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**ARTEMIA SITES IN IRAN**

T. J. Abatzopoulos, N. Agh, G. Van Stappen, S.M. Razavi Rouhani, P. Sorgeloos-2006

J. Mar. Biol. Ass. U.K. 86: 299-307

**Abstract:**

Field surveys were conducted in order to collect information on the occurrence of wild *Artemia* populations in hypersaline environments such as salt lakes, lagoons and salty rivers. The mating behaviour of *Artemia* populations and the presence or absence of males were carefully recorded. Sampling involved the use of plankton nets. Collected cysts were characterized on the basis of their diameter and chorion thickness, while nauplii (instar-I) were characterized on the basis of their total length. *Artemia* populations were found at 17 different geographical locations scattered over 12 Iranian provinces. All Iranian *Artemia* populations are parthenogenetic with the exception of *Artemia urmiana* from Urmia Lake. During the last five years severe salinity increase has caused a dramatic reduction of population sizes in several hypersaline settings in Iran. The study of cyst and naupliar biometry revealed substantial differences between populations and can be used, to some extent, for their discrimination. Cyst diameter mean values range from 243.2 to 285.4  $\mu\text{m}$ . For some Iranian parthenogens, cyst diameters were among the smallest recorded so far for parthenogenetic *Artemia*. The total length of newly hatched nauplii ranges from 455.5 to 529.8  $\mu\text{m}$ .

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**COMPARATIVE STUDY BETWEEN PROBIOTIC BACTERIUM ARTHROBACTER XE-7 AND CHLORAMPHENICOL ON PROTECTION OF PENAEUS CHINENSIS POST-LARVAE FROM PATHOGENIC VIBRIOS**

Jiqu Li, Beiping Tan, Kangsen Mai, Qinghui Ai, Wenbing Zhang, Wei Xu, Zhiguo Liufu, Hongming Ma-2006

Aquaculture 253 (1-4): 140-147

**Abstract:**

A strain of *Arthrobacter* XE-7, isolated from *Penaeus chinensis* was evaluated for potential use as a probiotic for shrimp post-larvae. In vitro studies demonstrated antagonism against *Vibrio parahaemolyticus*, *Vibrio anguillarum* and *Vibrio nereis*. During the 14-day challenge experiment, the shrimp post-larvae aged 10 days were reared in water with addition of either *Arthrobacter* XE-7 (106 CFU/ml), chloramphenicol (2 mg/l) or the three pathogenic vibrios (106 CFU/ml): Controls, (V) pathogenic vibrios alone, (A) *Arthrobacter* XE-7 alone, (C) chloramphenicol alone, (AV) pathogenic vibrios in combination with *Arthrobacter* XE-7, and (CV) pathogenic vibrios in combination with chloramphenicol. The surface growth rate of nitrogen and the attenuation rate of bacterium in culture water were detected for the first 7 days, and the cumulative mortality was recorded for the whole challenge experiment. Treatment A had no significant higher survival than the Control. However, Treatment AV produced significantly higher survival than Treatment V ( $p < 0.05$ ); Furthermore, it was not significantly lower than those of Treatment CV. Comparable attenuation rate of vibrios was observed in Treatment AV and CV, and it was significantly lower than that in Treatment V ( $p < 0.05$ ). In addition, results of the surface growth rate of nitrogen show that the *Arthrobacter* XE-7 has the nitrification ability to oxidize ammonium to nitrite.

Both chloramphenicol and *Arthrobacter* XE-7 are able to comparably protect the shrimp post-larvae from the pathogenic vibrios. Then, *Arthrobacter* XE-7 can be regarded as a probiotic bacterium for the culture of shrimp larvae.

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EGG-ASSOCIATED MICROFLORA OF PACIFIC THREADFIN, POLYDACTYLUS SEXFILIS AND AMBERJACK, SERIOLA RIVOLIANA, EGGS. CHARACTERISATION AND PROPERTIES

David W. Verner-Jeffreys, Izumi Nakamura, Robin J. Shields-2006

Aquaculture 253 (1-4): 184-196

Abstract:

The microflora of rinsed eggs of Pacific threadfin, *Polydactylus sexfilis*, and amberjack, *Seriola rivoliana*, were characterised, using a combination of culture based and non-culture based methods. The adherent microflora of eggs, examined within a few hours of release, varied both qualitatively and quantitatively. Similar *Pseudoalteromonas* strains were recovered from the eggs of both species and *Photobacterium damsela* subsp. *damsela* was recovered from more than one batch of Pacific threadfin eggs.

Many of the 16S rRNA gene sequences directly amplified and cloned from egg homogenate samples shared high homology to the partial 16S rRNA gene sequences of organisms cultured from the same samples of homogenate, suggesting that the majority of the bacteria in these samples were culturable on Marine Agar (MA).

One of the organisms isolated from the eggs of Pacific threadfin, *Vibrio* str ME2-03, was shown to be highly virulent to hatched Pacific threadfin larvae in challenge experiments. This shows that, as with other fish species, egg-associated transfer of bacterial pathogens could be significant in Pacific threadfin culture, illustrating the likely importance of treating eggs prior to transport, either to other rearing areas or to other hatcheries.

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SPAWNING, EARLY DEVELOPMENT, AND FIRST FEEDING IN THE LEMONPEEL ANGELFISH CENTROPYGE FLAVISSIMUS

Ike Olivotto, Scott A. Holt, Oliana Carnevali, G. Joan Holt-2006

Aquaculture 253 (1-4): 270-278

Abstract:

The present study investigates, for the first time, critical processes in early life history in captive rearing of the lemonpeel angelfish *Centropyge flavissimus*. Video recordings of courtship behaviors in the 300 L spawning tank showed several courtship behaviors to be similar to those described for wild fish, but courtship activities associated with harem maintenance were not observed in the captive fish. Typical courtship activity was seen on every day of observation, but gamete release occurred on only 7 of 10 observation days. The reason for the lack of gamete release was not obvious. Tank spawning began when temperature and photoperiod conditions were changed to spring and reached a maximum peak (in terms of egg number) during the summer, when the temperature was 28 °C. Egg production and fertilization rate remained relatively constant day to day and spawning continued for months at a time as long as temperature and photoperiod were maintained at optimum levels. Once the embryo hatched (15 h post fertilization) and the yolk sac stage was reabsorbed (48 h post hatching), larvae were ready to feed. Cultured *Parvocalanus* sp. nauplii or size-sieved wild zooplankton were suitable first food. Proper environmental conditions included rearing the larvae at 28 °C. This study provides the first data on the influence of temperature and first food offered on larval survival in the lemonpeel angelfish.

