Cultured copepods as food for West Australian dhufish (Glaucosoma hebraicum) and pink snapper (Pagrus auratus) larvae

M.F. Payne a,*, R.J. Rippingale a, J.J. Cleary b

a School of Environmental Biology, Curtin University of Technology, GPO Box, U1987, Perth, 6845 Western Australia, Australia
b Aquaculture Development Unit, South Metropolitan College of TAFE, 1 Fleet Street, Fremantle, 6160 Western Australia, Australia

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Abstract

Copepods have often improved larviculture of marine fish species that are not easily reared using rotifers. One such species is Glaucosoma hebraicum. G. hebraicum larvae were reared on a combined diet consisting of equal numbers of cultured copepod nauplii and rotifers and a diet of rotifers only. Growth was significantly greater in larvae fed with the combined diet. Survival was 37% in the copepod/rotifer-fed larvae compared to 5% in the rotifer-fed larvae. Two separate methods of presenting copepod nauplii to Pagrus auratus larvae were also examined. Firstly, copepods nauplii were provided as the sole diet during the first feeding phase followed by rotifers. Secondly, rotifers were supplemented with copepod nauplii for an extended period. P. auratus larvae grew faster than rotifer fed controls in both trials. Larvae fed with the supplemented diet for an extended period grew fastest. There was no significant difference in survival and swim bladder inflation in P. auratus larvae, although those treatments with copepods in their diet were consistently higher. Improved larval growth and survival in both fish species were attributed to preferential selection of copepod nauplii and their high nutritional content. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Calanoid copepods; Glaucosoma hebraicum; Pagrus auratus; Larval fish; Feeding and nutrition, fish
1. Introduction

The Aquaculture Development Unit (ADU; Fremantle, Western Australia) has been developing culture techniques for temperate marine finfish for the past 9 years. In this time, a highly successful culture technique, based on a method described by Palmer et al. (1992), has been standardised for commercial fingerling production of black bream (*Acanthopagrus butcheri*) and pink snapper (*Pagrus auratus*). Better than 50% survival of pink snapper from hatchling to day 35 is achieved with this semi-intensive green water technique (G. Partridge, unpublished data).

West Australian dhufish (*Glaucosoma hebraicum*) is one of West Australia’s premier table fish and as such has a high market value (Kailola et al., 1993). Recently, ADU has commenced research on the culture of this species. However, larviculture techniques used to rear black bream and pink snapper do not provide for high survival rates in dhufish (Cleary, unpublished data). Alternative approaches are required to successfully culture this species.

Rotifers are provided as the sole diet for first feeding larvae in most larviculture systems, including the semi-intensive technique used at ADU. Pink snapper larvae are readily reared on rotifers Battaglene and Talbot, 1992; Hecht et al., 1996 hence, the success of this technique for this species. In contrast, high mortality of dhufish larvae in the green water system suggests that rotifers may not be an appropriate food for these larvae.

Copepod nauplii show promise as a rotifer replacement in larval diets. Where problems have occurred in the development of larviculture practises for new aquaculture species, copepods have often provided significant benefits (Witt et al., 1984; Doi et al., 1997). These benefits include an increased feeding response by larvae (Kuhlmann et al., 1981; Doi et al., 1997) and a higher nutritional content (Watanabe et al., 1983; Kraul et al., 1992). Further work on the latter has indicated that copepods fed on selected algal species contain docosahexanoic acid/eicosapentanoic acid (DHA:EPA) ratios of approximately 2:1 (Støttrup et al., 1999), which is highly desirable for larviculture (Sargent et al., 1997).

Currently, large scale calanoid copepod production systems, such as those described by Støttrup et al. (1986) and Schipp et al. (1999), cannot match the production of large scale rotifer cultures. Hence, copepods must be used judiciously in order to maximise their benefits in larviculture. This may include the use of copepods as a long-term supplement to rotifers throughout the larval phase or as a short-term replacement for rotifers during the critical first feeding phase.

The calanoid copepod *Gladioferens imparipes* has considerable potential as a live food for larviculture. This temperate estuarine species is amenable to high-density culture (Rippingale and MacShane, 1991) and can contain desirable ratios of essential fatty acids (Payne et al., 1998). Concurrent with the development of large-scale cultivation of this copepod is the opportunity to test the effect of a copepod diet on larval dhufish.

