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Functional response of the mysid *Leptomysis lingvura* to prey density

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Trabajo Fin de Título para la obtención del título de Máster Interuniversitario en Oceanografía

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Abstract

Mysids are key components in coastal ecosystems because they are a major link in the food-chain. The relationship between mysids and their prey is essential to appreciate the role in the food-chain and also to design laboratory experiments to better represent nature. For this reason, it was decided to determine *Leptomysis lingvura´*s predation rate with different concentration of *Artemia* nauplii. The mysids were placed in bottles for 24 hours. Then the water was filtered and the *Artemia* counted. In this way, *Leptomysis lingvura´*s predation rate was determined to vary between 1.39 and 36.57 *Artemia*·mysid^{-1}·h^{-1}, depending of food concentration. The predation rate functional response was type III with prey size, predator size and prey density being the principal factors influencing it.

Introduction

Mysids are shrimps (Crustacea, Mysida) that inhabit many varied aquatic habitats (Mauchline and Murano, 1977; Tattersall and Tattersall, 1951). Recent studies that investigated the phylogenetic relationships of the order Mysidacea have concluded that it is actually composed of several different orders. These orders are the Mysida, the Lophogastrida and the Stygiomysida; and they comprend a total of 1200 species and 187 genera (Meland et al., 2015). They are omnivorous and eat small planktonic organisms as well as organic detritus, but they seem to prefer animal-matter as food (Mauchline, 1980; Murano, 1999; Tattersall and Tattersall, 1951; Lehtiniemi and Nordström, 2008). Morphologically, a common trait of mysids is that adult females are provided with a marsupium between pairs of pereopods and keep their embryos in it until they grow to juveniles (Murano, 1999).

Three basic divisions can be denoted along the Mysida body: the cephalon, the thorax and the abdomen. The carapace, situated above the thorax, is fused to the first fourth somites, leaving the last thoracic somites uncovered. The inner lateral walls of the caparace are membranous tissues and have a respiratory function. The cephalon is divided into twelve different sections where they are, among others, the eyes, the antennule, the labrum and the maxilla. On the other hand, the thorax is fractionated in eight different parts, each of which have a pair of appendages (Fig. 1) (Meland et al., 2015). The first three thoracic appendages are modified like maxilipeds (Gómez, 2000).

The abdomen is composed of seven segments in the early larval stages, fusing the last two segments during its development into young juveniles. Generally, the following parts along the abdomen can be distinguished: the pleopods with natatory function; the uropods, located in the last pair of abdominal appendages; the statocyst, that appears as a large, clear vesicle, serves as an equilibrium organ for the stabilization of the position and for directional swimming, being these an exclusive feature of the family Mysidae, order Mysida; and the telson; (Meland et al., 2015). This last part is one of the main features to be observed in the Mysida taxonomic identification (Murano, 1999).

Mysids are marine crustaceans, but a few species are known as marine relicts inhabiting fresh- and brackish-water lakes and rivers (Mees et al., 1993; Murano, 1999). They are abundant in different habitats such as the oceanic water column, seagrass meadows, the seafloor, caves, etc. (Herrera, 2010; Mauchline, 1980; Murano, 1999).

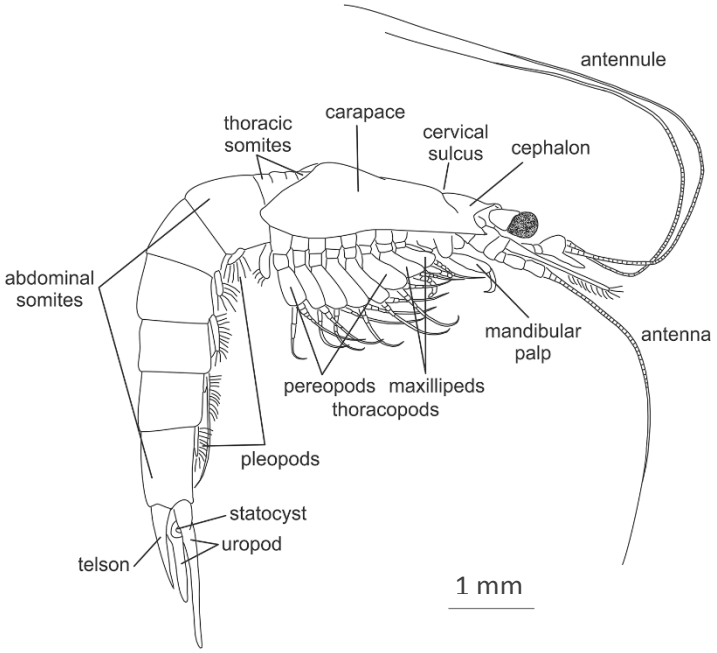

Figure 1. Morphology of Mysida. Adapted from Meland et al., 2015.

