INFORMATION OF INTEREST

- 52 Cultured Aquatic Species FAO Fact Sheets (available from website or on CD-ROM)
- European Parliament Intergroup on Climate Change, Biodiversity & Sustainable Development – Seminar March 3, 2010 "Can a growing aquaculture industry continue to use fishmeal and fish oil in feeds and remain sustainable?" see website for for report, press release and presentations: see website for seminar report, press release and presentations by Ahold, Crawford, Cueff, FAO, IFFO, MCS, Ragnar, Smith, Tacon and Wathe.

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- 467 April 23, 2010

REVIEW ARTICLE
LIVE FEEDS FOR EARLY STAGES OF FISH REARING
Luís E. C. Conceição , Manuel Yúfera, Pavlos Makridis, Sofia Morais, Maria Teresa Dinis-2010
Aquaculture Research 41(5): 613 - 640
Special Issue: Basic and Applied Aspects of Aquaculture Nutrition: Healthy Fish for Healthy Consumers, Sponsored by Organization for Economic Cooperation and Development (OECD) Krakow, Poland, September 17-18, 2008 Invited Papers. Issue editors: K. Dabrowski and R. Hardy
Abstract:
Despite the recent progress in the production of inert diets for fish larvae, feeding of most species of interest for aquaculture still relies on live feeds during the early life stages. Independently of their nutritional value, live feeds are easily detected and captured, due to their swimming movements in the water column, and highly digestible, given their lower nutrient concentration (water content>80%). The present paper reviews the main types of live feeds used in aquaculture, their advantages and pitfalls, with a special emphasis on their nutritional value and the extent to which this can be manipulated. The most commonly used live feeds in aquaculture are rotifers (Brachionus sp.) and brine shrimp (Artemia sp.), due to the existence of standardized cost-effective protocols for their mass production. However, both rotifers and Artemia have nutritional deficiencies for marine species, particularly in essential n-3 highly unsaturated fatty acids (HUFA, e.g., docosahexaenoic acid and eicosapentaenoic acid). Enrichment of these live feeds with HUFA-rich lipid emulsions may lead to an excess dietary lipid and sub-optimal dietary protein content for fish larvae. In addition, rotifers and Artemia are likely to have sub-optimal dietary levels of some amino acids, vitamins and minerals, at least for some species. Several species of microalgae are also used in larviculture. These are used as feed for other live feeds, but mostly in the 'green water' technique in fish larval rearing, with putative beneficial effects on feeding behaviour, digestive function, nutritional value, water quality and microflora. Copepods and other natural zooplankton organisms have also been used as live feeds, normally with considerably better results in terms of larval survival rates, growth and quality, when compared with rotifers and Artemia. Nonetheless, technical difficulties in mass-producing these organisms are still a constraint to their routine use. Improvements in inert microdiets will likely lead to a progressive substitution of live feeds. However, complete substitution is probably years away for most species, at least for the first days of feeding.
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REVIEW ARTICLE
EFFECTS OF PROTEIN-, PEPTIDE- AND FREE AMINO ACID-BASED DIETS IN FISH NUTRITION

