

EVALUATION OF PARTIAL WATER REUSE SYSTEMS USED FOR ATLANTIC SALMON SMOLT PRODUCTION AT THE WHITE RIVER NATIONAL FISH HATCHERY

S.T. Summerfelt, M. Sharrer, M. Gearheart, K. Gillette, B.J. Vinci-2009

Aquacultural Engineering 41(2):78-84

Abstract:

Eight of the existing 9.1 m (30 ft) diameter circular culture tanks at the White River National Fish Hatchery in Bethel, Vermont, were retrofitted and plumbed into two 8000 L/min partial water reuse systems to help meet the region's need for Atlantic salmon (*Salmo salar*) smolt production. The partial reuse systems were designed to increase fish production on a limited but biosecure water resource, maintain excellent water quality, and provide more optimum swimming speeds for salmonids than those provided in traditional single-pass or serial-reuse raceways. The two systems were stocked with a total of 147,840 Atlantic salmon parr in May of 2005 (mean size 89 mm and 8.5 g/fish) and operated with 87–89% water reuse on a flow basis. By the time that the smolt were removed from the systems between March 28 to April 12, 2006, the salmon smolt had reached a mean size of 24 cm and 137 g and hatchery staff considered the quality of the salmon to be exceptional. Overall feed conversion was <1:1. The Cornell-type dual-drain circular culture tanks were found to be self-cleaning and provided mean water rotational velocities that ranged from a low of 0.034 m/s (0.2 body length per second) near the center of the tank to a high of 39 cm/s (2.2 body length per second) near the perimeter of the tank. The fish swam at approximately the same speed as the water rotated. System water quality data were collected in mid-September when the systems were operated at near full loading, i.e., 24 kg/m³ maximum density and 52.1 and 44.1 kg/day of feed in system A and system B, respectively. During this evaluation, afternoon water temperatures, as well as dissolved oxygen (O₂), carbon dioxide (CO₂), total ammonia nitrogen (TAN), and total suspended solids (TSS) concentrations that exited the culture tank's sidewall drains averaged 14.8 and 15.9 °C, of 7.9 and 8.2 mg/L (O₂), 4.0 and 3.2 mg/L (CO₂), 0.72 and 0.67 mg/L (TAN), and 0.52 and 0.13 mg/L (TSS), respectively, in system A and system B. Dissolved O₂ was fairly uniform across each culture tank. In addition, water temperature varied diurnally and seasonally in a distinct pattern that corresponded to water temperature fluctuations in the nearby river water, as planned. This work demonstrates that partial reuse systems are an effective alternative to traditional single-pass systems and serial-reuse raceway systems for culture of fish intended for endangered species restoration programs and supplementation programs such as salmon smolt.

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DESIGN KEYS OF A RECENT RECIRCULATING FACILITY BUILT IN CHILE OPERATING WITH FLUIDIZED BED BIOFILTERS

Rafael I. Morey-2009

Aquacultural Engineering 41(2): 85-90

Abstract:

The fast evolution of recirculation systems for salmonids has challenged the engineering companies to develop new and better design and engineering practices, to improve the water quality and system flexibility. One of the major factors that affect the water quality parameters is the total suspended solids produced within the system. The design of water flow from the water inlet into the culture tank down to the effluent pipeline and the water filtration unit, will determine a system's performance. Two recirculating systems for 250 and 1500 m³ have been designed and built applying specific design keys focused in good solids removal, system removal exchange, piping size and layout, filtration process, biofiltration units, gas balancing and CO₂ removal, oxygenation devices, and disinfection process. All these treatments have been designed and built for both facilities, and they are currently operating with very good results. Both facilities are in separate isolated buildings but in the same hatchery site. They share a common heat pump unit that delivers chilled water to the incubation room, and the makeup

water is from several wells on site. This paper describes the main design keys used under this project focusing on the small recirculation system (250 m³).
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PROBLEMS AFFECTING NITRIFICATION IN COMMERCIAL RAS WITH FIXED-BED BIOFILTERS FOR SALMONIDS IN CHILE

Esteban J.M. Emparanza-2009

Aquacultural Engineering 41(2): 91-96

Abstract:

The present case study focused on the problems that affect the nitrification process at three commercial recirculating aquaculture systems (RAS) for salmonids with fixed-bed biofilters operating in Chile, where the main factors were found to be management problems: (1) large variations in daily feeding, which results in unstable nitrogenous compounds (TAN, NO₂⁻, NO₃⁻) concentration; (2) variable daily water exchange, producing unstable culture conditions (variations in pH and temperature); (3) high densities of culture, which results in overall bad culture conditions (high CO₂ concentration, high amount of fine solids, high oxygen consumption). When properly managed, the RAS have proven to tolerate up to 15% of daily variation in feeding, as low as 10% of daily “new” water inlet, and densities as high as 60 kg fish/m³ without showing any nitrification problems. The results from this study demonstrates that maintaining good water quality is essential to secure an efficient growth of both the target species and the nitrifying bacteria, therefore, the production strategies should consider both the target species and the nitrification process requirements.

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GROUNDWATER WATER TREATMENT FOR IRON AND MANGANESE REDUCTION AND FISH REARING STUDIES APPLIED TO THE DESIGN OF THE RUTH BURNETT SPORT FISH HATCHERY, FAIRBANKS, ALASKA

James T. Fish-2009

Aquacultural Engineering 41(2): 97-108

Abstract:

Studies at the Fairbanks Experimental Fish Hatchery (FEFH) were conducted to investigate the operational characteristics of media filtration groundwater treatment for iron and manganese reduction, water reuse and recirculation technologies for fish rearing, and conditions of fish gill tissue during rearing. Results were used to aid in the design and planned operation of the Ruth Burnett Sport Fish Hatchery (RBSFH), currently under construction in Fairbanks, Alaska. Under a two-stage filtration scenario, with hydraulic loading rates of 0.39 and 0.43 cm/s for Stages 1 and 2, respectively, manganese dioxide media filtration typically removed dissolved iron from 5 to 6.5 mg/L down to 0.1 mg/L or less, and allowed for suitable fish rearing and health (based on gill condition) in treated groundwater. Poor water quality from filter equipment malfunction or improper operation typically manifested tissue damage (epithelial lifting, hypertrophy, degeneration, and in some cases iron adhesion) observed in fish gills. Design refinements from initial use, including changes in hydraulic loading rates and transition from single-stage to two-stage filtration, were required for long-term use of media filtration and were included in the design of the future hatchery. Dissolved manganese removal from groundwater (from 0.7 to <0.05 mg/L) was also implemented by continuous low-level potassium permanganate addition. Small-scale flow-through, fully recirculating, and partial reuse rearing systems were used to mimic planned future fish production, and resulted in 97% or greater survival and adequate growth (average specific growth rate between 1 and 2%) and health of rainbow trout during most rearing trials.