These suprabenthic crustaceans have been recognized as inhabitants of sandy beaches where they play an important role in nutrient regeneration in the surf zone when the water retreats (Fishelson et al., 1968; San Vicente and Sorbe, 1999). In fact, they are able to bioturbate fine sediments by breaking the diffusive boundary layer with their feeding and swimming behavior (San Vicente and Sorbe, 2013). 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; Castro, 1995). Also, in aquaculture, mysids are known to be a high quality food for some species of cephalopods and fishes (Domingues et al., 2001; Otero-Ferrer et al., 2012). Pelagic mysids migrate daily, descending to the deep layers during the day and rising to the thermocline to feed at night (Lindén et al., 2003; Mauchline, 1980).

Also, mysids are valuable food-chain components, especially in seagrass areas (Rappé et al., 2011). They are found, in high abundance in *Cymodocea nodosa* seagrass meadows around the Canary Islands, as seen in the work of Herrera (2013) and also in *Posidonia oceanica* seagrass meadows in the Mediterranean Sea (Barberá-Cebrián et al., 2001; Barberá-Cebrián et al., 2002; Sánchez-Jerez et al., 1999). Mysida are the major taxa in suprabenthic communities associated with *C. nodosa* seagrass meadows ecosystem, comprising up to 65% of the suprabenthos total abundance in the studied areas in Gran Canaria (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. It also highlights the fact that mysids are the preferred diet of some commercial fish associated with shallow seagrass meadows (Barberá-Cebrián et al., 2002; Guillén and Martínez-Hernández, 1995). Accordingly, the combination of *Cymodocea nodosa* seagrass meadows and mysids likely plays an important role in maintaining coastal productivity (Herrera, 2013).

For this reason, it is essential to understand the predation rates of these crustaceans to quantitatively predict their impact on the food chain of coastal ecosystems.

Ingestion represents the greatest of all interactions between an animal and its environment (Spomer, 1973) so to know the feeding process may be essential in any zooplankton ecological experiment. The ingestion rate is a measure of mass or energy flow into the animal, and it is equal to the product of the clearance rate (defined as the volume of food suspension from which an animal would have to remove all cells/organisms in a unit of time to provide its measured ingestion) and food concentration (Peters, 1984). Generally, there have been many ingestion rate studies in copepods (Almeda et al., 2010; Berggreen et al., 1988; Frost, 1972; Hansen et al., 1997), but not many studies have been done in mysids. Fulton (1982) calculated the predation rate and clearance rate in *Neomysis americana* and *Mysidopsis bigelowi* to determine the functional response of these species. He found that both species have a curvilinear functional response, with a negative logarithmic relationship between prey density and clearance rates. He also described prey motility and escape behavior that affected predation rates.

Webb et al. (1987) determined the differences between ingestion rates of *Mesopodopsis slabberi* in various phytoplankton concentration and studied variations between sexes, size classes and day/night feeding. Gorokhova and Hansson (1997) demonstrated that *Mysis mixta* feed twice as much in darkness as they do in the light with a relation between the consumption rates and the incubation time, which has been suggested to be due to the nonuse of vision in capturing prey, and maybe the use of mechano-reception (Viherluoto and Viitasalo, 2001). Hansson et al. (2001) denoted a relation between the consumer densities and the ingestion rates showing an intraspecific interaction. In other studies, it was reflected that there were not significant growth differences between mysids fed with enriched organisms (*Artemia,* in this case) with

mysids fed with non-enriched organisms, but the first ones had higher survival percentage (Domingues et al., 2001).

Here, we determine the predation rates of the marine mysid *Leptomysis lingvura* to understand its role in the food chain of the coastal ecosystems.

Leptomysis lingvura (G.O. Sars, 1866) is one of the mysid species found along the coast of Gran Canaria (Canary Islands, Spain) (Fig. 2). This species is extensively distributed in the Mediterranean Sea and in the northeast Atlantic, from Norway to Morocco. Three subspecies are identified for the distribution area: *L. lingvura lingvura* in the Atlantic Ocean; and *L. lingvura marioni* and *L. lingvura adriatica* for the Mediterranean Sea (Wittman and Wirtz, 1981). *L. lingvura* characterized for having an 8-segmented exopod of fourth male pleopod, a short carapace with a triangular face and a small, wide telson (Herrera, 2013; Wittman and Wirtz, 1981) (Fig. 2). *Leptomysis lingvura* was described as a species with variable population densities throughout the year (San Vicente and Claude, 1999). Also, this mysid displays characteristic behavior; it forms dense swarms near the coast with complex internal structure and could be a potential response to reduce predation (Barberá-Cebrián et al., 2002; 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, there are previous studies of the growth rate for this mysid species (Herrera, 2010; Herrera, 2013) and it can complete its life cycle in captivity (Herrera, 2010; Herrera et al., 2011a; Herrera et al., 2011b). This capacity to grow well in captivity greatly improves studies of growth and secondary production in the laboratory.

Figure 2. Top view of the mysid *Leptomysis lingvura* with *Artemia nauplii.* From Herrera, 2013.

With the aim of better understanding the role of mysids in coastal ecosystem food chains and for having greater knowledge of this species and its feeding behavior for future studies, *Leptomysis lingvura* predation rates were measured with different concentrations of food.

Material and methods

Samples were taken at Puerto de Taliarte (27° 59.334'N, 15° 22.125'W) and Sardina (28º 09.058'N, 15º 41.588'W), on the east and northwestern coast, respectively, of Gran Canaria, Canary Islands (Fig. 3), at depths between 5 and 10 meters using SCUBA equipment and a hand net.