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CHARACTERISTICS OF SPAWNING BEHAVIOUR IN CULTURED GREENBACK FLOUNDER RHOMBOSOLEA TAPIRINA

N.W. Pankhurst, Q.P. Fitzgibbon-2006

Aquaculture 253 (1-4): 279-289

Abstract:

Cultured stocks of 2nd generation 2+ year old greenback flounder *Rhombosolea tapirina* were maintained at low density and under conditions of minimal disturbance over 4 reproductive seasons. Natural in-tank spawning began in the second year after introduction in 2 separate tank systems and continued for 3 successive seasons until the experiment was terminated. Video records showed spawning on 5 out of 34 days on which filming occurred, with spawning behaviour consisting of approach and courting of an ovulated female by a male, followed by a circular paired swim in mid-water culminating in egg release. Spawning was concentrated in austral winter and spring in all 3 study years. In the first year, spawning episodes were strongly correlated with lunar phase (new moon), whereas in years 2 and 3, initiation of substantive spawning for the season coincided with the new moon but there was little evidence of lunar synchronisation thereafter. Volumes of eggs produced and egg fertility were highly variable and not clearly related to season. Most spawning events occurred between midnight and 07:30 h, with the majority between 04:00 and 06:00 h (2 h before sunrise). The results of the present study further emphasize the utility of low disturbance maintenance for the development of naturally spawning cultured broodstock, and suggest that wild stocks are likely to show pre-dawn spawning in winter and spring, possibly synchronised to lunar phase.

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EARLY WEANING OF FAT SNOOK (*CENTROPOMUS PARALLELUS* POEY 1864) LARVAE

Tarcisio T. Alves, Jr., Vinicius R. Cerqueira, Joseph A. Brown-2006

Aquaculture 253 (1-4): 334-342

Abstract:

Feeding trials were conducted with fat snook larvae in an attempt to decrease the period of weaning without compromising larval growth and survival. Fat snook larvae of 30 days post-hatch (DPH; initial mean standard length =  $9.6 \pm 1.4$  mm) were assigned to five feeding trials in which larvae received *Artemia* for 5, 10 and 15 days (co-fed with a locally prepared dry diet), *Artemia* for 10 days (co-fed with a commercial dry diet) and *Artemia* only (control treatment). Standard length, length-specific growth rate (SGR), condition index, and survival were monitored. Behavioral observations (swimming activity and feeding) were also conducted. Larval survival (over 91%) and condition were not significantly affected by treatment. Fat snook larvae were successfully weaned by 35 DPH, but larvae weaned by 40 DPH displayed higher growth rates (final mean SGR =  $7.57\% \text{ day}^{-1}$ ) and were significantly larger (final mean standard length = 16.4 mm) by the end of the experiment. There were no significant differences in any growth parameter between larvae weaned by 40 and 45 DPH. However, comparisons between treatments using different dry diets revealed a significant difference in the frequency of dry diet ingestion, although it did not influence the growth of larvae. Neither larval swimming time nor motionless duration was significantly different among treatments.

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EFFECTS OF DIET, STOCKING DENSITY, AND ENVIRONMENTAL FACTORS ON GROWTH, SURVIVAL, AND METAMORPHOSIS OF MANILA CLAM *RUDITAPES PHILIPPINARUM* LARVAE

Xiwu Yan, Guofan Zhang, Feng Yang-2006

Aquaculture 253 (1-4): 350-358

Abstract:

A series of experiments was conducted to evaluate the effects of diet, stocking density, and environmental factors on growth, survival, and metamorphosis of Manila clam *Ruditapes philippinarum* larvae. These experiments examined the following factors: diet (Isochrysis spp., Chlorella spp., and a mixture of Isochrysis spp. and Chlorella spp. [1:1 w/w]), stocking density (5, 10, 15, and 20 larvae ml<sup>-1</sup>), light intensity (un-shaded, partially shaded, and fully shaded), water filtration (unfiltered and sand-filtered), water exchange (50% and 100% once every other day; 25%, 50%, and 100% once daily; 50% and 100% twice daily), and the use of substrate (with and without sand as the substrate). Results indicated that Chlorella spp. could replace 50% of Isochrysis spp. as a food source for the Manila clam larvae without affecting growth, survival, and metamorphosis. Larval growth decreased significantly with increasing stocking density. A density of 5–10 larvae ml<sup>-1</sup> appeared to be optimal for normal growth of Manila clam larvae. Neither diet nor stocking density used in the study had a significant effect on larval survival. Under partially shaded (light intensity = 1000–5000 lx) and fully shaded (light intensity < 500 lx) conditions, larval growth was significantly faster than under direct sunlight (un-shaded). A water exchange rate of 50% twice daily provided optimum larval growth. Larvae grew significantly faster in the unfiltered water than in the sand-filtered water. Using sand as the substrate in the culture system significantly depressed the metamorphosis rate. The type and particle size of sand used as the substrate did not significantly affect growth and metamorphosis rates of the larvae.