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COMPARATIVE GROWTH STUDY OF WILD- AND HATCHERY-PRODUCED ARCTIC CHARR (*SALVELINUS ALPINUS* L.) IN A COLDWATER RECIRCULATION SYSTEM

Sten Ivar Siikavuopio, Steinar Skybakmoen, Bjørn-Steinar Sæther-2009

Aquacultural Engineering 41(2): 122-126

Abstract:

The growth performance of Arctic charr of wild (W) and hatchery (H) origin was compared in a commercial coldwater recirculation system (Villmarksfisk, Bardu, 68°N, 19°E, Norway). The initial individual body mass was 115 g and similar between groups. The rearing temperature was 9.2 °C and the fish were held under continuous light (24:0 L:D). At the end of the experiment (day 240), the average body mass of the H fish was 451 g compared to 231 g in the W fish. The accumulated mortality of wild Arctic charr was about 40%; 10 times higher than the mortality of hatchery-produced Arctic charr (4%). The difference in growth performance and survival rate impose a great disadvantage of using this wild caught fish as compared to commercially available hatchery-produced Arctic charr in coldwater recirculation system. However, further improvements in the production chain (catching, live transport, quarantine, size grading, etc.) may still make production of wild caught Arctic charr profitable, especially as it demands a higher price in niche markets.

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PREVALENCE OF ZOONOTIC TREMATODE PARASITES IN FISH FRY AND JUVENILES IN FISH FARMS OF THE MEKONG DELTA, VIETNAM

Cu Pham Thien, Anders Dalsgaard, Nguyen Thanh Nhan, Annette Olsen, K. Darwin Murrell-2009

Aquaculture 295(1-2): 1-5

Abstract:

Zoonotic parasites are a significant food safety problem, particularly in Asia. In Vietnam fishborne zoonotic trematodes (FZT) are highly prevalent in fish cultured in grow-out farms. However, FZT infection status of juveniles produced and distributed by hatcheries and nurseries is unknown. Here we report an epidemiological investigation on FZT in fry and juveniles of major cultured freshwater fish species in four provinces of the Mekong Delta of Vietnam. No FZT infections were found in 14 species of fry sampled from hatcheries. In contrast, nursery juveniles of river catfish, hybrid catfish, giant gouramy, climbing perch, common carp, kissing gouramy, silver barb, silver carp, grass carp, Indian carp, pacu, tilapia and snakeskin gouramy were frequently infected with FZT metacercariae (range 1.2–29.7%). Seasonal variation in prevalence was observed: prevalence in river catfish and hybrid catfish were maximal in January, at the end of the flooding season, while the prevalence in juveniles of giant gouramy, climbing perch, common carp, kissing gouramy, silver barb, silver carp grass carp, mrigal and pacu were higher in the wet season, June to November. Overall, FZT prevalence was highest in climbing perch and giant gouramy (29.7% and 27.8%, respectively) and the lowest in river catfish (1.2%). The density of FZT metacercariae in fish varied seasonally only in climbing perch which was maximal in the wet season ($P < 0.05$), compared to the dry season (430 vs 28 metacercariae/100 g of fish). These results demonstrate that acquisition of infected seed stock from nurseries is a serious risk for Vietnamese grow-out fish farms, and stress that interventions to control FZT must focus also on these stages of the cultured fish production cycle.

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MICROSATELLITE PEDIGREE ANALYSIS REVEALS HIGH VARIANCE IN REPRODUCTIVE SUCCESS AND REDUCED GENETIC DIVERSITY IN HATCHERY-SPAWNED NORTHERN ABALONE

Matthew A. Lemay, Elizabeth G. Boulding-2009

Aquaculture 295(1-2): 22-29

Abstract:

The northern (or pinto) abalone, *Haliotis kamtschatkana*, is a broadcast-spawning marine gastropod that was recently listed as endangered in Canada. To aid in species recovery, a captive-breeding and supplementation program is underway in Barkley Sound, British Columbia. We genotyped first generation progeny for five microsatellite loci and used a pedigree reconstruction program (Pedigree 2.2) to identify their genealogical relationships in the absence of information on parental genotypes. We analyzed progeny from three separate group-spawning events and inferred considerable variation in the number of offspring produced by each parent; in the most severe case a single male sired all the progeny produced during one spawning event. After only one generation of captive-breeding we found a 55–60% reduction in allelic richness and a 17–18% reduction in heterozygosity relative to the diverse wild source population. This study illustrates the difficulty of managing genetic diversity in hatchery populations of a broadcast-spawning species, even when gametes are collected separately from each individual broodstock.