Konrad Dabrowski, YongFang Zhang, Karolina Kwasek, Piotr Hliwa, Teresa Ostaszewska-2010
Aquaculture Research 41(5): 668 - 683
Special Issue: Basic and Applied Aspects of Aquaculture Nutrition: Healthy Fish for Healthy Consumers, Sponsored by Organization for Economic Cooperation and Development (OECD) Krakow, Poland, September 17-18, 2008 Invited Papers. Issue editors: K. Dabrowski and R. Hardy
Abstract:
In the present review, we summarize data related to the utilization of purified diets formulated with the purpose of determining the amino acid requirements in fish independent of the ontogenetic stage and the morphological characteristics of the digestive tract. Expanding present knowledge on the formulation of protein, free amino acid (FAA) and synthetic dipeptide-based diets can provide possible insights that might lead to a better understanding of the mechanism of amino acid utilization in the growth of fish. Differences exist in the utilization of protein, dipeptides or free amino acids for growth between stomach-possessing and stomachless fish with respect to their response to manipulating the proportion of protein and dipeptides in the formulas. Free amino acid-based diets are uniformly inferior. The effects of diet manipulation on indispensable FAA concentrations in the body (muscle) are not simply the result of deamination or the protein synthesis/degradation ratio. The hydroxyproline/proline ratio was confirmed to be of value in quantifying muscle collagen degradation/synthesis and can perhaps be used to quantify the amino acid requirement necessary to maximize the utilization (deposition) of dietary amino acids. In summary, indispensable amino acid requirements for maximum growth in fish can be addressed using diets formulated from protein/peptide/FAA sources.
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REVIEW ARTICLE
REQUIREMENT FOR AMINO ACIDS IN ONTOGENY OF FISH
Roderick Nigel Finn, Hans Jørgen Fyhn-2010
Aquaculture Research 41(5)): 684 - 716
Special Issue: Basic and Applied Aspects of Aquaculture Nutrition: Healthy Fish for Healthy Consumers, Sponsored by Organization for Economic Cooperation and Development (OECD) Krakow, Poland, September 17-18, 2008 Invited Papers. Issue editors: K Dabrowski and R Hardy
Abstract:
Amino acids are vital for all living organisms. During early fish ontogeny, they are important fuel molecules, signalling factors and major substrates for the synthesis of a wide range of bioactive molecules and proteins. Because the majority of fish eggs are cleidoic, i.e. closed free-living systems following ovulation and activation, early development of fish depends on the maternal provision of amino acids during oogenesis. While more than 600 proteins have been identified in the growing oocytes of fish, the major vehicles for supplying amino acids to the growing oocyte before ovulation are the vitellogenins, of which many genes and multiple forms are known. Here we review the importance of amino acids for the intermediary metabolism of fish embryos and larvae, where amino acids have been shown to be the preferred catabolic substrate. Subsequently, we address the specialization of the lysosomal pathway involved in the uptake and degradation of yolk proteins. This latter pathway is specifically modified in the germline to facilitate the long-term storage of egg yolk proteins. In marine teleosts, the degradative pathway may be activated before fertilization during oocyte maturation to release free amino acids for oocyte hydration and the acquisition of egg buoyancy. In other species, including freshwater fish, a more latent activation of acid hydrolases occurs after fertilization during the four phases of yolk resorption. The developmental contributions of the yolk syncytial layer, vitelline circulation and liver are essential components of the amino acid supply during fish ontogeny.
(Department of Biology, Bergen High Technology Centre, University of Bergen, Postboks 7803, N-5020 Bergen, Norway; email of R N Finn: nigel.finn@bio.uib.no)

REVIEW ARTICLE
FATTY ACID REQUIREMENTS IN ONTOGENY OF MARINE AND FRESHWATER FISH
Douglas R. Tocher-2010

Aquaculture Research 41(5): 717 - 732
Special Issue: Basic and Applied Aspects of Aquaculture Nutrition: Healthy Fish for Healthy Consumers, Sponsored by Organization for Economic Cooperation and Development (OECD) Krakow, Poland, September 17-18, 2008 Invited Papers. Issue editors: K Dabrowski and R Hardy
Abstract:
Essential fatty acid (EFA) requirements vary qualitatively and quantitatively with both species and during ontogeny of fish, with early developmental stages and broodstock being critical periods. Environment and/or trophic level are major factors, with freshwater/diadromous species generally requiring C18 polyunsaturated fatty acids (PUFA) whereas marine fish have a strict requirement for long-chain PUFA, eicosapentaenoic, docosahexaenoic and arachidonic acids. Other than marine fish larvae, defining precise quantitative or semi-quantitative EFA requirements in fish have received less attention in recent years. However, the changes to feed formulations being forced upon the aquaculture industry by the pressing need for sustainable development, namely the replacement of marine fish meal and oils with plant-derived products, have reintroduced EFA into the research agenda. It is particularly important to note that the physiological requirements of the fish to prevent deficiency pathologies and produce optimal growth may not parallel the requirements for maintaining nutritional quality. For instance, salmonids can be successfully cultured on vegetable oils devoid of long-chain n-3 PUFA but not without potentially compromising their health benefits to the human consumer. Solving this problem will require detailed knowledge of the biochemical and molecular basis of EFA requirements and metabolism.
(Institute of Aquaculture, University of Stirling, Stirling FK9 4LA, Scotland, UK; email of D R Tocher: d.r.tocher@stir.ac.uk)