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BATCH FECUNDITY OF THE SWIMMING CRAB *PORTUNUS TRITUBERCULATUS*  
(BRACHYURA: PORTUNIDAE)

Katsuyuki Hamasaki, Kyohei Fukunaga, Shuichi Kitada-2006

Aquaculture 253 (1-4): 359-365

Abstract:

We assessed batch fecundity of the swimming crab *Portunus trituberculatus* for the purpose of seed production. Oocyte number and number and body size of first zoeas were examined for females collected from natural habitats in the Seto Inland Sea of Japan. The relationships between carapace width (CW) of females and batch fecundity were analyzed using a power function. Oocyte number was examined for the overwintering females. Size and number of first zoeas were determined for ovigerous females collected from May to August. Oocyte number increased with increasing female body size and predicted estimates ranged between 0.8 and 4.5 million for CW of 130–240 mm. Size of first zoeas (distance between tips of dorsal and rostral spines of the carapace) ranged between 1.22 and 1.62 mm and tended to linearly decrease with advancing hatching date, i.e., increasing hatching temperatures. Number of first zoeas increased with female body size and showed no fluctuation throughout the breeding season in females of the same size. Predicted numbers of first zoeas ranged between 0.7 and 3.8 million for CW of 130–240 mm. Number of first zoeas being less than the oocyte number for females of the same size, it is suggested that egg loss occurred from oviposition to hatching.

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SALINITY TOLERANCE OF EMBRYOS OF OBSCURE PUFFER *TAKIFUGU OBSCURUS*

Zhou Yang, Yafen Chen-2006

Aquaculture 253 (1-4): 393-397

Abstract:

Salinity tolerance of embryos of obscure puffer *Takifugu obscurus* was investigated at salinities of 0, 4, 8, 12, 16, 20, 24, 28, and 32 parts per thousand (ppt), respectively. Survival rates of embryos at 0, 4

and 8 ppt salinities were higher than 90% throughout the experiment, and there were no significant differences between 0 and 8 ppt ( $P > 0.05$ ), whereas most embryos died gradually at salinity of 12 ppt or higher after four days. Total hatch rates at 0, 4, and 8 ppt were 95.0%, 95.0%, and 91.0%, respectively. A few embryos hatched at salinities of 12, 16, 20, and 28 ppt; however, all larvae were deformed and died in 24 h post-hatch. Only at salinity of 8.0 ppt or lower, the embryos hatched into viable larvae. Hatching period at 0, 4, and 8 were 171, 182, and 182 h, respectively. Within the tolerable salinity range (0–8 ppt), there were no significant differences in total hatch rates, viability of 24 h post-hatch larvae, and rate of embryonic development ( $P > 0.05$ ). We concluded that embryos of obscure puffer could not tolerate salinities of 12 ppt and higher, but could well adapt to salinities below 8 ppt. Thus, it is viable to incubate embryos of obscure puffer under lower salinity conditions. (Nanjing Institute of Geography and Limnology, Chinese Academy of Sciences, 73 East Beijing Road, Nanjing 210008, People's Republic of China; email of Zhou Yang: [yangzhouff@vip.sina.com](mailto:yangzhouff@vip.sina.com))

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#### GROWTH AND SURVIVAL OF JUVENILE COBIA, *RACHYCENTRON CANADUM*, AT DIFFERENT SALINITIES IN A RECIRCULATING AQUACULTURE SYSTEM

Matthew J. Resley, Kenneth A. Webb, Jr., G. Joan Holt-2006

Aquaculture 253 (1-4): 398-407

Abstract:

Cobia (*Rachycentron canadum*) is an emerging aquaculture candidate for both offshore cage culture and land-based systems such as recirculating aquaculture systems. The ability to grow cobia at salinities other than oceanic (34 ppt) could present culturists with additional production opportunities with this species. Culture at low salinities could also reduce the incidence of disease and simplify water management. In two trials of 8 weeks each, this study investigated growth and survival of juvenile cobia reared at salinities of 5, 15, and 30 ppt. The trials were conducted in 456-L tanks, with 10 fish per tank. Water temperature was maintained at  $27 \pm 1$  °C and dechlorinated municipal tap water (0 ppt, 56.8 ppm Ca<sup>2+</sup>) was added to seawater (30 ppt, 325.3 ppm Ca<sup>2+</sup>) in order to achieve treatment salinities. Early juveniles were used in both trials with average initial weights of 6.0 g for the first trial and 6.7 g for the second trial. During both trials, fish were fed to satiation twice daily with a diet prepared on site, and the amount fed was measured to determine feed efficiency. Fish from each tank were counted and weighed collectively each week until the end of each of the 8-week trials to monitor growth and survival. Survival among treatments was not significantly different in the first trial, but in the second trial survival was significantly lower in the 5 ppt treatment (68.3%) than in the 15 (90%) or the 30 ppt (92.5%) treatments. Feed efficiency was extremely high in both trials with all treatments ranging between 1.05 and 1.13. Fish reared at a salinity of 5 ppt grew as well or better than the fish reared at salinities of 15 and 30 ppt (mean weight gained, 96.2–115.3 g). This study indicates that culture of cobia juveniles may be practical in salinities as low as 5 ppt.

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#### GNOTOBIOTICALLY GROWN ROTIFER *BRACHIONUS PLICATILIS SENSU STRICTU* AS A TOOL FOR EVALUATION OF MICROBIAL FUNCTIONS AND NUTRITIONAL VALUE OF DIFFERENT FOOD TYPES

Nguyen Thi Ngoc Tinh, Nguyen Ngoc Phuoc, Kristof Dierckens, Patrick Sorgeloos, Peter Bossier-2006

Aquaculture 253(1-4): 421-432

Abstract:

Axenic rotifers (*Brachionus plicatilis sensu strictu*, clone 10) were obtained by treating amictic eggs with glutaraldehyde. Depending of the batch of rotifers, total disinfection could be obtained by exposure to 50–100 ppm from 1 to 2 h at 28 °C. The hatched axenic neonates were used to test the effect of microbial communities (MCs) which were isolated from either normal-performing or crashed rotifer cultures. These MCs were either used directly or were first regrown on Marine Agar. MCs

were introduced to gnotobiotic *Brachionus* cultures in combination with three different food types, i.e. *Chlorella*, wild-type yeast and the *mnn9* yeast mutant, which is deficient in cell wall-bound mannoprotein. In the absence of MCs or when heat-killed MCs were added, *Chlorella* was always the best food, while lower growth rates were observed with wild-type yeast and the *mnn9* mutant as food. In the presence of live MCs and when rotifers were fed with *Chlorella*, the added MCs had no effect on rotifer performance. When yeasts were used as major food, all the tested MCs were able to increase the rotifer growth rate. The experiments with heat-killed MCs yielded no increase in rotifer growth rate, suggesting that the observed enhancement in rotifer growth rate was truly a probiotic effect rather than a nutritional effect. The results of this study demonstrate that gnotobiotic rotifer cultures obtained from axenic amictic eggs can be used as a test system for studying microbial-attributed as well as nutritional functions in the aquatic food chain. In addition, since the MCs originating from the crashed rotifer cultures did not decrease the growth rate in the tested rotifer cultures, it is likely that the observed crashes were not due to the presence of a standing deleterious MC.

