13. LIVE FOOD AND FEEDING ECOLOGY OF LARVAL SNAPPER *(PAGRUS AURATUS)*

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The relationships between mouth morphology and live food selection were studied in snapper from first feeding larvae to metamorphosis. The mouth width was a limiting factor for snapper larvae to ingest food particles before the body length reached 5.6 mm (20-day old); then the size of the gape opening became a limiting factor for food ingestion. The change of the limiting factor from mouth width to gape size coincided with the onset of larval metamorphosis. The relationship between mouth size and food particles predicted that it would not be physically possible for larval snapper to consume a rotifer (0.13 mm) until the fish reached a notochord length of 2.4 mm; *Artemia* nauplii (0.45 mm) until 4.8 mm; and copepods (0.83 mm) until 6.8 mm. The food selectivity trial for larval fish confirmed that these physical limitations were the major factor determining the prey size that could be ingested by a fish of given size. Consumption rate analyses showed that 6-day-old larvae were capable of consuming 17 rotifers when subjected to a 12:12 lighting regime. The daily consumption rate increased 3-fold to 49 rotifers for 12-day-old larvae. These results suggest that the size of live food offered to fish larvae should be determined by mouth morphology at different developmental stages.

Mortality in snapper larvae has been associated with the onset of first feeding and the transition between live feeds. Exogenous feeding of snapper larvae (as for many other planktivorous fish) is limited by the size of mouth. Although larval snappers' foraging behaviour has been studied, knowledge on gape size limitation and food selectivity in snapper larvae is lacking. The gape limitation for live food greatly affects the survivorship of the larval snapper. Snapper larvae have a limited 'window' of opportunity during which they can start their first feeding. If the live food provided is too large for the mouth size then the snapper will inevitably be unable to feed and

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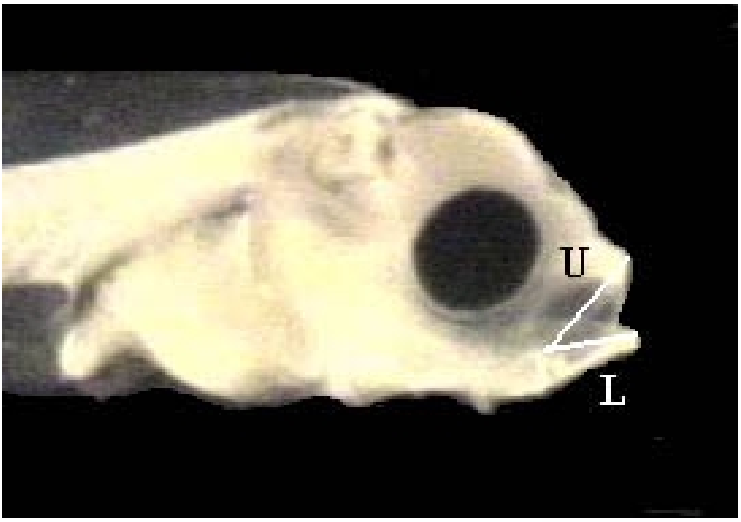
subsequently die from starvation. Understanding the ontogenetic diet change will assist in providing the appropriate food for fish larvae at each developmental stage.

As the larval snapper grow and develop, their visual acuity also refines. This implies that not only will the snapper be able to consume more live food, but also will they become more efficient predators, able to capture more prey items. The ability to capture and ingest more prey items means that the consumption rate and daily food requirements will increase dramatically, so the amount of live food provided may also need to be increased to achieve better fish growth and survival.

The objectives of this study were to determine (a) the morphological limitations that inhibit larval snapper from capturing a particular prey item, (b) how this relates to the actual fish size at which a particular prey item is ingested, and (c) the changes in selectivity of prey with increasing fish size. This study also aimed to determine the food consumption rate for larval snapper at different sizes.