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IMPACT OF A NEW ARTIFICIAL SHELTER ON ARCTIC CHARR (*SALVELINUS ALPINUS*, L.) BEHAVIOUR AND CULTURE PERFORMANCE DURING THE ENDOGENOUS FEEDING PERIOD

D. Benhaïm, C.A. Leblanc, G. Lucas-2009

Aquaculture 295(1-2): 38-43

Abstract:

Shelter is of major importance in many species of fish both in the wild and in aquaculture. Sheltering behaviour of Arctic charr has been poorly studied in aquaculture. A new type of shelter made of PVC agricultural drain cut in half was tested on culture performance and behaviour during the endogenous feeding period. This device offered grooves where alevins could position themselves and lie in a vertical position. A first experiment compared fish with and without shelter in incubator compartments. All fish were measured at 122, 158, and 190 days post fertilization (dpf) and observed at 126, 139 and 157 dpf. Fish provided with shelter showed better growth performances, lower mortality and started first exogenous feeding about six days later compared to fish without shelter. These effects from shelter provision were also associated with much less mobility in fish provided with shelter. At 126 dpf, all fish provided with shelter were immobile while other fish displayed horizontal stationary body movement (86%) or swam against the water current (7%). At 157 dpf, 85% of fish without shelter were immobile compared to 95% in fish provided with shelter. Both categories displayed stationary body movements. In most cases, there was one single fish per groove and a stable average value of 2.4 grooves was maintained between two successive fish throughout the study. The second experiment was a preference test where the fish were placed in similar compartments but occupied by a half shelter. We found that 61% of the fish were located under the shelter at 122 dpf while at 157 dpf, 58% were on the shelter and 42% out of the shelter. The present results revealed Arctic charr behavioural characteristics in the presence of a new type of artificial shelter at very early stages of development. This shelter enables the fish to stabilize in a vertical position without producing any movement and to choose by itself its favorite location throughout development. This device could be used to improve Arctic charr growth, performance and fish welfare during the endogenous feeding period.

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DESCRIPTION OF THE LARVAL MORPHOLOGY OF CAPTIVE REARED PANULIRUS ORNATUS SPINY LOBSTERS, BENCHMARKED AGAINST WILD-CAUGHT SPECIMENS

Greg Smith, Matt Salmon, Matt Kenway, Michael Hall-2009

Aquaculture 295(1-2) : 76-88

Abstract:

The spiny lobster *Panulirus ornatus* is a high value seafood product in a number of South East Asian countries. However, this species is relatively rare in the wild compared to other Palinurid lobsters, and

the development of an aquaculture sector for *P. ornatus* offers a potential avenue of matching supply with demand. To be a true sustainable farming sector it is essential that closed-life cycle production technology is developed. Recent efforts to complete the larval cycle of *P. ornatus* in captivity have resulted in repeated success and sufficient material to compile a complete morphological description of the larval (phyllosoma) phase. A morphological comparison is made between hatchery reared phyllosoma and specimens collected from the wild. The size of wild caught and captive reared phyllosomas did not differ significantly. However, it was noted that some hatchery reared individuals undergo truncated development with the ability to metamorphose in a shorter than expected time frame compared to estimates of wild phyllosomas. Observations are made on the plasticity of the larval duration in *P. ornatus*. Up to a total of 24 morphological increments were recorded in captive and wild *P. ornatus* phyllosoma. These were divided into 11 distinct stages by determining the commencement and completion of specific morphological traits. This descriptive morphological key provides a singular reference point for monitoring larval development in this species. The variable nature of the larval duration of *P. ornatus* suggests that the optimisation of husbandry and nutrition conditions may significantly reduce the length of the hatchery phase and enhance the possibility of providing seedstock for an aquaculture industry based on closed-life cycle spiny lobster culture. (AIMS@JCU and Australian Institute of Marine Science, PMB no.3 Townsville MC, QLD 4810, Australia; email of Greg Smith: g.smith@aims.gov.au)

EFFECTS OF PROTEIN AND LIPID CONCENTRATIONS IN BROODSTOCK DIETS ON GROWTH, SPAWNING PERFORMANCE AND EGG QUALITY OF YELLOWFIN SEA BREAM (*ACANTHOPAGRUS LATUS*)

Mohammad Zakeri, Jasem G. Marammazi, Preeta Kochanian, Ahmad Savari, Vahid Yavari Mahsa Haghi-2009

Aquaculture 295(1-2) : 99-105

Abstract:

A study was conducted to determine the effects of dietary protein and lipid concentrations on growth, spawning performance and egg quality of yellowfin sea bream, *Acanthopagrus latus*. Nine diets representing a combination of three protein concentrations (40, 50 and 60%) and three lipid concentrations (15, 20 and 25%) were tested with three replicates. Each replicate was stocked with 10 fish with a sex ratio of 1:1 and the average weights were 415 g and 236 g for females and males, respectively. Fish were fed to satiation twice daily. The weight gain of *A. latus* broodstock was not significantly ($P > 0.05$) different among fish fed diets with the various protein and lipid concentrations. Except for relative fecundity and survival rate of 3-day-post-hatch (3DPH) larvae, spawning performance of *A. latus* was not significantly affected by different concentrations of dietary protein or lipid. Relative fecundity was found to be significantly elevated by dietary lipid at 20% concentration. However, survival rate of 3DPH larvae was highest from broodstock fed diets with 40% protein and 25% lipid, 50% protein and 15% lipid and 60% protein and 15% lipid concentrations. Egg diameter generally increased with increasing dietary protein from 40 to 60% at each lipid concentration. Total length of hatchlings followed an inverse relationship with dietary protein regardless of the lipid concentration. The oil globule diameter (OGD) of hatchlings significantly increased with decreasing dietary protein from 60 to 40%. Yolk sac length (YSL) and OGD of hatchlings was generally greatest at 15% dietary lipid concentration irrespective of protein concentrations. Total length of 3DPH larvae was greatest from broodstock fed diets with 50% protein and 20% lipid, respectively. Body protein content of broodstock was not significantly affected by dietary protein and lipid concentrations. However, increasing dietary lipid generally resulted in increasing body lipid content regardless of the dietary protein concentration. Protein and lipid contents of eggs, hatchlings and 3DPH larvae were significantly affected by dietary protein and lipid concentrations of the broodstock diets. The present study revealed that the best reproductive performance of *A. latus* broodstock was achieved at 40% dietary protein and 20% dietary lipid concentrations based on relative fecundity, fertilization rate, hatchability and survival of 3DPH larvae. (Department of Marine Biology, Faculty of Marine Science, Marine Science and Technology University, Khoramshahr, Iran; email of Mohammad Zakeri: Zakeri.mhd@gmail.com)

THE RISK OF PARASITE TRANSFER TO JUVENILE FISHES BY LIVE COPEPOD FOOD WITH THE EXAMPLE TRIAENOPHORUS CRASSUS AND TRIAENOPHORUS NODULOSUS
Franz Lahnsteiner, Manfred Kletzl, Thomas Weismann-2009

Aquaculture 295(1-2): 120-125

Abstract :

Natural zooplankton is a potential food resource for juvenile fish in fish farms as it is a good source of fats, carbohydrates, and protein. However, it is also a potential source of parasites and pathogens. The present study was conducted (1) to estimate the risk of parasite transfer by live copepod food under intensive farming conditions using the parasites *Triaenophorus crassus* and *Triaenophorus nodulosus* as example and (2) to look for strategies to avoid parasite infestation of juvenile fish.