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#### EFFECT OF TURBIDITY, PREY DENSITY AND CULTURE HISTORY ON PREY CONSUMPTION BY GREENBACK FLOUNDER *RHOMBOSOLEA TAPIRINA* LARVAE

G.W. Shaw, P.M. Pankhurst, S.C. Battaglione-2006

*Aquaculture* 253 (1-4): 447-460

Abstract:

Fish larvae cultured in turbid “green water” conditions commonly show improved feeding, growth and survival, however, the underlying mechanisms remain unclear. Greenback flounder *Rhombosolea tapirina* (Günther) larvae, reared in either green water (*Tetraselmis suecica*, 5 NTU) or clear water tanks were used in short duration feeding trials to investigate the effect of larval culture history, live prey density (0.01–5 prey ml<sup>-1</sup>), and turbidity level (0–40 NTU) on feeding performance. Prey consumption was density-dependent at prey densities below 0.1 ml<sup>-1</sup> and 0.05 ml<sup>-1</sup> for feeding on rotifers and *Artemia*, respectively. Green water reared larvae fed in green water consumed more rotifers across the range of prey densities tested compared with clear water reared larvae fed in clear water. At low prey density, where absolute performance capabilities of the larvae are tested, green water provided immediate improvement to rotifer intake at turbidity levels of 5–20 NTU for larvae with experience of either a clear or green water environment. However, larvae with experience of a green water environment outperformed larvae with experience of a clear water environment. Thus mechanisms that operate over the short term, such as contrast enhancement and chemical stimulation of feeding, as well as mechanisms that operate over the longer term, such as possible differences in retinal development, improvements in handling times and experience, are likely responsible for improved early larval performance in green water.

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#### SPECIFIC PATHOGEN FREE CULTURE OF THE PACIFIC OYSTER (*CRASSOSTREA GIGAS*) IN A BREEDING RESEARCH PROGRAM: EFFECT OF WATER TREATMENT ON GROWTH AND SURVIVAL

Sean E. Matson, Christopher J. Langdon and Sanford Evans-2006

*Aquaculture* 253 (1-4): 475-484

Abstract:

A specific pathogen free (SPF) filtration system was built to exclude *Haplosporidium costale*, Seaside Organism (SSO) from the Pacific oyster (*Crassostrea gigas*) hatchery and nursery of the Molluscan Broodstock Program at Hatfield Marine Science Center in Newport, Oregon. Since its inception in

1999, all groups of Pacific oyster seed produced have tested negative for SSO or any other certifiable infectious agent under histological examination. Microparticle filtration to 1  $\mu\text{m}$ , further filtered to 0.35  $\mu\text{m}$  for larvae, or in combination with ultraviolet sterilization, for juveniles was used in the system to exclude SSO from seawater drawn from Yaquina Bay, where it is a resident. The SPF water had negative effects on larval and juvenile oyster growth, and juvenile survival. A series of experiments assaying different water treatments was conducted in order to remedy these effects. The addition of calcium bentonite and calcium montmorillonite significantly improved larval growth over filtered water alone in multiple experiments, increasing the growth of larval cultures by as much as 33% at a dose of 5 ppm day<sup>-1</sup>. These two clays' adsorptive qualities are likely responsible for their beneficial effects. Effects of clay additions to SPF water on juvenile oyster growth were less pronounced and less temporally consistent than in larvae. Clay additions that benefited larvae did not always result in a significant increase in seed growth. Our short-duration seed experiments with clay additions showed that calcium bentonite at a dose of 2 ppm day<sup>-1</sup> inconsistently resulted in significant improvement in seed growth compared with SPF water with no clay addition. (Hatfield Marine Science Center, Oregon State University, 2030 SE Marine Science Drive, Newport, OR 97365, USA; email of S. Matson: [sean.matson@oregonstate.edu](mailto:sean.matson@oregonstate.edu))

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#### EVALUATION OF REPRODUCTIVE PERFORMANCE AND EARLY GROWTH OF FOUR STRAINS OF NILE TILAPIA (*OREOCHROMIS NILOTICUS*, L) WITH DIFFERENT HISTORIES OF DOMESTICATION

George O. Osure, Ronald P. Phelps-2006

Aquaculture 253 (1-4): 485-494

Abstract:

Nile tilapia *Oreochromis niloticus* is the primary tilapia species being cultured in the world, but many of the stocks being cultured were founded from a limited number of fish collected from the wild in the 1960s and 1970s. Such limited founding stocks and the numerous generations since offers the possibility of inbreeding depression. An evaluation of reproductive and growth characteristics of one highly domesticated stock of *O. niloticus* (Ivory Coast), two stocks not as domesticated (Egypt and Sagana), and one recently collected from the wild (Lake Victoria) was conducted at Auburn University. Brood fish held in 2-m<sup>3</sup> hapas were checked weekly; females holding eggs or sac fry in their mouths were transferred to the hatchery to continue eggs and sac fry incubation. Growth was evaluated during primary (1–30 days post-swimup) and secondary nursery (31–90 days post-swimup). The four strains differed in relative fecundity (seed/g female), percentage of females that spawned (11.6% to 57.2%) and in incubation success (5.3% to 91.3%). The combined effects of relative fecundity, percentage of females spawning, and incubation success, resulted in the Ivory Coast strain giving eight times more fry per kg of female brooder used than the Lake Victoria strain. Average weights of fingerlings for the four strains at the end of primary nursery ranged from 2.1 to 2.8 g; survival was similar for all strains. Secondary nursery results for the Egypt and Ivory Coast strains were similar when in a common production setting for 60 days. Average weights of Egypt and Ivory Coast fingerlings were 21.8  $\pm$  7.3 and 21.0  $\pm$  6.5 g, respectively, when produced in organically fertilized ponds, 87.9  $\pm$  23.1 and 103.2  $\pm$  3.9 g when produced in outdoor tanks and given a commercial feed, and 36.1  $\pm$  2.6 and 36.5  $\pm$  2.4 g when produced in a recirculating system and given a commercial feed. No genotype–environment interaction for growth or survival by Egypt and Ivory Coast strains was seen in three secondary nursery settings.