The experiments were conducted in 30-L aquaria with one side blackened out to provide contrast for the live food. Snapper were initially stocked at a density of 50 larvae per litre. All aquaria were equipped with air-stones to maintain the oxygen level above 3.5 mg L–1. The temperature was controlled at 20.8 ı 0.4°C. Fish larvae were first fed on day 3 with small strain rotifers (0.14 mm) at a density of 15 rotifers per millilitre, moving to the large strain rotifers (0.33 mm) by day 9. At day 15, *Artemia* nauplii (0.45 mm) were introduced to the aquaria at a density of 5 nauplii per millilitre. All *Artemia* were removed from the system every second day and replaced with newly hatched nauplii, since juvenile *Artemia* are too large for the larval snapper.

Five fish were randomly selected from each aquarium every day starting on day 3 and continuing until day 24 to measure the morphological change of fish mouth. Five fish were randomly selected from each aquarium every 2 days starting on day 4 for the food selectivity trial. All measurements were obtained using a dissecting microscope and eyepiece micrometer. The upper and lower jaw lengths were measured to determine the gape dimension (Figure 13.1), as well as the notochord length of each fish. However, the mouth



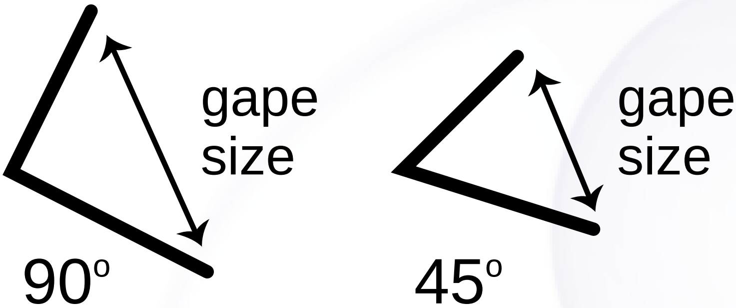


Figure 13.1. *Fish mouth and gape size.*

width was taken only in the feeding morphology trial, while the stomach contents and numbers were recorded only for the food selectivity trial.

The mouth width was taken by a direct measurement. A comparison of the food size and mouth dimensions was made to determine the physical limitations that may stop a larval snapper from feeding on a given sized prey. In the food selectivity trial three types of live food were used including rotifer *(Brachionus plicatilis)*, *Artemia* nauplii and cyclopoid copepods to determine the food selectivity of snapper of a particular size.

The abundance of prey items in the stomach and the environment was used to determine the electivity index (ε) for each prey item. The electivity index was used to determine whether or not a particular prey item was selected for or against in respect to the other food items available in the environment. The electivity index was calculated with the following equation:

$$\varepsilon_i = \frac{m\alpha_i - 1}{(m-2)\alpha_i + 1}, i = 1, \ldots, m$$

Where ε_i is the electivity index for prey item i, αi is the preference index for prey item *i*, and *m* is the number of prey species in the environment. The electivity values range from –1 to 1, where 1 indicates a positive selection for that prey item, –1 indicates an avoidance of that prey item and zero implies a random selection. The αi for each prey item was calculated using the following equation:

$$\alpha_i = \frac{r_i/n_i}{\sum_{i=1}^{m} r_i/n_i}, i = 1, \ldots m$$

Where r_i and n_i are the proportions of prey type i in the stomach and the environment.

Snapper larvae in the food consumption trials were fed rotifers at a density of 15 rotifers per millilitre. The rotifers used for the consumption experiment were dyed using methyl red for 30 minutes. Rotifers at a density of 15 per millilitre were added to the aquarium 2 hours after lights had been switched on. Five fish were randomly selected every hour, commencing one hour after the dyed rotifers were introduced into the system, and continuing for six consecutive hourly samples. The consumption rate was determined by the following equation:

$$F = \frac{\left(S_t - S_0 e^{-Rt}\right)R}{1 - e^{-Rt}}$$

Where F is the consumption rate (prey number per hour), S_t is the number of prey in the gut after time t, S_0 is the number of prey in the gut at the beginning of the time period, R is the evacuation time, and t is the time between samples. The evacuation time was determined by the passage of food items in the digestive tract.