This study aims primarily to determine the effect of supplementing a rotifer diet with *G. imparipes* nauplii on the growth and survival of West Australian dhufish larvae. In addition, two methods of presenting copepod nauplii to larval fish are examined. In the
first method, copepod nauplii are provided during the brief first feeding phase, followed by rotifers. In the second method, rotifers are supplemented with copepod nauplii for a longer period. Limited numbers of dhufish larvae necessitated the use of pink snapper larvae for these latter trials.

2. Material and methods

2.1. Experimental system

Trials were conducted in a seawater flow-through system located at ADU. The system comprised six 140-L cylindrical containers, each receiving gentle aeration and subject to a 10L/14D cycle. Containers had dark blue sides and white bottoms, and were covered with shade cloth to give a mean light intensity of 244 lux at the water surface. Water outlets were screened with 53 μm mesh. The microalgae *Nannochloropsis oculata* was constantly delivered to each container by a dosing pump Acromet such that a density of 0.5–1.5 million cells/ml was maintained. *Isochrysis galbana* (T-Iso) was added once daily to each container to a density 50–100,000 cells/ml. Detritus was siphoned from the bottom of each container every second day starting from

<table>
<thead>
<tr>
<th>Fatty acid</th>
<th>Enriched rotifers</th>
<th>Enriched Artemia</th>
<th>Copepod nauplii</th>
<th>Copepod adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:0</td>
<td>1.5 ± 0.2</td>
<td>1.8 ± 0.1</td>
<td>6.0 ± 0.9</td>
<td>78.1 ± 6.6</td>
</tr>
<tr>
<td>14:1</td>
<td>1.3 ± 0.0</td>
<td>0.7 ± 0.0</td>
<td>–</td>
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<tr>
<td>16:0</td>
<td>7.9 ± 1.6</td>
<td>14.0 ± 0.3</td>
<td>13.4 ± 1.6</td>
<td>76.0 ± 7.2</td>
</tr>
<tr>
<td>16:1</td>
<td>4.5 ± 1.0</td>
<td>6.1 ± 0.2</td>
<td>1.8 ± 0.4</td>
<td>18.1 ± 3.8</td>
</tr>
<tr>
<td>17:0</td>
<td>–</td>
<td>0.8 ± 0.1</td>
<td>–</td>
<td>1.7 ± 0.3</td>
</tr>
<tr>
<td>18:0</td>
<td>2.6 ± 0.7</td>
<td>5.3 ± 0.1</td>
<td>2.4 ± 1.2</td>
<td>8.1 ± 0.9</td>
</tr>
<tr>
<td>18:1</td>
<td>8.4 ± 2.2</td>
<td>22.1 ± 0.3</td>
<td>11.3 ± 2.0</td>
<td>103.5 ± 18.5</td>
</tr>
<tr>
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<td>3.7 ± 0.9</td>
<td>9.1 ± 0.1</td>
<td>2.7 ± 0.4</td>
<td>36.1 ± 3.5</td>
</tr>
<tr>
<td>18:3n–3</td>
<td>2.9 ± 1.5</td>
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<td>1.7 ± 0.3</td>
<td>24.0 ± 2.1</td>
</tr>
<tr>
<td>18:4n–3</td>
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<td>3.0 ± 0.0</td>
<td>4.5 ± 0.7</td>
<td>22.6 ± 1.9</td>
</tr>
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<td>–</td>
<td>–</td>
</tr>
<tr>
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<td>–</td>
<td>3.9 ± 0.4</td>
</tr>
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<td>1.8 ± 0.7</td>
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</tr>
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<td>13.2 ± 1.2</td>
<td>15.4 ± 0.2</td>
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<td>10.1 ± 1.4</td>
</tr>
<tr>
<td>22:6n–3</td>
<td>7.6 ± 0.6</td>
<td>3.2 ± 0.0</td>
<td>10.1 ± 0.9</td>
<td>49.1 ± 4.8</td>
</tr>
<tr>
<td>24:0</td>
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<td>0.7 ± 0.1</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>DHA/EPA</td>
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<td>0.2 ± 0.0</td>
<td>3.0 ± 0.0</td>
<td>4.9 ± 0.0</td>
</tr>
<tr>
<td>DW (μg/individual)</td>
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<td>2.64</td>
<td>0.10</td>
<td>6.12</td>
</tr>
<tr>
<td>Length (μm)</td>
<td>100–280</td>
<td>570–580</td>
<td>125–265</td>
<td>880–970</td>
</tr>
</tbody>
</table>

– indicates not detected.
DHA/EPA values with different superscripts are significantly different (P < 0.05).
day 12 post-hatch. Hereafter, the term ‘day’ will refer to the number of days post-hatch. Films on the water surface were removed daily using paper toweling.