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#### SURVIVAL, DEVELOPMENT AND GROWTH OF THE PACIFIC WHITE SHRIMP LITOPENAEUS VANNAMEI PROTOZOEAL LARVAE, FED WITH MONOALGAL AND MIXED DIETS

Pablo Piña, Domenico Voltolina, Mario Nieves, Mariana Robles-2006

Aquaculture 253 (1-4): 523-530

Abstract:

The larvae of the Pacific white shrimp *Litopenaeus vannamei* are fed with microalgae from the stage of protozoa I (PZ I), until they change to mysis I (M I). Most hatcheries use monoalgal diets based on the diatom *Chaetoceros muelleri*, but there is no information on the advantages of this microalga in comparison to other species used for larval feeding, supplied alone or in mixture. In this paper, the survival rate, rate of development, total length and final weight of protozoa larvae (PZ) of *L. vannamei* fed with the microalga *C. muelleri* (CHGRA) are compared to those obtained with the Tahitian clone of *Isochrysis* sp. (TISO) and with *Tetraselmis suecica* (TETRA), supplied as monoalgal and mixed diets until the stage of mysis I (M I). With TETRA, mortality was 100% before the change to PZ III, the second lowest survival until M I was with the mixture TISO + TETRA and the highest was with CHGRA as the only food source. After 114 h of culture, the best development was with CHGRA supplied alone or in any mixture (90–95% M I), the lowest was with TISO (13%) and the mixture TISO + TETRA gave an intermediate value. The larvae fed with TISO had also the lowest total length (1.8 mm), compared to the 2.5–2.6 mm found with all diets containing CHGRA. The presence of TETRA improved the food value of TISO for growth, but not for survival, whereas TISO affected the performance of CHGRA. After 114 h of culture, the larvae fed with TISO had the lowest organic weight, those fed with TISO + TETRA and TISO + CHGRA had intermediate weights and the best results were with CHGRA alone, or mixed with TETRA or with the other two species. All rations were different in weight because they were used in equal cell concentrations. In a separate experiment, TISO was supplied as a single and double daily ration because of its low individual weight, and this increased the final weight of the larvae by less than 30%, but it did not improve final survival rate, rate of development or final length. In addition, the weight gain was lower than with the CHGRA diet, showing that TISO is not appropriate for *L. vannamei* PZ larvae, and that a monoalgal diet based on CHGRA is a convenient option for early larval feeding of this species, possibly because of its high content of the PUFAs, EPA and ARA, and because of a low demand of DHA of these larvae. The absence of this PUFA in TETRA is a possible cause of the total mortality observed when this alga was supplied as a monospecific diet.

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#### EFFECTS OF LIPID ON GROWTH AND FEED UTILIZATION OF WHITE SEABASS (*TRACTOSCION NOBILIS*) FINGERLINGS

Lus M. López, Ana Luisa Torres, Eduardo Durazo, Mark Drawbridge, Dominique P. Bureau-2006

Aquaculture 253 (1-4): 557-563

Abstract:

A study was carried out to examine the effect of lipid level on growth and feed utilization of white seabass. Fingerling white seabass (27 days old,  $0.65 \pm 0.05$  g,  $32 \pm 3.2$  mm) were fed four formulated diets with four levels of lipid (15.5%, 18%, 19.5% and 21.5% of dry matter) at one level of protein (61% crude protein, dry matter (DM) basis) for six weeks. Survival exceeded 90% for all treatments. Weight gain (g) and specific growth rate (SGR, % day<sup>-1</sup>) values indicated that fish fed diets with 15.5% and 18% lipid exhibited higher growth performance. Lowest growth was recorded for fish fed diets with 19.5% and 21.5% lipid. Feed intake (FI, g fish<sup>-1</sup>) was also significantly ( $P < 0.001$ ) affected by dietary lipid levels and tended to decrease with increasing lipid levels. However, the fish that showed the highest FI were those that were fed the 15.5% and 18% lipid diets. Feed conversion ratio (FCR) values indicated that diets containing 19.5% and 21.5% lipid were more efficiently utilized. No significant differences in muscle composition were observed among fish fed the different diets. However, there was a strong linear relationship ( $P < 0.05$ ) between dietary lipid level and liver lipid. Hepatosomatic index (HSI) increased with dietary lipid level. Results indicated that fish performed best with the diets containing 15.5% and 18% lipid when protein concentration was  $61.45 \pm 0.07\%$ . And, reduced growth and increased body fat were evident when dietary energy increased



from 24.2 to 24.9 kJ g<sup>-1</sup>. More work is needed to determine the precise dietary protein and carbohydrate requirements for this profitable aquaculture species.