An easy and routinely applicable aniline blue staining method was developed to check the infestation levels of copepods with procercoids during the on-growing season of juvenile fish. From the copepod species occurring in zooplankton *Cyclops* spp. was infested frequently ($9.4 \pm 12.0\%$, maximum 38.7%), *Diaptomus* spp. infrequently ($1.5 \pm 1.6\%$, maximum 3.2%), *Daphnia* spp. never. Juvenile grayling, *Thymallus thymallus*, and coregonids, *Coregonus* sp., which had been fed with natural zooplankton revealed infestation rates with *T. crassus* of circa 5%, with *T. nodulosus* of circa 10%. As the occurrence of procercoids in the zooplankton was temporary limited, *Triaenophorus* infestation can be avoided by using artificial food instead of live copepods during the risky season.

To prevent parasite infestation of juvenile fish methods were investigated to eradicate procercoids from copepods by chemical treatment (sodium chloride, hydrogen peroxide, citric acid treatment) and by freeze-thawing methods. Chemical methods failed to remove procercoids. In fish, which had been fed with frozen thawed zooplankton, no *Triaenophorus* spp. infestation was observed. Their survival rates were similar as in the control fed with live zooplankton, however the weight of the fish was significantly lower.

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DOMESTICATION AFFECTS SPAWNING OF THE IDE (LEUCISCUS IDUS)—PRELIMINARY STUDY

Sławomir Krejszeff, Katarzyna Targońska, Daniel Źarski, Dariusz Kucharczyk-2009

Aquaculture 295(1-2): 145-147

Abstract:

Ide, *Leuciscus idus*, breeders in Polish fish farm are cultured or are collected from the wild. The data about differences in reproduction of different ide forms in captivity are limited. In the present paper domesticated and wild stock are reproduced artificially. Cultured fish do not require application of spawning agents. For obtaining good-quality oocytes only stimulation with temperature and photoperiod is necessary.

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ACROSOME REACTION OF CHINESE MITTEN-HANDED CRAB *ERIOCHEIR SINENSIS* (CRUSTACEA: DECAPODA) SPERMATOOZOA: PROMOTED BY LONG-TERM CRYOPRESERVATION

Xianjiang Kang, Genliang Li, Shumei Mu, Mingshen Guo, Shaoqin Ge-2009

Aquaculture 295(3-4): 195-199

Abstract:

The effects of three media, two temperatures, and fourteen durations of cryopreservation from 0 h to 450 d on in vitro acrosome reaction (AR) of spermatozoa in Chinese mitten-handed crab *Eriocheir sinensis* (Crustacea: Decapoda) were investigated. The spermatozoa of good quality were obtained

from spermatophores by a glass homogenizer in an ice-bath and centrifugation at 4 °C. At 0 h, 2 h, 1 d, 3 d, 15 d, 30 d, 60 d, 90 d, 120 d, 150 d, 180 d, 270 d, 360 d, and 450 d of cryo-storage in Ca²⁺-free artificial seawater, 10% (v/v) glycerol, and 5% (v/v) dimethylsulfoxide at – 80 °C and in liquid nitrogen (– 196 °C), the changes in spermatozoal morphology, the time of beginning AR, and the time of maximum percentage of AR were observed. The relationships of the changes on AR presented with the different media, temperatures, and durations of cryopreservation were speculated. In this study, the cryopreserved spermatozoa all underwent AR in less than 1 h of settlement under room temperature while the percentage of AR in the control was only about 4.9%. Meanwhile, cryopreservation shortened both the time of beginning AR (from 30.11 min of the uncryopreserved spermatozoa to 0 min of cryopreserved spermatozoa on the 30th day) and the time of maximum percentage (from 59.88 min of the uncryopreserved spermatozoa to 0 min of cryopreserved spermatozoa on the 60th day). Whereas the effect of media on sperm cell AR was negligible ($P > 0.05$), the treatments of spermatozoa with short- and long-term cryopreservation resulted in extremely significant differences in the time of beginning AR as well as in the time of maximum percentage of AR ($P < 0.01$). The present data indicate that cryopreservation for long or short periods can promote the AR of sperm cells in *E. sinensis* and physiologically affect the ability to capacitate. It may be that the mechanism of AR in this study is the direct promotion of membrane fusion of the acrosomal cap, or destruction of the proteins inhibiting AR and activation of the proteins promoting AR, by cryopreservation. In addition, the results also show that cryopreservation can protect the spermatozoa because AR can occur in almost all sperm cells cryopreserved for less than 15 d.

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DECAPSULATED ARTEMIA CYSTS AS DIETARY SUPPLEMENT FOR JUVENILE CRAYFISH (*PACIFASTACUS LENIUSCULUS*, ASTACIDAE) AT DIFFERENT FOOD SUPPLY FREQUENCIES FROM THE ONSET OF EXOGENOUS FEEDING UNDER CONTROLLED CONDITIONS

R. González, J.D. Celada, J.M. Carral, Á. González, M. Sáez-Royuela, V. García-2009
Aquaculture 295(3-4): 200-204

Abstract:

Considering that the use of decapsulated Artemia cysts as direct food for juvenile crayfish could be an alternative to live nauplii, a 100-day experiment was carried out under controlled conditions to evaluate the effects of cysts, comparing with nauplii, as supplement to a dry diet for salmonids on the survival and growth of juvenile signal crayfish (*Pacifastacus leniusculus*) from the onset of exogenous feeding (stage 2). The reduction of feeding frequency was also tested. According to a bifactorial design, six treatments, differing in the supplement and feeding frequency, were tested: the dry diet supplemented with Artemia nauplii or decapsulated cysts was supplied once a day, once every two days and once every three days. Survival rates ranged from 56.7% to 81.7%, rising significantly with increasing the feeding frequency. The highest growth (12.94 mm carapace length and 593.08 mg weight) was reached by the crayfish that received the dry diet supplemented with cysts once a day, with significant differences from the rest of the treatments. Considering the supplement, the cysts supported significantly higher growth than the nauplii. Regarding the feeding frequency, growth was higher when the food was supplied once a day, showing significant differences from the other two frequencies (once every two days and once every three days). This study shows that decapsulated cysts are better dietary supplement than live nauplii. In crustacean culture, this is the first report of successful use of Artemia cysts from the onset of exogenous feeding.