2.2. Larval diet enrichment and fatty acid analysis

Live foods used for fatty acid analysis and in all feeding trials were enriched as follows. Copepod nauplii collected from intensive cultures fed with T-Iso were placed in clean seawater containing T-Iso (~ 2 x 10^3 cells/ml) and N. oculata (~ 1.5 x 10^6 cells/ml) for 6 h at 23°C prior to use. A sample of adult copepods was also enriched in this manner for fatty acid analysis. Artemia nauplii (Prime Artemia®; Premium Gold) and rotifers (Brachionus spp.; comprising approximately 90% Brachionus rotundiformis and 10% B. plicatilis) were both enriched with Super Selco® according to the manufacturer’s directions.

Fatty acids were analysed using techniques modified from Dunstan et al. (1992). For each diet, triplicate samples comprising approximately 200,000 copepod nauplii, 50,000 enriched Artemia nauplii, or 400,000 enriched rotifers were collected on 50 mm discs of 53 μm mesh using a Millipore® filtering apparatus. Animals were rinsed from the mesh using dichloromethane (DCM)/methanol/water (1:2:0.8 v/v; Bligh and Dyer, 1959; 20 ml) and homogenised. Samples were covered and stored in the refrigerator overnight.

Fig. 1. Growth of dhufish larvae fed with a combination of copepod nauplii (50%) and rotifers (50%) and rotifers only (mean 3 reps ± se).
before being filtered under gentle vacuum and rinsed with DCM/methanol/water (50 ml). Lipids were extracted in DCM from a mixture of DCM/water (1:1 v/v). The solvent was removed using a Bucci® rotary evaporator and the remaining lipid dissolved in methanol (5 ml). Samples were transferred to 20 ml reaction tubes, combined with acidified methanol (4 ml), toluene (2 ml) and an internal standard (nonadecanoic acid; 0.5 mg) and heated to 50°C for 16 h. The cooled reaction mixture was transferred to hexane (20 ml), washed twice with deionised water (20 ml), and dried over anhydrous sodium sulphate.

The relative fatty acid methyl ester (FAME) composition of these solutions was determined by gas chromatography (GC; Hewlett Packard (HP) #5890). The GC was fitted with a HP Innowax column (30 m × 0.25 mm id × 0.5 μm film thickness). Temperature programming for each analytical run was as follows: increased from 180°C to 200°C at 5°C each min, held at 200°C for 3 min, increased to 250°C at 2°C/min and held at this temperature for 18 min. Retention times were determined relative to that of the internal standard and a mixture of FAME standards (Sigma® #189-19).

DHA:EPA ratios of the diets were compared using a one-way ANOVA.

2.3. West Australian dhufish

For this trial, temperature was maintained at 22.5 ± 1°C. Daily water exchange occurred at the rate of 150% from stocking to day 10, increasing to 220% from day 11 to day 20 and 260% after day 21. Dissolved oxygen, pH and ammonia-nitrogen
measured 89–95% saturation, 7.9–8.1 and < 0.002 mg/l, respectively, in all containers throughout the trial.

Larvae were obtained from stripping eggs and sperm from wild-caught dhufish (G. hebraicum) broodstock. Day 2 larvae (2.97 ± 0.05 mm TL) were stocked into each of six containers at a density of 6/1, and two diets were each randomly allocated to three replicate containers. The treatment group was fed with a mixed diet consisting of copepod nauplii (50%) and enriched rotifers (50%) while the control diet comprised enriched rotifers only. Feeding commenced on day 3 and live prey items were maintained at the rate of 10/ml, measured twice daily. Weaning onto enriched Artemia commenced when larvae had reached an average length of approximately 6 mm and was conducted over an 8-day period. The length of three larvae from each container was recorded every 3 days and a subjective assessment of gut content conducted. Swim bladder inflation, as an indicator of larval development, was also recorded in these larvae. At the conclusion of the trial, all surviving fish were counted.

Lengths of larvae on specific days, survival and swim bladder inflation were compared using one-way ANOVAs. Growth rates, indicated by the regression gradients of transformed data, were compared using dummy variables.

2.4. Pink snapper

Two trials were conducted using pink snapper (P. auratus) larvae. For each, temperature was maintained at 20 ± 1.5°C and daily water exchange occurred at the rate
of 110% from stocking to day 7, increasing to 150% from day 8 to day 15 and 220% after day 16. Dissolved oxygen, pH and ammonia-nitrogen measured 88–95% saturation, 7.9–8.1 and <0.06 mg/l, respectively, in all containers throughout the trials.