During the 2 days of acclimatization, mysids were placed in a plastic tank of 40 L and were fed twice daily with 100-150 *Artemia* nauplii per mysid. 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.

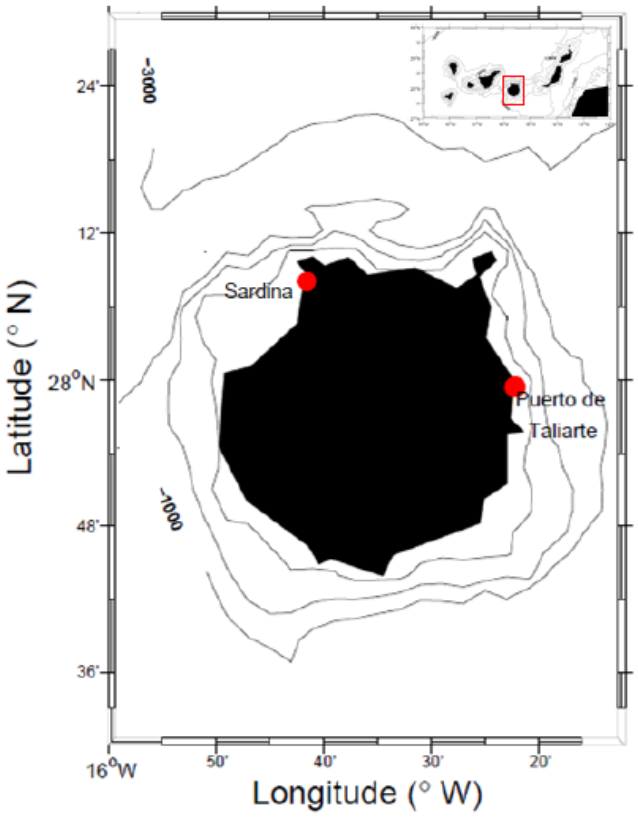

Figure 3. Location of the sampling area.

During this acclimatization, mysids were identified by species using a binocular microscope, following the works of Tattersall and Tattersall (1951), Wittman (1981), Murano (1999) and Herrera (2013). After this, mysids were transferred to 70 liter aquaria (Fig. 4), where the water recirculation system 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 the entire experiment, the seawater temperature was maintained at 19.23±0.58ºC, the pH was maintained at 7.86±0.02, and the NH_4^+, NO_3^- and NO_2^-, at concentrations below 0.04, 10 and 0.01±0.02 mg/l respectively.

In this experiment, the predation rates of the mysid *Leptomysis lingvura* were compared for different *Artemia* concentration, following the methodology of Fulton (1982). For each concentration, 4 bottles (Fig. 4) were used (due to the triplicates, so that it can be possible to determine if there is a significant variation with the same technique and because it is the minimum number to have a correct standard deviation); a control bottle to observe the prey development without the influence of predators knowing that intrinsic growth rate does not occur in *Artemia* as they are just nauplii and do not breed during the experiment; and the experimental bottles with prey and predators.

Figure 4. a. Aquaria with seawater recirculation system. b. Experimental and control bottles, for the predation rates study.

Initially, *Artemia* concentration (organisms per milliliter) was determined with a Bogorov chamber and a stereoscopic microscope. After that, the bottles were filled with the corresponding prey concentration. Then, a total of 6 mysids (for the first three experiments) and 2 mysids (for the others) were added to the experimental bottles, which were topped off with seawater, and closed. Tubes through the tops supplied air (Fig. 3). After 24 hours (6 hours in the case of the three lower concentrations because the prey was eaten after that time), a prey count was conducted (filtering the bottle and taking an aliquot and counting the number of *Artemia* per milliliter) in both control and experimental bottles, to determine the predation rates.

To measure the predation rate, expressed in prey·predator^{-1}·hour^{-1}, the expression given by Fulton (1982), was used:

$$P = \frac{C_0 - C_1}{N \cdot t} \quad (1)$$

where C_0 is the initial number of *Artemia* in the bottle; C_1 is the number of *Artemia* at the end of the experiment; N is the number of predators in the bottle and t is the time (expressed in hours).

After estimating the predation rate, the type of functional response of the species was determined by plotting the predation rate (expressed in prey·predator^{-1}·hour^{-1}) versus prey concentration (expressed in prey·l^{-1}).

All statistics were run using the R statistical package (R Development Core Team, 2010). The Shapiro-Wilk test was applied to confirm normality and the homoscedasticity of the residuals was assessed graphically. When the data did not have a normal distribution, the Krukal-Wallis test was applied to determine significant differences between food treatments and the post hoc test of Conover was applied to detect which treatments differ from others.

Results

A predation rate study was made to understand the consumption of *Artemia* that the mysid *L. lingvura* can have. From this experiment, the prey that were consumed by mysids for each prey concentration was obtained (Table 1). The relationship between prey concentration and predation rate for this mysid species was also obtained.