REVIEW ARTICLE
WATER-SOLUBLE VITAMINS IN FISH ONTOGENY
Rune Waagbø-2010
Aquaculture Research 41(5): 733 - 744
Special Issue: Basic and Applied Aspects of Aquaculture Nutrition: Healthy Fish for Healthy Consumers, Sponsored by Organization for Economic Cooperation and Development (OECD) Krakow, Poland, September 17-18, 2008 Invited Papers. Issue editors: K Dabrowski and R Hardy
Abstract:
Studies on vitamin requirement at early stages are difficult and vary in quality, both due to the scientific approach and vitamin analysis. Focus has been on water-soluble vitamins that cause dramatic losses of the offspring in practical farming situations or in wild life, like vitamin C and thiamine deficiencies respectively. Practical solutions including vitamin administration through brood stock and larvae diets have confirmed and corrected the vitamin deficiencies. For the other water-soluble vitamins, the situation is not so obvious. Descriptive studies of folate and vitamin B6 during fish ontogeny have shown a net loss of vitamin during endogenous feeding and a steady transfer of vitamin from the yolk sac into the body compartment, and finally, dramatic increases in body vitamin levels after the start of feeding. The kinetics of mass transfer with ontogeny appears, however, to differ between vitamins. Start of feeding of fish larvae with live or formulated feeds includes several challenges with respect to water-soluble vitamins, including aspects of live feed enrichment and stability, micro-diet leaching, variable feed intakes, immature gastrointestinal tract, variable bioavailability of vitamins and larvae vitamin storage capacity. Consequently, the exact minimum requirements are difficult to estimate and vitamin recommendations need to consider such conditions.
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REVIEW ARTICLE
ROLES OF LIPID-SOLUBLE VITAMINS DURING ONTOGENY OF MARINE FISH LARVAE
Kristin Hamre, Christel Krossøy, Erik-Jan Lock, Mari Moren-2010
Aquaculture Research 41(5): 745 - 750

Special Issue: Basic and Applied Aspects of Aquaculture Nutrition: Healthy Fish for Healthy Consumers, Sponsored by Organization for Economic Cooperation and Development (OECD) Krakow, Poland, September 17-18, 2008 Invited Papers. Issue editors: K Dabrowski and R Hardy
Abstract:
The roles of lipid-soluble vitamins during ontogeny of marine fish larvae are a subject topic where only fragments of the whole picture are known. Most of the research has been focussed on the larval requirements and the availability of these vitamins in the live feed organisms used for early-stage larvae, while the function of the vitamins in the larvae themselves is largely unknown. Our knowledge is mostly extrapolated from research on other vertebrates and also in part from juvenile and adult fish. Vitamin A is known to be essential for establishing body and organ axes in vertebrate embryos and interacts with other nutrients such as vitamin D and fatty acids through the steroid/thyroid nuclear hormone receptor family. In marine fish larvae, excess vitamin A stimulates pigmentation, but at the same time induces vertebral deformities. Live feed organisms contain very little vitamin A but marine fish larvae appear to convert carotenoids in Artemia and copepods to vitamin A, while rotifers, which contain little carotenoids, should be enriched with vitamin A. Vitamin E acts as an antioxidant and is important for the protection of marine fish larvae against the oxidation pressure probably present in intensive rearing systems. Vitamin E may also have other roles connected to its modulation of cell and tissue red-ox balance. In marine fish larvae and juveniles, vitamin E has been shown to enhance the symptoms of vitamin C deficiency, while protecting against the oxidative effect of n-3 fatty acids. Vitamin D is important for the modulation of calcium and phosphorus homeostasis and for the development of the vertebrate skeleton. Vitamin K influences bone development and coagulation of the blood. There is little information on vitamins D and K connected to the ontogeny of marine fish larvae.
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REVIEW ARTICLE
REGULATION OF GENE EXPRESSION BY NUTRITIONAL FACTORS IN FISH
S. Panserat, S. J. Kaushik-2010
Aquaculture Research 41(5): 751 - 762
Special Issue: Basic and Applied Aspects of Aquaculture Nutrition: Healthy Fish for Healthy Consumers, Sponsored by Organization for Economic Cooperation and Development (OECD) Krakow, Poland, September 17-18, 2008 Invited Papers. Issue editors: K Dabrowski and R Hardy
Abstract:
In the past few years, molecular tools have been increasingly used to complement basic husbandry techniques to assess the response at the whole animal or the farm level. This review aims at giving some examples from researches undertaken in fish nutrition and gene expression and, more recently, on nutrigenomics and proteomics as applied to fish nutrition and feeding.
(Nutrition, Aquaculture & Genomics 'NuAGe' Unit, UMR 1067, INRA, 64310 Saint-Pée-sur-Nivelle, France ; email of S. J. Kaushik : kaushik@st-pee.inra.fr)