Pink snapper larvae were obtained from naturally spawning F2 broodstock maintained at ADU. For both trials, day 2 larvae (3.01 ± 0.02 mm TL) were stocked into each of six containers at a density of 25/l, and two diets were each randomly allocated to three replicate containers. Feeding commenced on day 4 and live prey items were stocked at the rate of 10/ml, topped up three times daily. The length of 10 larvae from each container was recorded every 2 days in the first trial and every 3 days in the second. Subjective examinations of larval gut content were conducted regularly. At the conclusion of each trial, all surviving fish were counted and swim bladder inflation recorded for 10 fish from each replicate.

For the first trial, the treatment diet consisted of copepod nauplii from day 4 to day 10 and enriched rotifers from day 11 onwards. The control diet comprised enriched rotifers throughout. Weaning onto enriched *Artemia* commenced when larvae had reached an average length of 7 mm and was conducted over 5 days. During this time, *Artemia* rations were gradually increased and rotifer rations gradually decreased. Water exchange was increased to 250% during this period. The trial was terminated on the second day of the larvae being fed exclusively on *Artemia*.

For the second trial, the treatment group was fed with a mixed diet consisting copepod nauplii (20%) and enriched rotifers (80%) throughout the trial while the control

![Fig. 4. Survival and swim bladder inflation (SBI) of snapper larvae fed with copepod nauplii from day 4 to day 10 post-hatch and then rotifers from day 11 onwards compared to those fed rotifers only (mean 3 reps ± sd).](image)
diet comprised enriched rotifers only. No weaning onto *Artemia* took place in this trial and it was concluded when larvae were around 7 mm in length.

Analysis of data followed the same methods used for dhufish larvae.

3. Results

3.1. Fatty acid analysis of larval diets

Both enriched rotifers and *Artemia* contained more EPA (20:5\(\text{n-3}\)) than DHA (22:6\(\text{n-3}\)) resulting in DHA:EPA ratios of 0.6 and 0.2, respectively (Table 1). In contrast, copepod nauplii and adults contained more DHA than EPA, thus recording DHA:EPA ratios of 3.6 and 4.9, respectively. In adult *G. imparipes*, fatty acids comprised a total of 438 mg/g DW or 43.8% of dry body weight.

3.2. West Australian dhufish

Overall, larvae fed with the treatment diet grew at a faster rate (\(P < 0.001\)) than larvae fed with the control diet (Fig. 1). From day 5 onwards, length of larvae fed with the treatment diet was significantly greater (\(P < 0.05\)) than the control-fed larvae. Larvae in the treatment group obtained a length of approximately 11 mm 9 days earlier.

![Fig. 5. Growth of snapper larvae fed with a mixture of copepod nauplii (20%) and rotifers (80%) and rotifers only (mean 3 reps ± se).](image-url)
than those in the control group. Copepods comprised almost all of the gut content of the treatment group larvae throughout the trial. Growth rates were similar between the two groups as they increased in length from 6 to 11 mm. There was a decline in growth rate in the control group between day 20 and day 23. Substantial numbers of copepods and adult copepods were observed in the treatment group from day 10 onwards, indicating that uneaten nauplii were being retained and growing rapidly in the larviculture containers. These copepods were observed being predated by dhufish larvae from day 17 onwards. Survival in the larvae fed with the treatment diet was 37% compared to 5% in those fed with the control diet (Fig. 2). This represents a significant difference ($P < 0.01$). Swim bladder inflation was 100% in both treatment and control groups on day 8.

### 3.3. Pink snapper

In the first trial, snapper larvae fed with the treatment diet grew faster ($P < 0.01$) than those fed with the control diet (Fig. 3). Most of this difference was attributed to faster growth rates from day 4 to day 10 and after day 22. During these times, copepods were the dominant prey item in stomachs of the larvae. From day 6 onwards, length of snapper larvae was significantly greater ($P < 0.001$) in the treatment group. On day 18, the length of larvae reared on the treatment diet was $6.6 \pm 0.1$ mm compared to $5.8 \pm 0.1$ mm in the control larvae. As in the dhufish trial, substantial numbers copepods were observed in the treatment group from day 12 onwards and were observed being

![Graph](image_url)  
Fig. 6. Survival and swim bladder inflation (SBI) of snapper larvae fed with a mixture of copepod nauplii (20%) and rotifers (80%) and rotifers only (mean 3 reps ± sd).
predated by snapper larvae from day 22 to day 25. Survival and swim bladder inflation was greater in the larvae fed with the treatment diet (Fig. 4). However, these differences were not significant, as there was large variation within treatments.