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BRACHIONUS VS ARTEMIA DUEL: OPTIMIZING FIRST FEEDING OF *UPOGEBIA PUSILLA* (DECAPODA: THALASSINIDEA) LARVAE

Filipa Faleiro, Luís Narciso-2009

Aquaculture 295(3-4) : 205-208

Abstract:

Larval rearing of many marine organisms is dependent on the availability of live food. The aim of this study was to optimize larval first feeding for the mud shrimp *Upogebia pusilla*, by comparing the effectiveness of the two most commonly used live feeds: *Brachionus plicatilis* and *Artemia* sp. nauplii. Survival, larval duration, molt synchronism and megalop size were compared using five feeding treatments: *Artemia* from zoea I to IV (B0), *Brachionus* during zoea I and *Artemia* from zoea II to IV (B1), *Brachionus* during zoea I and II and *Artemia* during zoea III and IV (B2), *Brachionus* from zoea I to III and *Artemia* during zoea IV (B3) and *Brachionus* from zoea I to IV (B4). The proportion of larvae that reached the megalop stage was 0.00% in treatment B0, 3.33% in treatment B1, 33.33% in treatment B2, 66.67% in treatment B3 and 76.67% in treatment B4. Larvae fed on rotifers until zoea III or zoea IV stages had a higher survival but no differences were found either in time to reach megalop or in megalop size. This study demonstrates that rotifers are essential for the survival and development of *U. pusilla* early larval stages but that rotifers can be successfully replaced by *Artemia* nauplii in the zoea IV stage.

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EFFECT OF DIETARY VITAMIN A ON SENEGALESE SOLE (*SOLEA SENEGALENSIS*) SKELETOGENESIS AND LARVAL QUALITY

Ignacio Fernández, Marta S. Pimentel, Juan B. Ortiz-Delgado, Francisco Hontoria, Carmen Sarasquete, Alicia Estévez, Jose Luis Zambonino-Infante, Enric Gisbert-2009

Aquaculture 295(3-4): 250-265

Abstract:

The effects of different levels of vitamin A (VA) in Senegalese sole larval performance and development were evaluated by means of a dietary dose–response experiment using enriched *Artemia* metanauplii as a carrier of this micronutrient. Larvae were fed from 6 to 27 days post hatch (dph) with enriched *Artemia* containing graded levels of total VA (1.3, 2.1, 4.5 and 12.9 µg VA mg⁻¹ DW). The content of VA in live prey directly affected its accumulation in larvae and early juveniles. Retinyl palmitate accumulated during larval ontogeny, whereas retinol showed the opposite trend, decreasing from hatching until 41 dph and then remaining constant until the end of the study.

In metamorphic larvae (10 and 15 dph), VA did not affect the number of thyroid follicles or the intensity of the immunoreactive staining of T3 and T4. However, at older stages of development (post-metamorphic larvae: 20, 30, 41 and 48 dph), VA decreased the number of thyroid follicles but increased their mean size and enhanced T3 and T4 immunoreactive staining. A dietary excess of VA did not affect either larval performance in terms of growth and survival or the maturation of the digestive system. However, the most remarkable impact of this morphogenetic nutrient was detected during skeletal morphogenesis. Dietary VA accelerated the intramembranous ossification of vertebral centrums, which led to the formation of a supranumerary haemal vertebra and a high incidence of fused and compressed vertebrae in fish fed 2.1, 4.5 and 12.9 mg VA mg⁻¹ DW. In addition, VA also affected those structures from vertebrae and caudal fin formed by chondral ossification, leading to defects in their shape and fusions with adjacent skeletal elements. In particular, the caudal fin was the region most affected by the dietary treatments. In order of importance, the bones with more developmental anomalies were the modified neural and haemal spines, epural, hypurals and parahypural. The impact of systemic factors such as thyroidal hormones in skeletogenesis should not be neglected since present results revealed that an excess of dietary VA affected the levels of T3 and T4, which might have affected bone formation and remodelling, leading to skeletal deformities.

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SPERM PRODUCTION IN THE RED CLAW CRAYFISH *CHERAX QUADRICARINATUS*
(DECAPODA, PARASTACIDAE)

Ana B. Bugnota, Laura S. López Greco-2009

Aquaculture 295(3-4) : 292-299

Abstract:

The objective of this study is to evaluate the effect of body size, temperature and annual cycle on sperm production in *Cherax quadricarinatus*. Sperm count and sperm mortality were estimated, the reproductive system was weighted, and macro and microscopical analysis of the testes and vasa deferentia were conducted. Sperm count and weight of the reproductive system are strongly related to male size, in contrast to sperm mortality. The spermatophore structure presented macro and microscopical differences between sizes. Males higher in size have more adherent spermatophores. This species has a reproductive cycle related to sperm production. Sperm count and weight of the vasa deferentia rise in summer, while the weight of the testes increases in winter. During the spring, the sperm cord presents a higher density than in other seasons. The temperature seems to affect sperm production being 27 and 29 °C the best assayed conditions. The present results are relevant information to obtain the best sperm viability selecting male size, season of sampling and the best temperature for the reproductive stock and future assays of spermatophore cryopreservation for this species aquaculture.