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#### BIOCHEMICAL COMPOSITIONS AND DIGESTIVE ENZYME ACTIVITIES DURING THE EMBRYONIC DEVELOPMENT OF PRAWN, MACROBRACHIUM ROSENBERGII

Jun-jie Yao, Yun-long Zhao, Qun Wang, Zhong-liang Zhou, Xian-cheng Hu, Xiao-wei Duan, Chuan-guang An-2006

Aquaculture 253 (1-4): 573-582

Abstract:

Biochemical composition and digestive enzyme activities of eggs during embryonic development were studied in the freshwater prawn, *Macrobrachium rosenbergii*. Proteins, lipids and carbohydrates were the main components in the embryos of *M. rosenbergii*. The proteins in yolk were used mainly as the structural substance, whereas the lipids and carbohydrates were used mainly as the energy sources. Protein content generally increased while lipid and carbohydrate contents decreased during the embryonic development. Seventeen amino acids, including eight essential amino acids, were found in every stage of embryonic development. The ratio of the contents of each essential amino acid (EAA) to total essential amino acid (TAA) remained unchanged during the different stages of embryonic development. The proportional content of glutamic acid was the highest among all the amino acids, and leucine content was the highest among the EAAs. The predominant fatty acids, in terms of relative proportion, were C16:0, C18:1n-9, C18:2n-6, C18:0 and C16:1 in each embryonic development stage. The monounsaturates (MUFA) were the preferentially utilized components of the unsaturates (UFA). C18:1n-9c was mainly used as an energy source during embryonic development, whereas C18:3n-3 and ARA mainly acted as the structural substances in embryos. SFA acted as the main energy source during early stages, from fertilized egg to gastrula stage, and MUFA acted as the main energy source from egg nauplius to egg metanauplius stage. HUFA were used mainly as energy sources during late stages. Of the five digestive enzymes assayed, activities of pepsin, trypsin and amylase were relatively high. Activities of pepsin, trypsin, amylase and cellulase increased during both the early and later embryonic stages, but decreased during the middle stages. The activity of lipase decreased after the gastrula stage. The gastrula stage was a special stage of embryonic development where organ anlage came into being. Activities of pepsin, trypsin, amylase and cellulase reached the highest level during the zoea stage. Variations of biochemical compositions and digestive enzyme activities were closely related to events in morphogenesis during the embryonic development of *M. rosenbergii*.

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#### INFLUENCE OF DIETARY PHOSPHORUS LEVELS ON GROWTH, METABOLIC RESPONSE AND BODY COMPOSITION OF JUVENILE SILVER PERCH (*BIDYANUS BIDYANUS*)

Shuenn-Der Yang, Tain-Sheng Lin, Fu-Guang Liu, Chyng-Hwa Liou-2006

Aquaculture 253 (1-4): 592-601

Abstract:

A growth trial was conducted to estimate the phosphorus requirement of juvenile silver perch. Effects of dietary phosphorus levels on the selected minerals in plasma, vertebrae and whole body, liver lipid classes and postprandial accumulated ammonia excretion of the fish were also examined. Eight semipurified (casein-gelatin based) diets were formulated to contain 42% crude protein, 15.74 MJ digestible energy/kg diet and phosphorus (monobasic sodium phosphate) levels ranging from 0.24% to 1.08%. Each diet was fed to triplicate groups of 12 fish (initial average weight of 2.27 g) over 8 weeks. At the end of the trial, percent weight gain increased significantly ( $P < 0.05$ ) with increasing dietary phosphorus from 0.24% to 0.72%; the value slightly decreased thereafter. A similar trend was

observed in the feed efficiency. The result of broken line regression indicated that phosphorus requirement of juvenile silver perch for maximal growth was satisfied with a diet containing 0.71% phosphorus (about 0.45 mg phosphorus per MJ digestible energy). The amount of postprandial ammonia excretion in fish fed lower dietary phosphorus levels was higher than that of fish fed diets with sufficient phosphorus. Lipid contents in the whole body and liver were higher in fish received lower dietary phosphorus levels. A similar tendency was also found in triacylglycerols, while phosphatidylcholine and phosphatidylethanolamine levels were significantly higher in fish fed diets with sufficient phosphorus. Plasma inorganic phosphorus concentrations increased with increasing dietary phosphorus levels and reached a plateau within 0.72–1.08% levels, but dietary treatment had no effects on plasma calcium, magnesium or zinc, and the activity of plasma alkaline phosphatase was higher in fish fed diets with insufficient phosphorus. The ash contents of the fish body and vertebrae were lower in fish fed lower dietary phosphorus levels. Calcium, phosphorus and magnesium concentrations in the whole body and vertebrae increased with increasing dietary phosphorus levels, and reached a plateau or even slightly decreased at phosphorus levels from 0.72% to 1.08%. However, concentrations of zinc in both body and vertebrae were not affected by dietary treatments. Signs of phosphorus deficiency were characterized by poor growth, loss of appetite, dark coloration, lower physical activity, poor bone mineralization and an increase in lipid content of fish body and liver.

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#### EFFECTS OF DIETARY VITAMIN A OR B-CAROTENE CONCENTRATIONS ON GROWTH OF JUVENILE HYBRID TILAPIA, OREOCHROMIS NILOTICUS × O. AUREUS

Chien-Jen Hu, Su-Mei Chen, Chih-Hung Pan, Chen-Huei Huang-2006

Aquaculture 253 (1-4): 602-607

Abstract:

A series of two 10-week feeding trials was conducted to evaluate the effects of dietary vitamin A or  $\beta$ -carotene supplementation on the growth of hybrid tilapia. In trial I, tilapia of 1.60 g body weight were fed diets supplemented with 0 to 50,000 IU vitamin A (as retinyl acetate)  $\text{kg}^{-1}$ . In trial II, basal diets without vitamin A supplementation were supplemented with 0 to 200 mg  $\beta$ -carotene/kg and fed to tilapia of 0.48 g initial weight. Growth performance of fish fed diets without vitamin A or  $\beta$ -carotene supplementation was significantly ( $P < 0.05$ ) lower than other groups within the trial. Analyzed by the broken-line regression model, dietary vitamin A required for optimal growth of juvenile tilapia was 5850 to 6970 IU  $\text{kg}^{-1}$  based on the weight gain and liver vitamin A retention. Further, dietary  $\beta$ -carotene for optimal growth of juvenile tilapia was 28.6 to 44.3 mg  $\text{kg}^{-1}$  at a dietary vitamin A content of 84 IU  $\text{kg}^{-1}$ . Tilapia is able to utilize  $\beta$ -carotene to fulfill the dietary vitamin A requirements. The conversion ratio by weights of  $\beta$ -carotene to vitamin A was approximately 19 : 1.