***Artemia* initial concentration (C_0) (ind·L^{-1})**	**nº mysids**	**Time (t) (hours)**	***Artemia* final concentration (C_1) (ind·L^{-1})**	**Total ingestion per mysid (I)**	**Predation rate (P) (prey·mysid^{-1}·h^{-1})**
50	6	6	0.00±0.00	8.33±0.00	1.39±0.00
100	6	6	14.00±24.25	15.33±2.31	2.39±0.67
200	6	6	36.00±16.83	27.33±2.8	4.56±0.47
483	2	24	135.00±50.85	174.00±25.43	7.26±1.06
867	2	24	337.78±55.51	263.50±27.78	11.02±1.16
1433	2	24	751.11±100.07	369.83±0.00	15.42±0.00
1966	2	24	962.22±130.01	502.39±65.01	20.93±2.71
3033	2	24	1635.56±96.69	698.72±48.34	29.12±2.01
4066	2	24	2507.78±357.40	852.56±48.86	35.53±2.03
5133	2	24	3377.78±40.73	877.78±20.37	36.57±0.85
6100	2	24	4422.22±50.92	830.89±25.46	34.95±1.06

Table 1. Ingestion and predation rate results. *Artemia* initial concentration obtained from the control bottles. Values represented with ±standard deviation.

The maximum predation rate (Table 1) was 36.57±0.85 *Artemia*·mysid^{-1}·h^{-1}, with an initial prey concentration of 5133 *Artemia*·l^{-1}. At a higher concentration, predation rate declines.

To analyze the normality of the data, the Shapiro-Wilk test was applied. The data did not follow a normal distribution (W=0.86512, p-value=0.8977·10^{-3}), so the Krustal-Wallis test was used. It detected significant differences between the diverse food treatments (chi-squared=30.357, 10 degrees of freedom, p-value=0.7487·10^{-3}). After that, pairwise comparisons were made using the post hoc Conover´s-test.

To determine the functional response type of this organism, the prey density was plotted against predation rates (Fig. 5). Conover´s test showed no significant differences among the three highest food concentration treatments ($p>0.05$). It revealed that, from a concentration of about 4000 *Artemia*·l^{-1}, the predation rate remains almost stable. The remaining treatments presented significant differences between them ($p<0.05$).

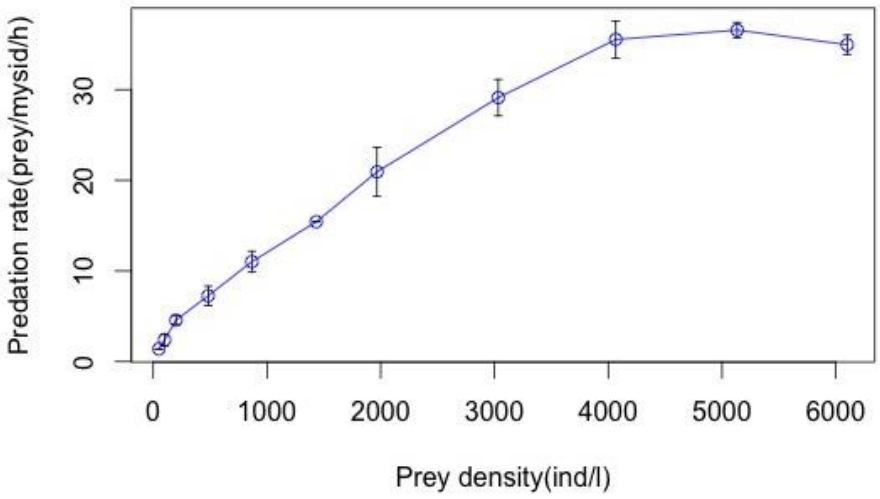

Figure 5. *Leptomysis lingvura* predation rate with different concentrations of food.

Thereafter, to obtain the functional response, three models were applied (Fig. 6). The first was lineal, the second logarithmically and the third was a sigmoidal model. The last one presented the best fit, checked through the residual standard error of the three models (4.22 for the lineal; 4.83 for the logarithmic; and 1.83 for the sigmoidal one), being able to do this because the *y*-variable is the same in all three cases. Therefore, was determined that the predation rate, for this mysid species and with this kind of food, has a sigmoidal trend.

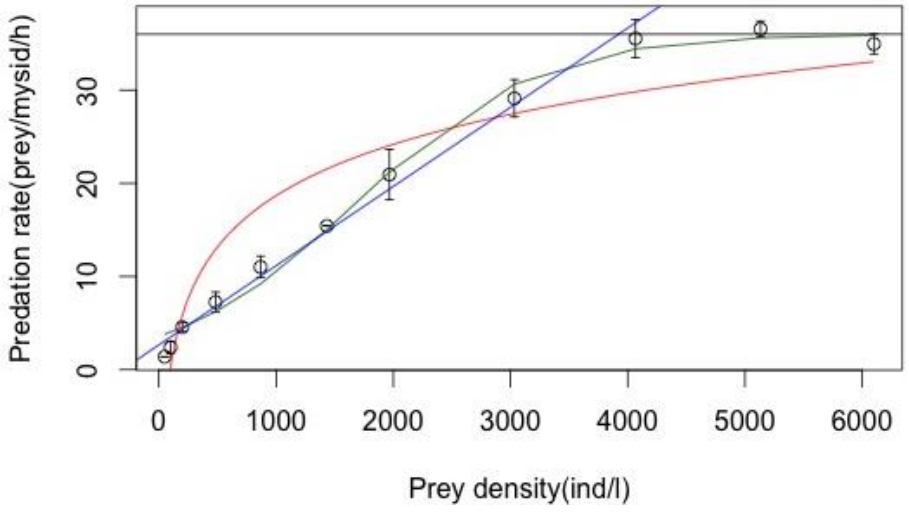

Figure 6. Adjustment of the linear (blue), logarithmic (red) and sigmoidal (green) models to see which of them has the best fit with the data. In the figure, the saturation point is also mark at 36 prey·mysid^{-1}·h^{-1}.