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THE RUSSIAN SEAFOOD REVOLUTION: SHIFTING CONSUMPTION TOWARDS
AQUACULTURE PRODUCTS

Trude Berg Andersen, Kristin Lien, Ragnar Tveters, Sigbjørn Tveters-2009

Aquaculture Economics & Management 13(3): 191 - 212

Abstract:

A food consumption revolution is taking place in Russia. After decades of severe constraints on food consumption options under the communist regime Russian consumers are now adopting new food products—including seafood products - at a high pace. Since Russian consumers have previously had very limited seafood consumption choices, the market can be seen as an interesting laboratory for investigating consumer responses to products that have previously not been available. Among imported seafood products are both wild and farmed species. Furthermore, Russian imports include both traditional species such as herring, and 'new' species such as pangasius. We analyze market integration among seafood products using Russian monthly import prices from 2002 to 2007 on several products, such as herring, salmonids and pangasius. We find that pangasius compete in the white fish segment, and is a price leader. In the salmonids market, farmed salmon trout appears to be the price leader, both in the fresh and frozen market segment.

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REPRODUCTIVE PERFORMANCE AND OFFSPRING QUALITY OF CHINESE MITTEN CRAB
ERIOCHEIR SINENSIS (H. MILNE-EDWARDS) FEMALES FED AN OPTIMIZED
FORMULATED DIET AND THE RAZOR CLAM *SINONOVACULA CONSTRICTA*

Xugan Wu, Yongxu Cheng, Chaoshu Zeng, Liying Sui, Paul C Southgate, Gang Zhou, Wenji Bian-2009

Aquaculture Research 40 (12): 1335 – 1349

Abstract:

After feeding female *Eriocheir sinensis* on an optimized formulated diet or fresh razor clam *Sinonovacula constricta* for 7 months, their reproductive performance and offspring quality were compared. To evaluate diet nutrient contents, the proximate, fatty acid and amino acid compositions of the formulated diet and the razor clam were analysed. The nutritional value of the diets was determined by assessing survival, gonadosomatic index (GSI) and hepatosomatic index (HSI) of female crabs from both diet treatments, together with the percentage of females that spawned, total

egg production per female and fecundity (number of eggs g⁻¹ female wet weight). Furthermore, the quality of eggs and newly hatched larvae from the two dietary treatments were determined using the following parameters: egg diameter, wet weight and dry weight, hatchability, proximate and fatty acid profile of eggs, larval carapace length, resistant to starvation and osmotic shock, larval survival and development to the zoea II stage.

Higher protein, phospholipids (PL) and amino acids (AA) contents were found in the razor clam while the formulated diet contains higher levels of ash, total lipid (TL) and 18:1n-9, 18:2n-6 and 22:6n-3 fatty acids. Although female crabs fed the two different diets showed similar reproductive performances, newly hatched zoea I larvae produced by the crabs fed the formulated diet had significantly longer mean carapace length and shorter development time to the zoea II stage under identical culture condition ($P < 0.05$). Moreover, dietary fatty acid appeared to have more significant effects on the fatty acid composition of the hepatopancreas than it did on mature ovaries or eggs. This suggests that the fatty acid profile of mature ovaries is indicative of the specific fatty acid required for ovarian development in *E. sinensis*.

In conclusion, our results show that the optimized formulated diet developed in this laboratory can totally replace the razor clam, a broodstock food widely used in *E. sinensis* hatcheries in China. This encouraging result should facilitate more reliable hatchery production of this important aquaculture species.

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ACTIVITIES OF DIGESTIVE ENZYMES DURING EMBRYONIC DEVELOPMENT IN THE CRAYFISH PROCAMBARUS CLARKII (DECAPODA)

Ying Dai, Ting-Ting Wang, Yu-Feng Wang, Xue-Jie Gong, Cai-Feng Yue-2009

Aquaculture Research 40(12): 1394 – 1399

Abstract:

The red swamp crayfish, *Procambarus clarkii* (Girard), has become an important freshwater species for Chinese inland aquaculture because of its high commercial value and consumer demand. The aim of this study was to gather information about the activity of digestive enzymes at different embryonic stages of *P. clarkii* in order to increase our knowledge about digestive physiology and to guide technology for maternal culture so as to improve the hatching rate. Embryonic developmental stages were divided into six stages: I, fertilized egg; II, cleavage and blastula; III, gastrula; IV, egg nauplius; V, eye pigment forming; and VI, prepared for hatching. Pepsin-specific activity decreased significantly from stage I to stage IV. Although it increased at stage V, the activity level declined again before hatching. Both trypsin- and amylase-specific activity levels dramatically increased in the middle stages of embryogenesis, whereas at the other embryonic stages the activities of these two digestive enzymes were much lower. Lipase-specific activity exhibited a low level during all embryonic stages. The pattern of digestive enzyme activity was related to organogenesis and the utilization of yolk proteins at different embryonic stages.

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DIETARY EFFECTS OF N-3 HIGHLY UNSATURATED FATTY ACID LEVELS ON EGG AND LARVAL QUALITY, AND THE FATTY ACID COMPOSITION OF THE EGGS OF CHILEAN FLOUNDER PARALICHTHYS ADSPERSUS BROODSTOCK

Rodolfo Wilson-2009

Aquaculture Research 40(12): 1400 – 1409

Abstract:

The effects of dietary n-3 highly unsaturated fatty acid (n-3 HUFA) on eggs and larval quality were investigated in the Chilean flounder *Paralichthys adspersus*. Broodstock were fed with three formulated diets with similar proximate compositions but different n-3 HUFA (2.1%, 3.1% or 4.1%)

estimated levels from 5 months before and during the spawning period. The diet with an intermediate n-3 HUFA level resulted in a significantly higher ($P < 0.05$) percentage of buoyant eggs ($68.2 \pm 2.9\%$), fertilization ($92.8 \pm 3.9\%$), normal cell cleavages ($93.5 \pm 1.9\%$), hatching rate ($87.7 \pm 4.1\%$) and normal larvae ($76.3 \pm 3.7\%$) compared with the other two diets. In contrast, high levels of n-3 HUFA produced larvae with a higher survival capacity when subjected to fasting. The diet with the lowest content of n-3 HUFA produces lower quality eggs and larvae. The n-3 HUFA level in eggs increased with an increase in the dietary level, and the n-3/n-6 ratios were 1:1, 2:1 and 3:1. The DHA/EPA and EPA/ARA ratios of 2 and 4 in eggs, respectively, were associated with improved egg and larval quality and were similar to the ratios found in eggs from wild broodstock. Attainment of optimal fatty acid contents in broodstock diets is one of the key factors for producing the high-quality spawning required for managed culture of this flounder.