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#### THE EFFECT OF NUCLEIC ACIDS ON GROWTH, UREA GENESIS AND NITROGEN EXCRETION OF GILTHEAD SEA BREEM SPARUS AURATA JUVENILES

A. Oliva-Teles, M.J. Guedes, C. Vachot, S.J. Kaushik-2006

Aquaculture 253 (1-4): 608-617

Abstract:

The aim of this trial was to evaluate the effect of dietary nucleic acids on ureagenesis and nitrogen balance in gilthead sea bream juveniles. For that purpose, 5 isonitrogenous (7.25% N) diets were formulated based on fish meal as protein source (FM-control diet) and to partially replace the fish meal nitrogen with two levels of nucleic acids (diets RNA1 and RNA2) or brewers yeast (diets BY1 and BY2). Each diet was fed for 10 weeks, to apparent visual satiety, to triplicate groups of 50 fish each with an average body weight of 12.7 g.

Inclusion of nucleic acid N either as brewers yeast or RNA led to significant improvement of feed intake and growth, except for fish fed diet RNA2. There were no differences in final weight between groups fed the yeast- and the RNA-containing diets. Although there was an improvement of growth rate of fish fed the RNA or yeast containing diets, dietary nucleic acid supplementation did not have a clear N sparing effect. At the end of the trial there were no significant differences in whole body composition among groups, except for the lipid content which was significantly higher in fish fed the Y2 diet.

Hepatic glutamate dehydrogenase activity levels did not differ among groups. Ornithine carbamyl transferase activities were very low in all groups, but appear to be induced by high levels of dietary RNA. Fish fed the yeast diets exhibited the highest arginase activity of all groups. No increase of uricase activities was observed in fish fed the RNA supplemented diets.

Ammonia and urea excretion of fish fed the RNA-including diets was higher or significantly higher than in the other groups. Plasma urea levels were higher in fish fed the RNA diets than in the other groups confirming excretion data in that dietary nucleic acid influenced urea excretion through uricolysis.

In conclusion, substitution of N supplied by fish meal by that supplied by brewers yeast had a positive effect on growth performance of sea bream, while dietary nucleic acid supplementation did not have a clear N sparing effect. At a dietary level of 11.5% of RNA extract, there was no improvement of fish performance compared to the control, possibly due to an insufficient capacity of fish to degrade high levels of nucleic acid. Data on excretion and plasma metabolites strongly suggest that purinolysis contributes also to ureogenesis in gilthead sea bream.

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#### NEW MICROALGAE FOR THE PACIFIC OYSTER CRASSOSTREA GIGAS LARVAE

E. Ponis, I. Probert, B. Véron, M. Mathieu, R. Robert-2006

Aquaculture 253 (1-4): 618-627

Abstract:

The number of microalgae of high nutritional value actually available to mollusc hatcheries is limited to a few species and this represents a constraint for the industry. Fifteen microalgal species belonging to seven different taxonomic classes were selected from the Algobank-Caen microalgal culture collection of the University of Caen. An initial screening of these microalgae, based on their cytomorphological characteristics and growth performances, led to the selection of four species (*Imantonia rotunda*, *Emiliana huxleyi*, *Pseudoisochrysis paradoxa* and *Diacronema vlkianum*), which were then tested as food for *Crassostrea gigas* larvae. Two species (*I. rotunda* and *E. huxleyi*) were of poor food value for oyster larvae, while *P. paradoxa* and *D. vlkianum* resulted in high growth rate and low mortality. These two microalgae were then characterised (dry weight, ash, gross composition, fatty acids) at different stages of growth and their productivity in standard hatchery conditions (2-l glass carboys, 300-l cylinders) was assessed in order to evaluate the potential of these species for use in commercial hatcheries.

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#### COMPARISON OF DIETS CONTAINING VARIOUS FISH MEAL LEVELS ON GROWTH PERFORMANCE, BODY COMPOSITION, AND INSULIN-LIKE GROWTH FACTOR-I OF JUVENILE CHANNEL CATFISH ICTALURUS PUNCTATUS OF DIFFERENT STRAINS

Menghe H. Li, Brian C. Peterson, Charles L. Janes, Edwin H. Robinson-2006

Aquaculture 253 (1-4): 628-635

Abstract:

A 3 × 3 factorial experiment was conducted in flow-through aquaria to evaluate effects of diets, containing 0%, 4%, or 8% menhaden fish meal, on growth performance, body composition, and insulin-like growth factor-I (IGF-I) of juvenile channel catfish of Mississippi “normal” (MN), NWAC103 [formally known as USDA103], or USDA303 strains. Twenty fish with an average weight of 4.7 ± 0.1 g fish<sup>-1</sup> (± S.D.) were stocked into each of 36, 110-l aquaria (four aquaria per treatment). Fish were fed 28%-protein diets containing various levels of fish meal to approximate satiation twice daily for 9 weeks. Regardless of fish strain, fish fed diets containing 4% or 8% fish meal had higher diet consumption, final weight, and feed efficiency (FE) than fish fed an all-vegetable diet. Regardless of fish meal level, NWAC103 and USDA303 channel catfish consumed more diet, gained more weight, and converted diet more efficiently than MN fish. No differences were observed in diet consumption, final weight, and FE between NWAC103 and USDA303 strains. There was an interaction in specific growth rate between fish strain and fish meal level. Specific growth rate was greater for MN fish fed diets containing 4% or 8% fish meal than fish fed the all-vegetable diet, whereas there were no differences in specific growth rate for NWAC103 and USDA303 fish fed various diets. Fillet protein was lower and fillet fat was higher for NWAC103 and USDA303 strains than for the MN strain. Plasma IGF-I levels were greater in NWAC103 and USDA303 channel catfish than in MN fish. Levels of IGF-I were similar between NWAC103 and USDA303 fish. The addition of fish meal to the all-vegetable diet for the three strains did not affect levels of IGF-I. Mean plasma IGF-I concentration was positively correlated to specific growth rate. Results from the present study indicated that the optimum inclusion level for fish meal was 4% of a soybean meal-based diet (fish meal levels higher than 8% were not evaluated in the present study). Including 4% fish meal in the diet improved the performance more for the MN strain than for NWAC103 and USDA303 strains, suggesting that a genotype-diet interaction exists in juvenile channel catfish. Performance of the NWAC103 and USDA303 channel catfish fed the all-vegetable diet was better than MN fish fed the same diet. Plasma IGF-I concentration may be a good indicator for channel catfish growth.