In this case, a type III functional response was obtained, with a notable increase of predation rates from the initial prey densities to an approximate concentration of 4000

Artemia per litter, where these predation rates stabilize, increasing less until the maximum predation rate, and organisms do not consume more while still increasing the prey concentration.

Another way to check whether the functional response is type II or type III is seeing the relationship between the ingestion/initial prey density (I/C_0) ratio and prey density (Fig. 7). Thus, if the proportion of prey consumed initially increases with the number of prey supplied to the mysids and then descends, it is identified with a type III functional response (Fig. 8) (Fernández-Arhex and Corley, 2004). As can be seen in Figure 7, data fit a type III functional response.

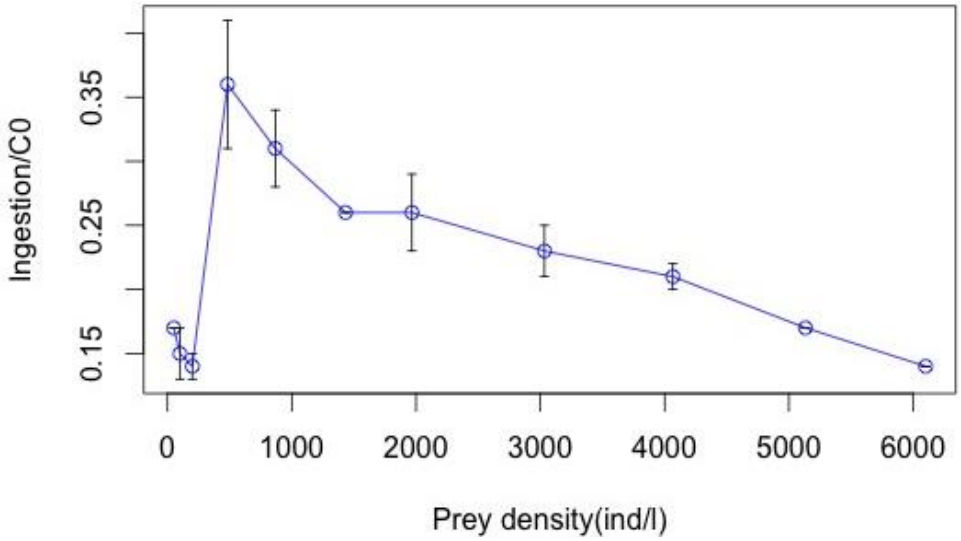

Figure 7. Ingestion and initial prey density ratio from our study.

From the sigmoidal model adjustment, the predation rate equation, for *L. lingvura* fed with *Artemia* nauplii was obtained, given by the expression:

$$P = \frac{36.03}{(1+e^{\left(\frac{1696.47+C_0}{770.88}\right)})} \quad (2)$$

where C_0 is the initial number of *Artemia* in the bottle. The parameters given by the sigmoidal model (Fig. 6) were 36.03 (the upper asymptote); 1696.47 (the crossover point) and 770.88 (the slope) (Table 2).

Parameter	Estimate	Standard Error	t-value	p-value
Asymptote	36.0299	0.7067	50.98	$<2\cdot10^{-16}$
Crossover point	1696.4647	72.1645	23.51	$<2\cdot10^{-16}$
Slope	770.8812	51.9225	14.85	$4.38\cdot10^{-15}$

Table 2. Parameter values of the sigmoid function fitted to the predation rate data with the standard error, t-value and p-value.

Therefore, knowing that predation rate and ingestion for one mysid follow the rule $P = I/t$, where t is the time; it was possible to obtain an expression for the ingestion, as:

$$I = \left(\frac{36.03}{\left(1+e^{\left(\frac{1696.47+C_0}{770.88}\right)}\right)} \right) \cdot t \qquad (3)$$

Discussion

When our results are compared with those obtained by other authors, it is clear that *L. lingvura* has higher predation rates than other mysid species (Table 3). However, mysids have lower predation rates than other organisms such as copepods (Table 3). These variations can be attributed to differences in prey size, taxonomy and feeding behavior.

If we focused on the differences between different types of organisms, it is necessary to denoted that some studies have reported that copepod ingestion rates are clearly influenced by food concentration and prey size (Almeda et al., 2010; Frost, 1972). It also affects the predator density because, with the same number of prey, the ingestion rate will be lower for higher numbers of predators in the same area. It has been shown that the effect of the density of mysids in a predation rate study is significant, and with a greater number of mysids per bottle predation rates were lower even when increasing the number of prey (Hansson et al., 2001). That is why in this study it was decided to put just two mysids per bottle, which may help to justify the high predation rates found here.