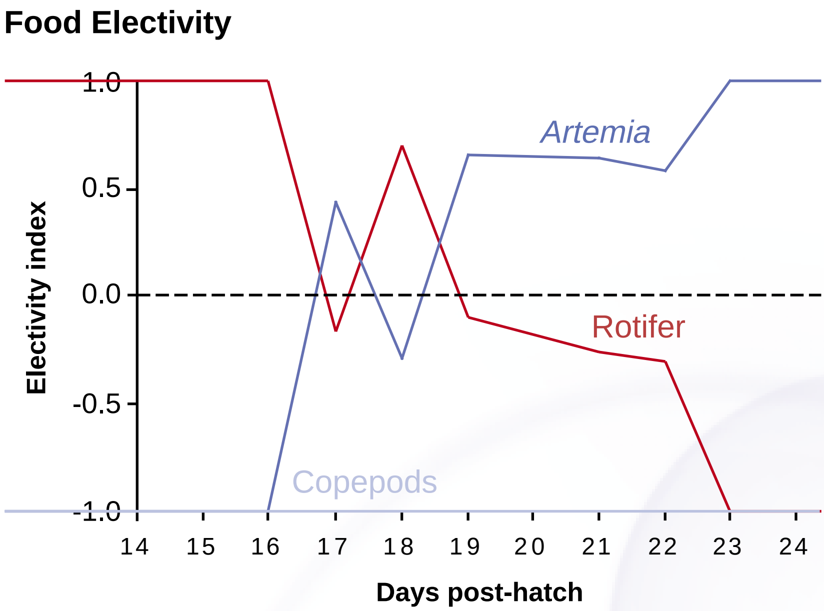


Figure 13.2. *Food electivity over time.*

The gape and mouth width dimensions were not linearly related in pre-metamorphic snapper but followed a natural logarithmic relationship. The gape opening and mouth width began in a linear relationship; however, once the gape reached a particular point (gape of 90°, 0.36 mm; and 45°, 0.27 mm) the mouth width increased dramatically. This point corresponded to a notochord length of 3.6 mm (10 days old). This could be due to the larval organism undergoing preliminary morphological changes in preparation for metamorphosis.

When comparing the width and gape dimensions against those of the live food, the gape was always the limiting factor when assuming that the mouth could open only to a 45° angle. However, when considering a 90° mouth opening, the width became the limiting factor until the fish reached a body length of 5.6 mm (20 days old), at which point gape became limiting.

Observations on feeding and sampled larvae showed that a 90° gape opening was not only feasible but also common, thus all results would be based on this measurement. The pre-metamorphic snapper (less than 20 days old) were limited in their food selection not by the mouth gape but by the width of the mouth.

The snapper larvae that were 4.2–4.9 mm long (i.e., 14–17 days old) selected for rotifers. After 19 days old, snapper reached a length of 5.3 mm and selected for *Artemia* nauplii. This was supported by the results of the electivity index, where before day 17 (length <4.7 mm) there was a positive selection for rotifers and a negative selection for both A. salina and copepods (Figure 13.2). By day 19 there was an increasing selection for *Artemia* nauplii and an increasing selection against rotifers. The electivity index for copepods was –1 for the entire experimental period. By day 24, fish larvae (6.4 mm long) were attempting to consume copepods. However, copepods were too large for the snapper larvae to capture.

Consumption rates for 6- and 12-day post-hatch larval snapper were measured at 20.8 ± 0.4°C. An evacuation time was 2 hours for 6-day-old larvae (2.8 mm long) decreasing to 1 hour for 12-day-old larvae (3.4 mm long). Two peaks of consumption rate were observed in a 6-hour feeding period. The total daily food consumption was estimated at 17 rotifers for 6-day-old larvae and 49 rotifers for 12-day-old larvae over a 12:12-h lighting cycle, assuming that fish did not feed in the dark.

In summary, it is theoretically possible for larval snapper (assuming a gape of 90° opening) to consume small-strain rotifers by day 3 (mouth first open), *Artemia* nauplii by day 16 (4.8 mm long), and copepods by day 27 (6.8 mm long). Once the larvae were physically capable of consuming *Artemia*, it took only 3 days for the snapper to positively select for the prey (i.e., electivity index of –1 on day 16 to +0.75 on day 19). This suggests that once larvae are physically able to consume a larger prey item, they will quickly select for the larger, more energy-rewarding prey.