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#### DEVELOPMENTAL CHANGES IN STOMACH, INTESTINE, AND SKIN GLYCOCONJUGATES IN SUMMER FLOUNDER (*PARALICHTHYS DENTATUS*): A LECTIN HISTOCHEMICAL STUDY

Bruno Soffientino, Marta Gomez-Chiarri, Jennifer Specker-2006

Aquaculture 253 (1-4): 680-687

Abstract:

This study asked whether the glycoconjugates of stomach, intestine, and skin epithelia and their mucous secretions change during metamorphosis in summer flounder. Larvae and juveniles were assayed histochemically with biotinylated lectins, and scored for differences in staining intensity and specificity between the two developmental stages. In the stomach epithelium, the number of positive lectins changed little from larvae to juveniles; however, the secreted mucus increased in staining with DBA, ECL, GSA II, PNA, and SBA lectins. In the intestine, a developmental decrease in the binding intensity of the intestinal brush border was noted for DSL, RCA120, VVA, SNA, and UEA I lectins, while intestinal goblet cells underwent a large increase in binding for GSA II. The skin mucous cells of the larvae were negative for DBA, DSL, ECL, PNA, RCA120, and SNA, but became positive in the juveniles. In conclusion, this study showed that changes in glycoconjugate expression occur during metamorphosis in the stomach, intestine, and skin of summer flounder. The changes in the gut glycoconjugates correlate developmentally with shifts in bacterial flora composition found by other studies, and therefore might be relevant to the study of bacteria–host relationships in summer flounder.

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FUNCTIONAL CHANGES IN DIGESTIVE ENZYMES AND CHARACTERIZATION OF PROTEASES OF SILVER CARP (♂) AND BIGHEAD CARP (♀) HYBRID, DURING EARLY ONTOGENY

Rina Chakrabarti, Raja Mansingh Rathore, Prabhat Mittal, Sunil Kumar-2006  
Aquaculture 253 (1-4): 694-702

Abstract:

Study of digestive enzyme and partial characterization of proteases of silver carp (♂) and bighead carp (♀) hybrid during early ontogeny was performed. Specific amylase activity was observed in 4 DAH ( $0.07 \pm 0.01$  mg maltose mg protein<sup>-1</sup> min<sup>-1</sup>) carp hybrid. Specific amylase activity showed polynomial relationship with the age of fish. Total protease, trypsin and chymotrypsin activities were  $14.37 \pm 2.21$ ,  $11.38 \pm 1.67$  and  $2.83 \pm 0.50$  mUnits mg protein<sup>-1</sup> min<sup>-1</sup> in 4 DAH fish, respectively. Total protease activity showed exponential trend, whereas trypsin and chymotrypsin activities showed polynomial relationships with the increasing age of the fish. Lipase activity was  $2.33 \pm 0.18$  mUnits in 4 DAH carp hybrid. Lipase activity showed polynomial trend with the increasing age of fish. In inhibition study, SBTI, PMSF, TLCK and TPCK inhibited the protease activity by 83.0% to 92.0%, 71.0% to 81.0%, 45.1% to 55.5% and 35.8% to 48.2%, respectively. SDS-PAGE showed the presence of various protein bands (20.9–69.4 kDa) in carp hybrid during ontogenic development. Substrate SDS-PAGE revealed the presence of several protease activity bands (19.1–73.7 kDa) in digestive tissue extract of fish during ontogenesis. Inhibition of protease activity bands in substrate SDS-PAGE with SBTI and PMSF revealed the abundance of serine proteases and inhibition of activity bands with TLCK and TPCK evidenced the presence of more than one isoform of trypsin and chymotrypsin in the digestive tissue extract of hybrid carp.

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EFFECT OF CULTURE DEPTH ON THE PROXIMATE COMPOSITION AND REPRODUCTION OF THE PACIFIC OYSTER, CRASSOSTREA GIGAS FROM GOSUNG BAY, KOREA

Thao T.T. Ngo, Sang-Gyun Kang, Do-Hyung Kang, Patrick Sorgeloos, Kwang-Sik Choi-2006  
Aquaculture 253 (1-4): 712-720

Abstract:

We investigated seasonal variation in the reproductive output and proximate composition of tissues (protein, lipid, and carbohydrate) of the Pacific oyster, *Crassostrea gigas* Thunberg, at the top (0–2 m) and bottom (3–5 m) of a long-line suspended culture in Gosung Bay, Korea. The water temperature was 2–3 °C higher at the surface than at the bottom from early spring to mid-summer. The chlorophyll a level was also higher at the surface during March and April, when a spring phytoplankton bloom occurred in the bay. The seasonal variation in the proximate composition of oyster tissues differed between the surface and the bottom as well. Carbohydrate levels in oysters at the surface were somewhat higher in fall and winter, when the oysters were actively accumulating carbohydrates in their tissues for future growth and reproduction. Oysters at the surface tended to produce more eggs during the spring to early summer spawning period; the gonadosomatic index (GSI) was significantly higher in surface oysters than in bottom oysters ( $p < 0.05$ ). The overall growth and reproduction rates of the surface oysters were higher, even though the bottom oysters were located only 1–3 m below them. Accordingly, our data suggest that culture depth in the traditional long-line suspended culture needs to be re-evaluated to maximize oyster production.

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