisms' parameters.

When the measured growth rates were compared with those calculated from the three models (Table 3), not one predicted the growth rate nor was there any agreement between them (Fig. 8). The likely cause for the disagreement is because all three models are mainly based on marine copepods, not mysids. Upon analysis of the daily growth rates (day^{-1}), it was found that for *Leptomysis lingvura* fed on 90 *Artemia* nauplii, the mean was 0.198 day^{-1}, while the closest model (Hirst and Sheader, 1997), at 0.142 day^{-1}, underestimated the measured daily growth rate by 28%. In the case of mysids fed with 240 *Artemia* nauplii, the differences with the models were even greater. The mean growth rate for these mysids was 0.252 day^{-1} while the mean closest model-based prediction (Huntley and López, 1992), at 0.354 day^{-1}, an overshoot of 40%.

Food concentration (*Artemia* nauplii/mysid)	Measured rate in$days^{-1} \pm$ *standard deviation* ($day^{-1} \pm \sigma$)	Huntley and López (1992) ($day^{-1} \pm \sigma$)	Hirst and Sheader (1997) ($day^{-1} \pm \sigma$)	Hirst and Lampitt (1998) ($day^{-1} \pm \sigma$)
90	0.198 ± 0.134	0.354 ± 0.009 $(13.4 * 10^{-3})$	0.142 ± 0.025 $(6.10 * 10^{-4})$	0.116 ± 0.023 $(1.22 * 10^{-4})$
240	0.252 ± 0.055	0.354 ± 0.009 $(9.77 * 10^{-4})$	0.157 ± 0.045 $(9.77 * 10^{-4})$	0.130 ± 0.037 $(1.95 * 10^{-3})$

Table 3. The daily growth rate (day^{-1}) obtained from the three secondary production models. The number in parenthesis is the p-value, which indicates the degree to which the model data is significantly different from the measured growth rate (It is significant when p-value<0,05).

The relation between the secondary production measurements and the calculated secondary production (growth rate) with the models can be seen on the regression equations of Table 3. It can be noted that none of the slopes lie parallel to the 1:1 line (Fig. 8).

The reason for testing these secondary production models was to know if they were applicable to planktonic marine crustaceans such as mysids. The importance of mysids in many ecosystems, such as seagrass meadows, generated the original interest in using them for this experiment. Knowing their growth and production was helpful for understanding these ecosystems (Herrera, 2013).

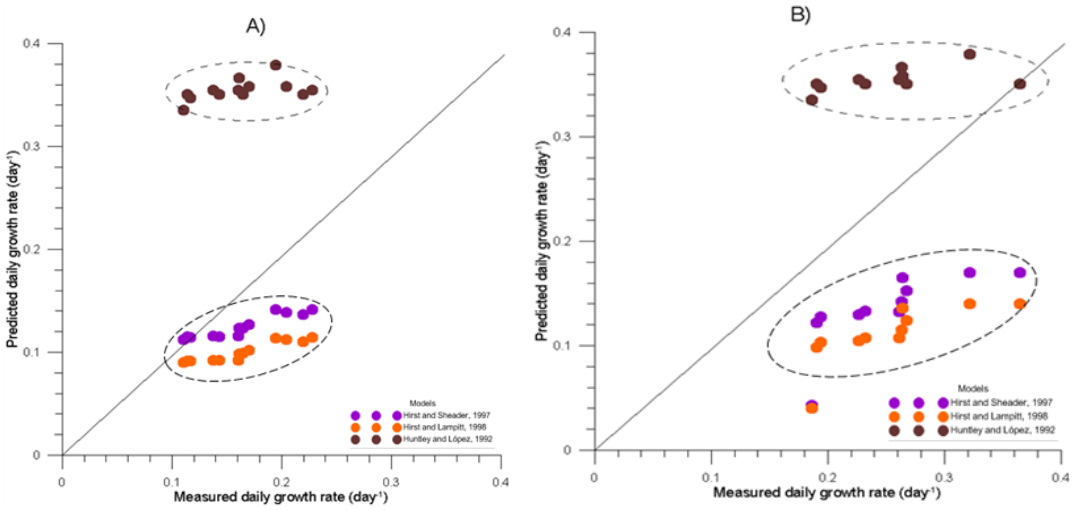

Fig. 8. Predicted daily growth versus measured daily growth in *Leptomysis lingvura* with two different food concentrations. (A) Models for mysids fed with 90 *Artemia*/mysid. (B) Models for mysids fed with 240 *Artemia*/mysid. The line in both graphics represents a 1:1 correspondence.