ENERGY AND PROTEIN DEMANDS FOR OPTIMAL EGG PRODUCTION INCLUDING MAINTENANCE REQUIREMENTS OF FEMALE TILAPIA OREOCHROMIS NILOTICUS
Ingrid Lupatsch, Raviv Deshev, Igal Magen-2010
Aquaculture Research 41(5): 763 - 769
Special Issue: Basic and Applied Aspects of Aquaculture Nutrition: Healthy Fish for Healthy Consumers, Sponsored by Organization for Economic Cooperation and Development (OECD) Krakow, Poland, September 17-18, 2008 Invited Papers. Issue editors: K. Dabrowski and R. Hardy
Abstract:
The daily requirements of a spawning tilapia female are quantified from the sum of the requirements for maintenance plus production of eggs. The protein and energy requirements for maintenance and the cost of depositing energy and protein towards growth or gonadal products were determined by supplying feed at increasing levels from zero to the maximum intake. Comparative body composition analyses of the females in addition to the amount and the content of eggs enabled us to quantify the total energy and

protein channelled into weight gain or alternatively into egg production. The amount of eggs produced increased with increasing feeding levels and ranged between 0.7 and 1.1 g eggs per kg−1 fish day−1. Regardless of feed allowance, the composition of eggs was similar and contained 235 mg protein and 10.5 kJ g−1 wet weight. In contrast, the whole body of tilapia contained 167 mg protein and 6.7 kJ g−1 on average. The energy requirement for maintenance was calculated to be 59.46 kJ × BW (kg)0.80 and 0.98 g × BW (kg)0.70 for digestible protein. The partial efficiency of producing gonads was 0.67 and 0.59 for digestible energy and digestible protein respectively.
(Centre for Sustainable Aquaculture Research, Swansea University, Singleton Park, Swansea SA2 8PP, UK; email of I. Lupatsch: i.lupatsch@swansea.ac.uk)

BIVALVE SHELLFISH QUALITY IN THE USA: FROM THE HATCHERY TO THE CONSUMER
Daniel P. Cheney-2010
Journal of the World Aquaculture Society 41(2): 192 – 206
Abstract:
Shellfish aquaculture has had a long tradition in Asia, Europe, and the western USA, but it is only within the past century that significant cultural and handling practices have been identified, developed, and introduced to improve and enhance shellfish food quality. Shellfish are now being marketed with an emphasis on product quality, product variety, reduced human health risk, and improved ease of preparation. Aquacultured bivalve shellfish products must now have the food quality characteristics of other high-quality seafood products and must meet accepted standards of taste, color, texture, and odor. This review summarizes current efforts within the shellfish industry to improve the food quality of aquacultured bivalve shellfish in the following focus areas: (i) genetic selection and controlled breeding; (ii) production tools; (iii) food safety protection and enhancement; and (iv) processing and creative marketing efforts, with major emphasis on the US shellfish aquaculture sector.
(Pacific Shellfish Institute, 120 State Avenue NE #142, Olympia, Washington 98501, USA)

THE RISKS AND BENEFITS OF FARMED FISH
Charles R. Santerre-2010
Journal of the World Aquaculture Society 41(2): 250 – 257
Abstract:
In recent years, a number of concerns have been raised about the safety of seafood. At the same time, published studies have extolled the benefits of eating fish. In this article we will attempt to describe the nutritional benefits of eating fish and compare these to the risks from mercury and polychlorinated biphenyls (PCBs). Our discussion will be directed at farmed fish which are often at the center of the controversies. This article is intended to be a brief overview and not a comprehensive review.
(Department of Foods and Nutrition, Purdue University, 700 W. State Street, West Lafayette, Indiana 47907-2059 USA