It is possible to deduce that with smaller prey, the ingestion should be higher to acquire more energy input and, conversely, with bigger prey the ingestion rates should be lower (Frost, 1972). These kind of feeding behaviors can also be useful to define the spatial distribution of the species; for example, Almeda et al. (2010) discovered that *Oithona davisae* has higher ingestion rates than many copepod species, being able to live in environments with high food concentration, such as occurs in bays and estuaries. This

fact can be applicable to mysids; in fact, it was shown in previous studies that *Leptomysis lingvura* are more common at high food concentration environments, such as coastal areas (Herrera, 2013; Herrera et al., 2014). When the predation rates of *Leptomysis lingvura* are compared with those from other mysids species, it is possible to observe the differences.

Other studies suggest that light conditions and starvation periods can interfere with mysids feeding behavior (Fulton, 1982; Gorokhova and Hansson, 1997), demostrating in some cases up to twice the consumption in darkness and a 27% more of ingestion in those experiments with a previous starvation period (Gorokhova and Hansson, 1997).

Organisms	**Species**	**Prey**	**Predation rate** **(prey·mysid^{-1}·h^{-1})**	**References**
Mysids	*Leptomysis lingvura*	*Artemia sp.*	1.39-36.57	This study
Mysids	*Paramesopodopsis rufa*	*Artemia sp.*	6.00	Metillo et al., 2007
Mysids	*Tenagomysis tasmaniae*	*Artemia sp.*	2.50	Metillo et al., 2007
Mysids	*Anisomysis mixta australis*	*Artemia sp.*	4.90	Metillo et al., 2007
Mysids	*Mesopodopsis slabberi*	Diatoms	0,5-5·10^{6}	Webb et al., 1987
Mysids	*Neomysis integer*	*Eurytemora affinis* (Copepod)	2.33	David et al., 2006
Mysids	*Mysis mixta*	*Cercopagis pengoi* (Cladoceran)	0.04-0.67	Gorokhova and Lehtiniemi, 2007
Mysids	*Mysidopsis bigelowi*	*Acartia tonsa* (Copepod)	0.28-2.08	Fulton, 1982
Copepods	*Oithona davisae*	*Oxyrrhis marina* (Dinoflagellate)	50-320	Almeda et al., 2010

Table 3. Comparison between predation rates between *Leptomysis lingvura* and other organisms.

An observation that can affect the results depending on laboratory conditions of light. In this experiment and, as seen in the material and methods of this study, it was decided to keep the mysids with a light:dark fotoperiod of 14:10 h; and they were in starvation 24 hours before the experiment.

Also the size of the predator can cause the difference between two species fed with the same prey. For example, Metillo et al. (2010) explained that the average predation rates obtained in their studies are lower than those observed in other experiments, probably because Tasmanian mysid species are smaller than other species (*Paramesopodopsis rufa*, the biggest of the three studied, has an average length of 9.8 mm). This fact matches with the predation rates observed by Metillo et al. (2010), having the higher predation rate the biggest mysid; and the lowest predation rate, the smaller one. If this applies to our study, it is possible to justify why *L. lingvura* has higher predation rates than other species, fed with *Artemia* nauplii, knowing than the average length of this mysid species varies from 12 to 17 mm (Herrera, 2013; Tattersall and Tattersall, 1951).

It is necessary to point out the fact that mysids have not the same predation rates at different stages of their life cycles, being more than twice higher in adults than in juveniles (David et al., 2006). For that reason, in this experiment, all mysids were, approximately, from the same age and with the same length, to avoid errors in this regard.

For this mysid species, we found a type III functional response. In this manner, a functional response will be of type I when the time needed by the predator to ingest the prey is not relevant (or consuming prey does not interfere with searching them). It will be type II if the curve follows the assumption that the predator is limited by its capacity to ingest prey with a high density of prey. It will be type III if the situation is the same situation as type II but with low density of prey (Holling, 1959).

This type of response can be explained by the increase in prey density leading to a boost in feed efficiency or predator searching to a decrease in handling time (the amount of time it takes the predator to handle the food (Sinervo, 1997)).

Some possible explanations for this functional response are the heterogeneity of the habitat/bottle (for this study, maybe all the *Artemia* nauplii may not be evenly distributed throughout the bottles), lack of learning to search prey in lower densities and switching to alternative prey (not given in this case, there were not cases of cannibalism in this

experiment) (Holling, 1959). This type of functional response brings about a mortality-density dependence (Fernández-Arhex and Corley, 2004), so it is needed to emphasize again the importance of prey density and behavior in this kind of study. Sigmoidal responses in feeding studies have been already reported by other authors, such as David et al. (2006) and Viherluoto and Viitasalo (2001), justifying this type of functional response to the omnivorous behavior of the species and to the prey and predator densities. In other studies, type I functional response, typical of planktonic filters (Hansson et al., 2001) has been observed; and type II, more common in carnivores organisms (Gorokhova and Hansson, 1997).