In this study, none of the models predicted mysid growth or secondary production as compared to the measured laboratory growth rate (Fig. 8). The Huntley and López (1992) model overestimated secondary production, as described in numerous papers (Miyashita et al. 2009, Gómez et al. 2012). The reason for this is, basically, that it does not consider first principles; it doesn't even consider biomass; it is simply a statistical relationship between growth and temperature. The Hirst and Sheader (1997) and Hirst and Lampitt (1998) models were closer to the measured growth and secondary production, but they still did not predict *Leptomysis lingvura* growth rate. Both underestimated secondary production in the mysids.

None of these three models considered the biological machinery that controls growth in a cell nor did they consider environmental variables, such as salinity, oxygen concentration, pH, chlorophyll-a and other parameters that may be relevant when making secondary production models. They only considered temperature and biomass.

As a consequence, outside the data set from which they were originally derived, they are not applicable.

Food concentration (*Artemia*/mysid)	Huntley and López (1992)	Hirst and Sheader (1997)	Hirst and Lampitt (1998)
90	$y = 0.002x + 0.354$ $r^2 = 0.001$	$y = 0.105x + 0.107$ $r^2 = 0.786$	$y = 0.092x + 0.084$ $r^2 = 0.801$
240	$y = -0.054x + 0.372$ $r^2 = 0.124$	$y = 0.474x + 0.015$ $r^2 = 0.551$	$y = 0.388x + 0.012$ $r^2 = 0.595$

Table 4. Regression equations of the model-predicted rates of secondary production. Note that none slope is close to the 1:1 line.

There are other models that have not been used in this study. The Hirst and Bunker (2003) model seems to describe Nature, as some authors have noted (Mackas et al., 2012). However, it includes chlorophyll as a variable, rendering it useless for carnivores as Ignatow et al., (1996) have shown for shrimps. The Stockwell and Johannsson (1997) and Shuter and Ing (1997) models also are useful for some situations (Miyashita et al., 2009, Gómez et al., 2012). Nonetheless, they are for freshwater zooplankton, specially, for cladocerans, and copepods.

The results of this study argue that, in future secondary production models, either first principles of growth or more environmental variables should be considered. More variables that resonate with different ecological conditions and organisms should be evaluated to learn how they affect growth and secondary production. Models are needed that respond realistically to the many situations that can occur in Nature. Such models would have a chance to predict close approximations of growth in Nature. In all cases, since a laboratory culture is Nature simplified, if a model cannot predict growth there, then it will never be able to simulate growth in the infinitely more complicated natural ocean.

Conclusions

1.- This study showed that the growth of the marine mysid, *Leptomysis lingvura* is influenced by its food concentration. There were significant differences between daily growth on 90 *Artemia* nauplii per mysid and 240 *Artemia* nauplii per mysid. The well-fed mysids grew 13% larger than the poorly-fed mysids.

2.- Here, for the first time, for this mysid species, we find the length-dry mass relationship. It was: $Dry - mass = 0.6557 * length + 3.1408, r^2 = 0.975$.

3.- None of the three secondary production models were able to accurately predict measured growth and secondary production of *Leptomysis lingvura*. The Huntley and López (1992) model overestimated secondary production, while the Hirst and Sheader (1997) and Hirst and Lampitt (1998) underestimated it.

4.- The growth of *Leptomysis lingvura* cannot be modelled from temperature and biomass alone.