PERCEPTIONS OF SEAFOOD SAFETY
Barbara Rasco-2010
Journal of the World Aquaculture Society 41(2): 258 – 265
Abstract:
Consumer perception affects how food products are positioned in the marketplace. In addition, misperception about product safety influences how products are labeled and marketed. Regulatory compliance issues facing aquaculture producers are driven both by science-based concerns over product safety and politics. Consumer perception of product safety often has little connection with any legitimate public health concern. This is particularly true for aquatic foods which have been politically targeted throughout the years by inaccurate assessment of product safety as part of a larger strategy to discourage purchases or to direct purchase to politically more acceptable product, for example from a "farmed" fish to a wild harvested one. Activists target the safety of foods harvested from the marine environment to promote an environmental agency, most recently mercury raising content in pelagic species such as tuna to scare women, particularly pregnant women, from consuming this otherwise

healthful food. Recent scares have involved colorant and feed additives for farmed salmon, leading to mandatory retail labeling in Western US markets of "added color" for all farm raised salmonids to increase consumer concern about product safety and discourage purchases. These efforts detract from improving overall food safety, specifically risks of microbial contamination and growth.
(School of Food Science, Washington State University, Pullman, Washington 99164-6376, USA)

FOOD DEFENSE IN AN AQUACULTURE SETTING
Barbara Rasco, Gleyn E. Bledsoe-2010
Journal of the World Aquaculture Society 41(2): 175 – 191
Abstract:
Developing an overall food protection program for aquaculture and its related food processing operations includes biosecurity and good aquaculture practices for husbandry operations, and good manufacturing practices, food safety (sanitation standard operating procedures, and hazard analysis critical control point) programs for processing. Because of recent intentional contamination incidents of food and feed, developing and implementing a food defense as part of an overall food safety and quality management system have become more critical. Recent developments in food defense, suitable preventive measures, mitigation strategies, and model implementation plans for an aquaculture operation are presented here.
(School of Food Science, Washington State University, Pullman, Washington 99164-6376, USA)

EVALUATION OF AN ULTRA-LOW-FLOW WATER DELIVERY SYSTEM FOR SMALL EXPERIMENTAL TANKS
North American Journal of Aquaculture 72(3): 195-200
Andrew Mitchell, Bradley Farmer-2010
Abstract:
An ultra-low-flow water delivery system was developed and tested for use in research studies requiring low flow in small water volumes. Small test systems save on the amount of fish, chemicals, and biologics needed in disease challenge and treatment experiments. The ultra-low-flow system, consisting of a semi-enclosed header tank with a variable-height standpipe and dulled, guarded syringe needle nozzles, can produce flows that result in 1–20 water exchanges/d for a 10-L volume. Water was prefiltered through two inline, 70-µm filters to limit flow loss due to particulates blocking the small-orifice nozzles. Accurate and precise flows are produced by the system, and needle nozzles should last at least 7 d before fouling requires them to be changed; nozzle changes can be made in about 5 s. Flows in the range of 5–135 mL/min were produced by using 3.8-cm-long needles (16, 18, 20, and 21 gauge) with standpipe heights of 15.2, 30.5, and 45.7 cm. Water flows through selected needle nozzles and standpipe heights varied by no more than 5% over a 7-d period. This ultra-low-flow system provides a practical, inexpensive, and precise water delivery system that should have multiple uses for fisheries research.
(U.S. Department of Agriculture, Agricultural Research Service, Harry K. Dupree Stuttgart National Aquaculture Research Center, Post Office Box 1050, Stuttgart, Arkansas 72160, USA; email of Andrew Mitchell: drew.mitchell@ars.usda.gov)

COMPARISON OF PERCENT HATCH AND FUNGAL INFESTATION IN CHANNEL CATFISH EGGS AFTER COPPER SULFATE, DIQUAT BROMIDE, FORMALIN, AND HYDROGEN PEROXIDE TREATMENT
Andrew J. Mitchell, David L. Straus, Bradley Farmer, Ray Carter-2010
North American Journal of Aquaculture 72(3): 201-206
Abstract:
Reduced survival of fish eggs is often a result of infestation with fungi Saprolegnia spp. However, timely chemical treatments often limit these infestations and increase survival. The effect of copper sulfate pentahydrate (CSP; 10 mg of CSP/L of water), diquat bromide (25 mg of diquat cation/L), formalin (433 mg/L), and hydrogen peroxide (H2O2; 250 mg/L) on percent hatch and fungal infestation