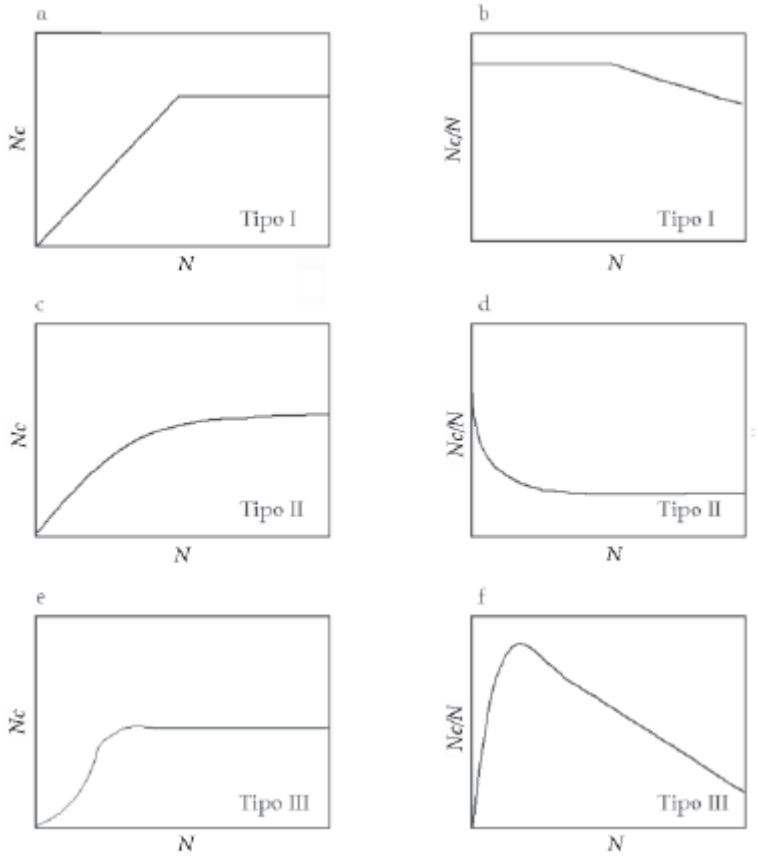

Figure 8. Types of functional responses for an organism and their I/C_0 ratio, where N is the prey density ($ind \cdot l^{-1}$) and N_c is the ingestion. Adapted from Fernández-Arhex and Corley, 2004.

One factor to consider in this kind of studies is the type of food given to the organism. Mysids are omnivorous (Mauchline, 1980; Murano, 1999) and in most of the studies shown here, they are given a strictly carnivorous diet. Some studies prove that mysids consume a 29% of fitoplankton, 50% of mesozooplankton, microzooplankton and meiofauna and a 21% of detritus material (Lehtiniemi and Nordström, 2008; Vilas et al.,

2007). This issue could be interesting to consider for future predation rates studies, understanding that the cost and difficulty of doing this kind of particularization become non-viable.

Moreover, the use of multiple independent methods in combination with trophic relationships are becoming more common. Gorokhova and Lehtiniemi (2007) suggested that no single analysis would be as complete as the use of different techniques. Other methods such as molecular diet analysis and stable isotopes should be done for future predation rates studies in order to have a complete assessment.

We argue that the main factors that influence predation rates of mysids are: 1) prey and predator size; 2) their density; 3) light conditions. These should be considered for future experiments. We should try to incorporate more variables in order to acquire a more holistic view of the process thereby making our model more akin to a natural process.

Conclusions

1.-In this study, the predation rate of *L. lingvura* varies from 1.39 to 36.57 *Artemia*·mysid^{-1}·h^{-1}, depending on food concentration.

2.- We established the *relationship* between prey concentration and predation rate, for this mysid species and is given by the equation:

$$P = \frac{36.03}{(1 + e^{\left(\frac{1696.47 + C_0}{770.88}\right)})}$$

3.- *Leptomysis lingvura* presents a type III functional response, indicating that the handling time for this species fed with *Artemia* nauplii decreased at high food densities.

4.- The main determinant of the predation rate, are prey/predator size and density. Future studies should focus in other unexplored variables.

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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 del experimento de ingestión 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 con el fin de conocer la concentración de dichos organismos y poder saber, de esta forma, la cantidad de agua con nauplios de *Artemia* que hay que proporcionar a los misidáceos.

Finalmente, y como parte esencial del proceso experimental, se procedió a la realización del estudio de tasas de ingestión; el cual consistía en obsevar (para diferentes concentraciones de alimento por litro de agua) cuántas presas eran ingeridas por los

misidáceos en un tiempo de 24 horas. Para ello se dispuso de 4 botellas de vidrio de 1 litro con aireación constante, las cuales fueron utilizadas una como botella control (solo con *Artemia*) y otras tres como botellas experimentales (donde se encontraban 2 misidáceos con la concentración de *Artemia* correspondiente). El experimento, como se puede observar, se ha realizado por triplicados para que haya una mayor representatividad estadística de los datos. El conteo final de la *Artemia* que no había sido ingerida se realizó filtrando el contenido de la botella a través de una malla y contando, posteriormente, las presas en la lupa.