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EFFECT OF SALINITY ON SURVIVAL, GROWTH, OXYGEN CONSUMPTION AND AMMONIA-N EXCRETION OF JUVENILE WHITELEG SHRIMP, *LITOPENAEUS VANNAMEI*
Peidong Zhang, Xiumei Zhang, Jian Li, Tianxiang Gao-2009

Aquaculture Research 40(12): 1419 – 1427

Abstract:

In this study, we tested the lower salinity tolerance of juvenile shrimps (*Litopenaeus vannamei*) at a relatively low temperature (20 °C). In the first of two laboratory experiments, we first abruptly transferred shrimps (6.91 ± 0.05 g wet weight, mean \pm SE) from the rearing salinity (35 000 mg L⁻¹) to salinities of 5000, 15 000, 25 000, 35 000 (control) and 40 000 mg L⁻¹ at 20 °C. The survival of *L. vannamei* juvenile was not affected by salinities from 15 000 to 40 000 mg L⁻¹ during the 96-h exposure periods. Shrimps exposed to 5000 mg L⁻¹ were significantly affected by salinity, with a survival of 12.5% after 96 h. The 24-, 48- and 96-h lethal salinity for 50% (LS50) were 7020, 8510 and 9540 mg L⁻¹ respectively. In the second experiment, shrimps (5.47 ± 0.09 g wet weight, mean \pm SE) were acclimatized to the different salinity levels (5000, 15 000, 25 000, 35 000 and 40 000 mg L⁻¹) and then maintained for 30 days at 20 °C. Results showed that the survival was significantly lower at 5000 mg L⁻¹ than at other salinity levels, but the final wet weight under 5000 mg L⁻¹ treatment was significantly higher than those under other treatments ($P < 0.05$). Feed intake (FI) of shrimp under 5000 mg L⁻¹ was significantly lower than those of shrimp under 15 000–40 000 mg L⁻¹; food conversion efficiency (FCE), however, showed a contrasting change ($P < 0.05$). Furthermore, salinity significantly influenced the oxygen consumption rates, ammonia-N excretion rates and the O/N ratio of test shrimps ($P < 0.05$). The results obtained in our work provide evidence that *L. vannamei* juveniles have limited capacity to tolerate salinities $< 10\,000$ mg L⁻¹ at a relatively low temperature (20 °C). Results also show that *L. vannamei* juvenile can recover from the abrupt salinity change between 15 000 and 40 000 mg L⁻¹ within 24 h.

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EFFECTS OF TEMPERATURE, DENSITY AND EARLY WEANING ON THE SURVIVAL AND GROWTH OF ATLANTIC DITCH SHRIMP *PALAEEMONETES VARIANS* LARVAE

Jorge Palma, Dominique P Bureau, Miguel Correia, José P Andrade-2009

Aquaculture Research 40(13): 1468 – 1473

Abstract:

This investigation examined the effects of temperature, density and early weaning on the survival and growth of *Palaemonetes varians* larvae. Survival of larvae raised at 17.5 °C was not significantly different (average + standard deviation) ($94 \pm 5\%$) from the survival of those raised at 19.5 °C ($95 \pm 5\%$) and at 21.5 °C ($94 \pm 4\%$). However, the duration of the larval stage was significantly longer for shrimp reared at 17.5 °C (17.3 ± 0.8 days) compared with shrimp reared at 19.5 °C (14.3 ± 0.7 days) and at 21.5 °C (11.3 ± 0.6 days). No significant differences ($P > 0.05$) were found in the survival rate, final weight and length of larvae reared at the densities of 5, 10, 20 and 50 larvae L⁻¹. The survival of

P. varians larvae fed solely on *Artemia* was significantly higher ($P < 0.05$) than larvae weaned with an artificial practical diet from Zoea II stage ($94 \pm 4\%$ and $82 \pm 1\%$, respectively, for *Artemia* and artificial diet-fed larvae), but no significant differences ($P > 0.05$) were observed in the final larval weight or length between these two treatments. The survival and growth of the larvae fed with the practical diet tested is a promising step ahead in the development of the culture of this species as it eliminates both the need for *Artemia* throughout all larval stages, and the need for more expensive artificial diets.

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PROBIOTIC MICROORGANISMS AND ANTIVIRAL PLANTS REDUCE MORTALITY AND PREVALENCE OF WSSV IN SHRIMP (*LITOPENAEUS VANNAMEI*) CULTURED UNDER LABORATORY CONDITIONS

Viridiana Peraza-Gómez, Antonio Luna-González, Ángel I Campa-Córdova, Melina López-Meyer, Jesús A Fierro-Coronado, Píndaro Álvarez-Ruiz-2009

Aquaculture Research 40(13): 1481 – 1489

Abstract:

The protective effect of a probiotic mixture (PM) and antiviral plants, against the white spot syndrome virus (WSSV) in *Litopenaeus vannamei*, was evaluated in three experiments. The PM was composed of four lactic acid bacteria (LAB) and one yeast strain. The plant mixture was composed of *Ocimum sanctum* and commercial antiviral plants (VPH®, HSV®). Shrimp in each experiment (weighing 2.7 ± 0.7 , 11.5 ± 1.3 , 11.70 ± 2.5 g) were cultured in 120-L plastic tanks and fed twice a day with commercial feed plus additives (plants or bacteria and yeast). Animals were monitored for the occurrence of WSSV by single-step and nested PCR. The PM and powdered antiviral plants added to the commercial feed showed an increase in survival and a decrease in the prevalence of WSSV in shrimp. The results showed that both the PM and the powdered antiviral plants can provide protection for shrimp against WSSV.