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VALORACIÓN PERSONAL (PERSONAL ASSESSMENT)

I.I Actividades desarrolladas

A lo largo del Trabajo de Fin de Título (TFT), se han desarrollado una serie de actividades que pueden resumirse según lo descrito en la temporalización de TFT realizada. Según lo señalado en la misma, estas actividades se pueden determinar de la siguiente manera: la búsqueda bibliográfica de información sobre el tema a tratar en el experimento, el mantenimiento de los organismos de cultivo durante la fase experimental del proyecto, la realización de medidas y modelos matemáticos de acuerdo con el objetivo principal del proyecto y, finalmente, la redacción del propio proyecto.

Durante la primera fase del proyecto, se realizó la búsqueda de información, tal y como se ha indicado con anterioridad. Tal búsqueda se elaboró a partir de libros y artículos cedidos gracias a la Universidad de Las Palmas de Gran Canaria o bien proporcionados por el equipo de investigación bajo el que se tuteló este TFT. Una vez obtenida toda la información requerida, se clasificó y estudió para la toma de los conocimientos requeridos para este experimento.

El proceso de mantenimiento de los organismos, consiste en la preparación diaria del alimento de los mismos, así como, en el conteo general de organismos que hay en el cultivo. También se realiza la retirada de todo material particulado y/o excretado por los organismos del cultivo con el fin de evitar el aumento de la concentración de amonio, nitritos y nitratos en los acuarios de cultivo. Los misidáceos del cultivo son alimentados con *Artemia*, la cual se obtiene en cistes que se compran a una empresa privada. Una vez llegan los cistes, se procede a la descapsulación de los mismos para poder obtener los huevos, desde donde eclosionarán los organismos. Para la eclosión de la *Artemia* se necesita un tiempo de 24 horas; pasado dicho tiempo se le aporta Easy-DHA Selco® para enriquecer, nutricionalmente, los organismos. Tras 48 horas después de la eclosión, se realiza el recuento de *Artemia* en 1 ml de agua con una lupa binocular (Fig. 4) con el fin de conocer la concentración de dicho organismos y poder saber, de esta forma, la cantidad de agua connauplios de *Artemia* que hay que proporcionar a los misidáceos.

Finalmente, y como parte esencial del proceso experimental, cada día se medían los misidáceos con una cámara réflex y mediante el software ImageJ, tal y como se menciona en el apartado "Material and methods" de este TFT. Estas medidas fueron procesadas, a través de la obtención de medias y desviaciones estándar, para la obtención de una curva de calibrado que relacionara el crecimiento (en longitud) con el tiempo. Por otro lado, algunos organismos eran sacrificados para poder obtener el peso seco y así poder adquirir la relación entre la longitud y el peso seco y, por lo tanto, lograr una curva de calibrado que relacionara el peso seco con el tiempo (debido a que

los modelos experimentales con los que se compararon los resultados obtenidos expresaban el crecimiento en peso seco y no en longitud).

Tras haber elaborado la ecuación de la recta pertinente se procedió a su sustitución en el modelo matemático elaborado y en los modelos obtenidos de los autores, y su posterior comparación.

Conforme se iban desarrollando y terminando los apartados del proyecto se procedía a la redacción correspondiente de los mismos, de tal forma que, la redacción de este TFT se ha llevado a cabo a la vez que el proceso experimental.

I.II Formación recibida

Aunque si bien podría no reconocerse como una formación, propiamente dicha, en este apartado puede ser considerable nombrar toda la información proporcionada para realizar el experimento, el aporte de manuales de cultivo tanto de *Artemia* como de misidáceos, así como, recomendaciones generales dentro del proceso meramente experimental.

También es necesario nombrar cierta formación recibida en programación y tratamiento de datos, desarrollo de gráficos, etc. durante la realización de este TFT en los programas informáticos R, Matlab y Grapher.

Así mismo, también se ha realizado un curso sobre cómo hacer exposiciones científicas en público.