Tras ello, se procedió al cálculo de los valores de la tasa de ingestión. Esto da una idea del tipo de respuesta funcional que tiene este organismo, lo que proporciona información sobre la relación del depredador con su entorno y su capacidad adaptativa. Una vez estos cálculos eran realizados, se realizó la comparación con los datos presentados por otros autores, tanto de misidáceos como de otros organismos, y se comenzó con los análisis estadísticos necesarios para evaluar si los datos mostrados eran significativos.

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.

Finalmente, declarar que durante este año académico se ha asistido a dos congresos, que han aportado conocimientos, ayuda y experiencias reflejadas en este trabajo:

- Challenges in the Environmental Management of Coastal and Marine Areas (CECOMA) 2016; celebrado del 25 al 29 de enero de 2016 en Las Palmas de Gran Canaria.

- ICES/PICES 6th Zooplankton Production Symposium; celebrado del 9 al 13 de mayo de 2016 en Bergen (Noruega).

Así mismo, se ha participado en La Noche Europea de los Investigadores, dentro del proyecto del marco europeo del mismo nombre, y organizado por la Fundación Canaria Parque Científico Tecnológico de la Universidad de Las Palmas de Gran Canaria.

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 para el experimento del presente trabajo, así como los trabajos meramente científicos del 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 las 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, se aprecia el hecho de adquirir conocimientos sobre la biología, morfología, comportamiento y metabolismo de los organismos zooplanctónicos así como el hecho de conocer y aprender cómo mantener unos cultivos de organismos marinos.

Respecto a los aspectos negativos, es posible destacar por encima del resto de debilidades que se pueden presentar a lo largo de la realización de un TFT el poco tiempo disponible para la realización del mismo, el cual es inferior para el caso de los másteres que para el grado, lo cual influye directamente en los estudios a realizar.

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

La valoración personal del TFT dependerá de todas las fortalezas y debilidades que posea el mismo basándose en su propio contenido como asignatura y dentro de la titulación cursada, así como a partir de las competencias adquiridas y las situaciones vividas a lo largo del tiempo de elaboración del mismo. Es por ello que, un alumno que ya haya realizado un TFT con anterioridad podrá tener una visión más amplia y comparativa de la asignatura y de cómo se trabaja en un grupo de investigación.

1. Aspectos positivos generales de un TFT para el máster cursado:

1.1 Realización de un proyecto con un enfoque más directo a la investigación científica, ajustándose a las líneas de trabajo que ofrece el máster; esto se traduce en:

1.1.1 Adquisición de capacidades propias de un investigador.

1.2.1 Aprender a trabajar en un grupo de investigación de manera correcta y cooperativa.

1.3.1 Ser capaz de buscar, sintetizar y redactar ideas para llegar a un objetivo concreto.

1.4.1 Capacidad de solucionar problemas inesperados y/o de última hora que puedan surgir en cualquier momento.

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

1.2 La carencia de obligación de redacción y lectura del mismo en un idioma concreto (por consiguiente, libertad de elección de idioma).

1.3 Disminución de créditos respecto a los TFT de grado, traduciéndose en una supuesta disminución de la carga lectiva y no presencial requerida para esta asignatura.

2. Aspectos negativos generales de un TFT para el máster cursado:

2.1 Disminución del tiempo disponible para la realización del TFT. Esto incluye:

2.1.1 Ajuste de un trabajo de investigación de pequeña magnitud a las horas establecidas según los créditos ECTS de la asignatura.

2.1.2 Impedimento (no imperativo) para la realización de un estudio de magnitud similar o mayor al de un TFT de grado, hecho que algunos tutores puedan no llegar a inferir para la titulación que se cursa.

2.1.3 Disminución general de las horas presenciales, repercutiendo de manera directa, más en los trabajos meramente experimentales que en aquellos de interpretación y análisis de datos.

3. Aspectos particularizados para el TFT del trabajo aquí expuesto:

3.1 Realización de un proyecto de investigación sobre aspectos metabólicos de los misidáceos de cara a mejorar futuros estudios, declarándose las siguientes consecuencias:

3.1.1 Focalización de cara a un trabajo perteneciente al tercer ciclo del rango de titulaciones impartidas por la universidad.

3.1.2 Adquirir nuevos conocimientos sobre los misidáceos, que se suman a los ya recibidos durante el TFT de grado.

3.1.3 Mayor experiencia de cara a proyectos futuros relacionados con el cultivo de este u otros organismos.

3.1.4 Aprender a renovar los conocimientos sobre la vida, comportamiento y fisiología del zooplancton, conforme se van descubriendo aspectos nuevos del mismo.

3.1.5 Poder centrarse más que con un TFT de grado en el posible futuro profesional del alumno.

3.2 Posibilidad de exponer el trabajo realizado en congresos nacionales e internacionales.

3.3 Haber sido capaz de darse a conocer en aquellos campos de la ciencia relacionados con los estudios de producción secundaria, ecología y fisiología del zooplancton.

3.4 Compartir la experiencia del trabajo en grupo, compañerismo dentro de un grupo de investigación y saber resolver los problemas de forma rápida y eficaz.