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BIOCHEMICAL CHANGES DURING LARVAL DEVELOPMENT IN THE SHORT NECK CLAM, *PAPHIA MALABARICA* CHEMNITZ

Raghavan Gireesh, Abraham Biju, Palaniyappan Muthiah-2009

Aquaculture Research 40(13): 1510 – 1515

Abstract:

Biochemical compositions were determined for eggs, D-shaped larvae, umbo larvae and pediveliger of the short neck clam *Paphia malabarica* Chemnitz. Spawned eggs were composed of 63.2% protein, 25.4% lipid and 11.4% carbohydrate. After 48 h of embryogenesis, 2.6% of the protein, 11.8% of the lipid and 3.2% of carbohydrate mass had been lost, providing 20.5%, 75.4% and 4.1% of the total energy expenditure of 0.2147 mJ embryo⁻¹. During 48 h of metamorphosis, lipid was utilized first, followed by a heavy consumption of protein; protein, lipid and carbohydrate lost 23.8%, 50.2% and 32.5% of their mass respectively. Protein and lipid supplied a comparable amount of energy for metamorphosis, 34.2% and 55.2%, respectively, whereas, carbohydrate contributed only 10.6% to the 2.733 mJ larva⁻¹ metamorphic energy expenditure.

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SHORT COMMUNICATION

DARKNESS AND UV RADIATION PROVOKED COMPENSATORY GROWTH IN MARINE PHYTOPLANKTON *PHAEODACTYLUM TRICORNUTUM* (BACILLARIOPHYCEAE)

Zhuoping Cai, Shunshan Duan, Wei Wei-2009

Aquaculture Research 40(13): 1559 – 1562

(Institute of Hydrobiology, Jinan University, Guangzhou 510632, China; email of S S Duan: tssduan@jnu.edu.cn)

EFFECT OF DIFFERENT DIETS ON LARVAL PRODUCTION, QUALITY AND FATTY ACID PROFILE OF THE MARINE ORNAMENTAL SHRIMP *LYSMATA AMBOINENSIS* (DE MAN, 1888), USING WILD LARVAE AS A STANDARD

R. Calado, A. Vitorino, A. Reis, T. Lopes da Silva, M.T. Dinis-2009

Aquaculture Nutrition 15(5) : 484 – 491

Abstract:

The present work evaluates the influence of broodstock diets [Marine Cuisine®– MC, MC supplemented with highly unsaturated fatty acid- (HUFA) enriched Artemia biomass – MC + AB, and MC supplemented with squid – MC + S] on larval production, newly hatched and early zoeal stage survival and fatty acid profile of newly hatched larvae of *Lysmata amboinensis*. These parameters are compared with those from larvae hatched from embryos spawned in the wild. The number (\pm SE) of larvae produced with MC and MC + S (1077 ± 219 and 1103 ± 184 , respectively) was similar to that in broodstock carrying embryos spawned in the wild (1224 ± 111), while those fed MC + AB displayed significantly lower values (1044 ± 161). Larvae produced with MC + AB displayed lower survival for all starvation periods, while larvae spawned in the wild displayed the highest survival. No larvae resisted 144 h of starvation and none moulted to zoea II. The fatty acid comparison revealed that larvae from embryos spawned in the wild displayed the highest levels of DHA, as well as higher DHA/EPA and n-3/n-6 ratios. These results suggest that broodstock diets commonly used to promote ornamental shrimp's maturation (based on mixed frozen components) are far from being optimal.

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A BALANCED AMINO ACID DIET IMPROVES *DIPLODUS SARGUS* LARVAL QUALITY AND REDUCES NITROGEN EXCRETION

M. Saavedra, P. Pousão-Ferreira, M. Yúfera, M.T. Dinis, L.E.C. Conceição-2009

Aquaculture Nutrition 15(5) : 517 – 524

Abstract:

Fish larvae present high amino acid requirements due to their high growth rate. Maximizing this growth rate depends on providing a balanced amino acid diet which can fulfil larval amino acid nutritional needs. In this study, two experimental microencapsulated casein diets were tested: one presenting a balanced amino acid profile and another presenting an unbalanced amino acid profile. A control diet, live feed based, was also tested. Trials were performed with larvae from 1 to 25 days after hatching (DAH). Microencapsulated diets were introduced at 8 DAH in co-feeding with live feed and at 15 DAH larvae were fed the microencapsulated diets alone. Results showed a higher survival for the control group ($8.6 \pm 1.3\%$ versus $4.2 \pm 0.6\%$ and $3.2 \pm 1.8\%$) although dry weight and growth were similar in all treatments. The proportion of deformed larvae as well as the ammonia excretion was lower in the group fed a balanced diet than in the unbalanced or control groups (38.3% deformed larvae in control, 30% in larvae fed unbalanced diet and 20% on balanced diet group). Furthermore, larvae fed the microencapsulated diets presented higher docosahexaenoic acid and arachidonic acid levels. This study demonstrates that dietary amino acid profile may play an important role in larval quality. It also shows that balanced microencapsulated diets may improve some of the performance criteria, such as skeletal deformities, compared to live feeds.

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PROTEIN QUALITY OF LARVAL FEED WITH INCREASED CONCENTRATION OF HYDROLYSED PROTEIN: EFFECTS OF HEAT TREATMENT AND LEACHING

A. Nordgreen, S. Tonheim, K. Hamre-2009

Abstract:

Four heat coagulated early weaning diets with increasing concentrations of pepsin hydrolysed protein, were investigated with regard to the change in protein quality during feed production and exposure to leaching. Water-soluble N, trichloroacetic acid-soluble N and amino acid (AA) profiles were determined in finished diets and in diets leached for 6 min. In vitro diet digestibility was measured and related to increasing inclusion of hydrolysed protein and N leakage. Seventeen to 47% of soluble N in the feed ingredients was made insoluble by heat denaturation during feed production, but the concentration of peptides and free amino acids (FAA) were not influenced. All peptides/FAA and 70–80% of water-soluble protein were lost after exposure to leaching. Increased inclusion of hydrolysed protein increased the loss of crude protein (15–30%). All taurine and 30% of histidine was lost during leaching, no other major changes in AA profile were found. There was no difference in digestibility between diets exposed to leaching. However, leached diets showed reduced digestibility as compared to diets that had not been exposed to leaching. In conclusion micro-bound type diets as used in this study have a low efficiency in delivering soluble N to fish larvae and should be carefully considered for this purpose.

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