I.III Nivel de integración e implicación dentro del departamento y relaciones con el personal

La integración dentro del departamento puede considerarse completa desde el comienzo del TFT. Desde el primer día se me suministró ayuda tanto a nivel bibliográfico como a nivel de material. Se me asignó la tarea de mantenimiento y limpieza del material de laboratorio usado por todo el equipo, así como los trabajos meramente directos de mi proyecto (que se describen en apartados anteriores).

Mi incorporación dentro del grupo de investigación Ecofisiología de los Organismos Marinos (EOMAR) se realizó de manera inmediata. Éste funciona de forma muy colaborativa, ayudándose los unos a los otros en cualquier momento y resolviendo, con la mayor brevedad posible, todas aquellas dudas que pueden ir surgiendo a lo largo de la jornada.

A nivel departamental, la integración puede definirse como óptima, siguiendo siempre un sistema basado en la cordialidad y el respeto, puedo declarar no haber tenido problema con ninguno de los investigadores y demás miembros del departamento de Biología en ningún momento, durante la realización de este TFT.

I.IV Aspectos positivos y negativos más significativos relacionados con el desarrollo del TFT

A la hora de valorar los aspectos positivos y negativos del TFT, es conveniente ser lo más objetivo posible y dar las razones más coherentes en la puntualizaciones adjudicadas a cada una de las características del mismo.

Entre los valores de la realización de un Trabajo de Fin de Título (a nivel general y no particularizando para el caso que aquí se presenta) destaca el hecho de aprender a elaborar trabajos de investigación, más propios de un científico que de un alumno y, por tanto, proporciona al alumno la posibilidad de ver que le espera en el mercado laboral de su carrera. Los TFT sirven además como plataforma de ampliación de conocimientos sobre el tema de interés del alumno, así como una manera de practicar y resolverse mejor en otros idiomas. Para el caso de este TFT en particular, quizás el mayor valor que presenta es la gran cantidad de conocimientos obtenidos sobre la biología, bioquímica y modelización matemática aplicable a los organismos zooplanctónicos.

Entre las carencias más significativas de un TFT destaca el poco tiempo disponible para la realización del mismo, ya que el alumno no está acostumbrado a la realización de trabajos científicos de tal magnitud, el pequeño límite de tiempos de presentación del TFT disponible y el hecho de que todos los créditos en inglés de la carrera estén destinados a esta asignatura.

I.V Valoración personal del aprendizaje conseguido a lo largo del TFT.

Desde un punto de vista más personal se puede proceder a valorar el aprendizaje conseguido durante el desarrollo del TFT a través de la numeración de los valores adquiridos durante la realización del mismo. Los aspectos más generales se pueden resumir de la siguiente forma:

1) Aprender a organizar y ordenar de forma adecuada y coherente un trabajo de investigación científico en un tiempo determinado.

2) Lograr extraer la información necesaria para la realización de dicho trabajo y ser capaz de sintetizarlo en la medida de lo posible.

3) Ser capaz de resolver, objetivamente, los problemas que hayan podido surgir durante la realización del TFT.

4) Aprender a trabajar dentro de un equipo de investigación y de llevar a cabo tus propios logros y metas.

5) Poder ser reconocido por el trabajo realizado.

6) Ser capaz de presentar, en un idioma extranjero, y delante de un jurado, el trabajo realizado.

En un nivel más relacionado con el presente TFT, se pueden denotar aspectos como:

7) Comprender el ciclo de vida y el comportamiento de los misidáceos en cultivo.

8) Aprender pautas de reconocimiento taxonómico de los organismos así como la posibilidad de evaluar diversas características de los mismos.
9) Establecer relaciones entre los diversos campos de la carrera.
10) Ser capaz de utilizar programas informáticos para la realización de modelos matemáticos relacionados con el campo de la Biología.
11) Tener capacidad de síntesis para realizar un trabajo (en un tamaño limitado) sobre el experimento realizado.

Por tanto, son estas las valoraciones y anotaciones pertinentes que deberán tener en cuenta los alumnos y las autoridades correspondientes de cara a los años venideros para poder proporcionar al alumno una experiencia más cómoda y más grata y así motivar al estudio de los océanos y de la ciencia en general.