in eggs of channel catfish Ictalurus punctatus was compared in two identical trials (five replicates for each chemical treatment per trial). The percent hatch in all chemical treatments was significantly better than percent hatch of the controls. The amount of fungal coverage on egg masses treated with CSP, formalin, and H2O2 was significantly less than that observed on the controls. Although not statistically different from the other treatments, H2O2 at 250 mg/L exhibited the highest average percent hatch (64%; control hatch = 34%), the lowest fungal coverage (1.5 cm; control coverage = 7.2 cm), and the lowest occurrence of fungi (50%; control occurrence = 100%) among the treatments.
(U.S. Department of Agriculture, Agricultural Research Service, Harry K. Dupree Stuttgart National Aquaculture Research Center, Post Office Box 1050, 2955 Highway 130 East, Stuttgart, Arkansas 72160, USA; email of Andrew Mitchell: drew.mitchell@ars.usda.gov)

DEVELOPMENT OF NEW INTENSIVE HATCHERY METHODS FOR ROSY RED FATHEAD MINNOW
Ashlee N. Horne, Nathan Stone, Carole R. Engle-2010
North American Journal of Aquaculture 72(3): 237-251
Abstract:
Fathead minnow Pimephales promelas farming practices have remained relatively unchanged for decades. To develop new intensive hatchery methods for the rosy red fathead minnow (a color variant of the fathead minnow), we evaluated spawning substrate preferences, egg mimics, anti-fungal treatments for eggs, and fry stocking densities. Rosy red fathead minnow laid significantly more eggs on a single-layer substrate than on a multilayered substrate but showed little preference between a firm substrate and a flexible substrate. The fish strongly preferred nesting substrates with glass-bead egg mimics over plain (control) substrates or substrates with painted-dot mimics. Eggs treated with chemicals (formalin or hydrogen peroxide at 500, 1,000, or 1,500 mg/L) had higher hatch rates (62.3–81.7%) than did controls (34.3%). The once-daily hydrogen peroxide treatment was equally effective as multiple applications (2–3 applications/d) and resulted in fewer deformities. When newly hatched rosy red fathead minnow fry were stocked at densities of 49, 198, 346, 495, and 643 fry/m2 in pools for 85 d, mean fish weight decreased logarithmically with final density (R2 = 0.953), while yield increased with initial density (R2 = 0.846). A cost analysis for fry production levels of 10, 30, 50, and 70 million fry found that the most costly stage was egg collection followed by fry holding, egg incubation, and egg removal. Estimated costs to produce 1 million fry decreased from US$514 to $356 with increasing fry production, indicating economies of scale. Use of spawning substrates with glass-bead egg mimics has the potential to decrease these costs by increasing egg collection efficiency.
(Aquaculture/Fisheries Center, University of Arkansas at Pine Bluff, Mail Slot 4912, Pine Bluff, Arkansas 71601, USA; email of Nathan Stone: nstone@uaex.edu)

INDUCED VOLITIONAL SPAWNING AND LARVAL REARING OF PINFISH
Matthew A. DiMaggio, Scott W. Grabe, Shawn M. DeSantis, Cortney L. Ohs-2010
North American Journal of Aquaculture 72(3): 252-257
Abstract
Aquaculture of marine baitfish is still in its infancy. Induced spawning of marine baitfish species has the potential to supplement this seasonal capture fishery and offer a consistent supply to anglers. The pinfish Lagodon rhomboides has been identified as a species with potential for commercial production, yet few studies have focused on the induced spawning and larval rearing of this baitfish. The purpose of this study was to evaluate the efficacy of using Ovaprim, composed of a salmon gonadotropin-releasing hormone analog (sGnRHa) and a dopamine antagonist (domperidone), to induce volitional spawning in pinfish. Additionally, a preliminary larval feeding regime was investigated, and growth and development of pinfish larvae were documented. A single dose of 0.50 mL of Ovaprim per kilogram of fish (sGnRHa: 20 μg/mL; domperidone: 10 mg/mL) was sufficient to induce volitional spawning 36–48 h after intraperitoneal injection of female pinfish. Observed fecundity was 2,565 eggs/female (13.1 eggs/g), and larval survival ranged from 10% to 117% through 33 d posthatch (DPH). Larvae were observed to have completed swim bladder inflation by 19 DPH, with 100% percent of larvae exhibiting

notochord flexion by the same date. This represents the first published study in which protracted larval rearing was successfully achieved after induced volitional spawning of pinfish.

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