In the second trial, snapper larvae fed with the treatment diet grew faster ($P < 0.01$) than those fed with the control diet throughout the trial (Fig. 5). Larval length was greater ($P < 0.05$) from day 6 onwards in the treatment group. Copepods were observed in the digestive tract of these larvae throughout the trial. On day 18, the length of larvae reared on the treatment diet was 6.8 ± 0.1 mm compared to 5.8 ± 0.1 mm in the control larvae. Uneaten copepods grew rapidly in the treatment group. However, snapper larvae did not attain sufficient size to predate them and large numbers remained at the conclusion of the trial. Survival and swim bladder inflation was greater in larvae fed with the treatment diet (Fig. 6). Again, these differences were not significant, as there was large variation within treatments.

4. Discussion

Clearly, the treatment diet of copepod nauplii and rotifers greatly increased growth (Fig. 1) and survival (Fig. 2) of dhufish larvae compared to the control diet of rotifers only. The abundance of copepod nauplii in the gut suggests the larvae had a strong preference for copepod nauplii. Also, copepod nauplii contained a higher DHA:EPA ratio (Table 1) than enriched rotifers, indicating they are a more efficacious diet for larval fish. It is likely that both these factors contributed to the success of this diet.

Little is known about the growth of dhufish larvae in the wild. Pironet and Neira (1998), as part of a study that described larval development, recorded that larvae grew to a length of approximately 7 mm in 40 days at 22–24°C. This is considerably slower than larvae fed with either treatment or control diet in the present study. Using the standardised commercial scale technique at ADU, larvae obtained a length of 8.5 mm in 26 days at 22–24°C (Cleary, unpublished data). This represents a growth rate less than the treatment diet but greater that the control diet used in the current study (Fig. 1). This higher growth rate compared to the latter may be explained by the abundance of harpacticoid copepods in the ADU larviculture tank and early addition of Artemia.

Decreased growth rate between day 20 and day 23 in rotifer-fed larvae in the current study (Fig. 1) suggests that larvae had grown too large to be sustained by rotifers alone and should have been offered Artemia before reaching 6 mm in length. A similar decrease in growth rate did not appear in the copepod-fed larvae at the same size as they were probably feeding on copepodids at this time.

Prior to this study, the highest survival of dhufish larvae achieved was approximately 3% using the standard commercial scale ADU technique (Cleary, unpublished data). While this survival represented a significant improvement on previous attempts to rear dhufish larvae, it was not sufficient to allow commercial development of dhufish aquaculture. The current study found that the provision of copepods can greatly improve larval survival in a small scale system. Efforts must now focus on the incorporation of copepods into a commercial scale system for rearing dhufish larvae.

As with dhufish larvae, copepods provided for increased growth of snapper larvae. In the first trial, increased growth rates were associated with predation on copepods; days
4–10 on nauplii and days 22–25 on copepodids and adult copepods. In the second trial, growth rates were higher throughout the trial for larvae fed with the diet supplemented with copepods. As in dhufish, it is likely that improved growth in snapper larvae fed with copepods was a result of preferential selection of copepods and their higher nutritional value.

Of the two snapper diets tested, highest growth rate in larvae (as indicated by length on day 18) was observed in those provided with supplementary copepods over the entire treatment period (second trial). Also, this feeding regime has the further advantage that it will be easier to facilitate on a larger scale. This feeding method requires the production of small numbers of copepod nauplii over a relatively long period. In contrast, the first trial required large numbers of copepod nauplii in a short space of time. Mass production system for copepods usually provide for daily removal of relatively small numbers of nauplii compared with production of rotifer (Støttrup et al., 1986; Sun and Fleeger, 1995). Thus, they are compatible with larviculture diets incorporating low level, long-term supplementation of rotifers with copepod nauplii.

Growth of snapper larvae reared on rotifers only (control group) in the present study compared well with published data for snapper larvae also reared on rotifers. Battaglene and Talbot (1992) measured *P. auratus* larvae of 5.6 mm on day 19 at 21.5 ± 1°C. In *P. auratus* larvae of the same age, Pankhurst et al. (1991) recorded lengths of approximately 5.1 mm at 17–22°C. In the present study, rotifer-fed larvae grew to 5.8 mm on day 18 at 20 ± 1.5°C in both trials. With copepods included in their diet, larvae attained lengths of 6.6 (trial 1) and 6.8 mm (trial 2) on day 18. Consistently, lower growth rates in snapper larvae reared on rotifers further contrasts the benefits of copepod nauplii in the diet of these larvae.

Snapper survival and swim bladder inflation rates were not significantly different in either trial (Figs. 2 and 4). Despite this, it is notable that in both trials larvae that had copepods in their diet recorded higher survival and swim bladder inflation rates. Large variation within treatments probably resulted from the cumulative effect of small variations in light intensity, aeration and water circulation between the small, flat-bottomed containers. With greater attention to these factors and a larger number of replicates per treatment, variation would probably be reduced. This may have resulted in significant differences being detected in the present study.

In the present study, first feeding dhufish and pink snapper larvae were similar in size (and presumably, mouth gape), as were copepod nauplii and rotifers offered to these larvae as prey. Given that snapper larvae will readily ingest rotifers, it is likely that (based on prey size) larvae of both fish species were equally able to ingest both prey items. Thus, increased proportions of copepod nauplii in the gut of both species were likely a result of increased selection of copepods over rotifers. However, this does require quantification in further work.

In addition to increased prey selection, much of the efficacy of copepods as a diet for dhufish and pink snapper larvae may be attributed to their fatty acid content, particularly their DHA:EPA ratio. Fatty acid content of copepods is dependent on their algal diet (Payne et al., 1998; Støttrup et al., 1999). In this study, copepod nauplii were enriched with T-Iso and *N. oculata*, which are high in DHA and EPA, respectively (Dunstan et al., 1993), prior to being fed to larvae. This combined algal diet provided copepod...
nauplii and adults with a desirable DHA:EPA ratio of around 2:1. Once added to the larval rearing containers, nauplii were able to continue feeding on both T-Iso and *N. oculata*, thus maintaining their DHA:EPA ratio.

Relatively low DHA:EPA ratios recorded in enriched rotifers probably contributed to decreased growth and survival in larvae fed only on rotifers. Fernandez-Reiriz et al. (1993) recorded a DHA:EPA ratio of 0.9 in rotifers enriched with Super Selco® compared to 0.5 recorded in the present work. In the current study, rotifers were obtained from cultures maintained on *N. oculata*, which is high in EPA (Dunstan et al., 1993). Hence, rotifers fed with this alga have an elevated EPA content (Tamaru et al., 1993). EPA stored in lipid reserves may have contributed to the low DHA:EPA ratio of rotifers used in the present study, thus decreasing their nutritional value.

*A. salina* enriched with Super Selco® contained low DHA:EPA ratios. Ratios of 0.7–0.8 are often reported (Kraul et al., 1993; McEvoy et al., 1995) compared to 0.2 in the present study. This may be explained by the instability of HUFAs in commercial preparations and the catabolism of these compounds by the target organism during enrichment (McEvoy et al., 1995). Despite this, *Artemia* were fed to larvae in both treatment groups in the present study, hence their nutritional status does not account for variations in larval growth and survival.

Fatty acids are only one of the many nutritional factors that are important for larval fish. Particular amino acids (Fyhn, 1989) and vitamins (Merchie et al., 1997) have also been confirmed as vital components of successful larval diets. These were not assessed in live prey used in the current study. Correlating improved growth and survival of copepod-fed larvae with detailed biochemical analyses of their copepod prey would add significantly to general knowledge of larval nutritional requirements and must be considered for future work.

This study suggests that, in dhufish and snapper, larval growth is increased whenever *G. imparipes* nauplii are included in the diet. Thus, larvae will likely benefit from having nauplii as large a proportion of their diet as possible. Providing copepods nauplii sufficient for large-scale aquaculture has proved difficult, but in this study, it was encouraging to observe the rapid growth to maturity of copepod nauplii added to the larviculture system, suggesting the possibility of adding copepod broodstock to green water larviculture systems to provide in situ nauplius production. In addition, adult *G. imparipes* contain considerable quantities of fatty acids (Table 1) and hence are a valuable food resource for later larvae and juvenile fish. With knowledge of the growth and fecundity of *G. imparipes* on different diets (Payne and Rippingale, 2000), a suite of carefully selected algal species could be used in these systems in order to give maximum copepod productivity and nutritional content. In situ copepod production could then be augmented with nauplii supplied from intensive copepod cultures. When used in conjunction with rotifers, this technique may make possible the commercial scale culture of a wider range of fish, including dhufish.

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