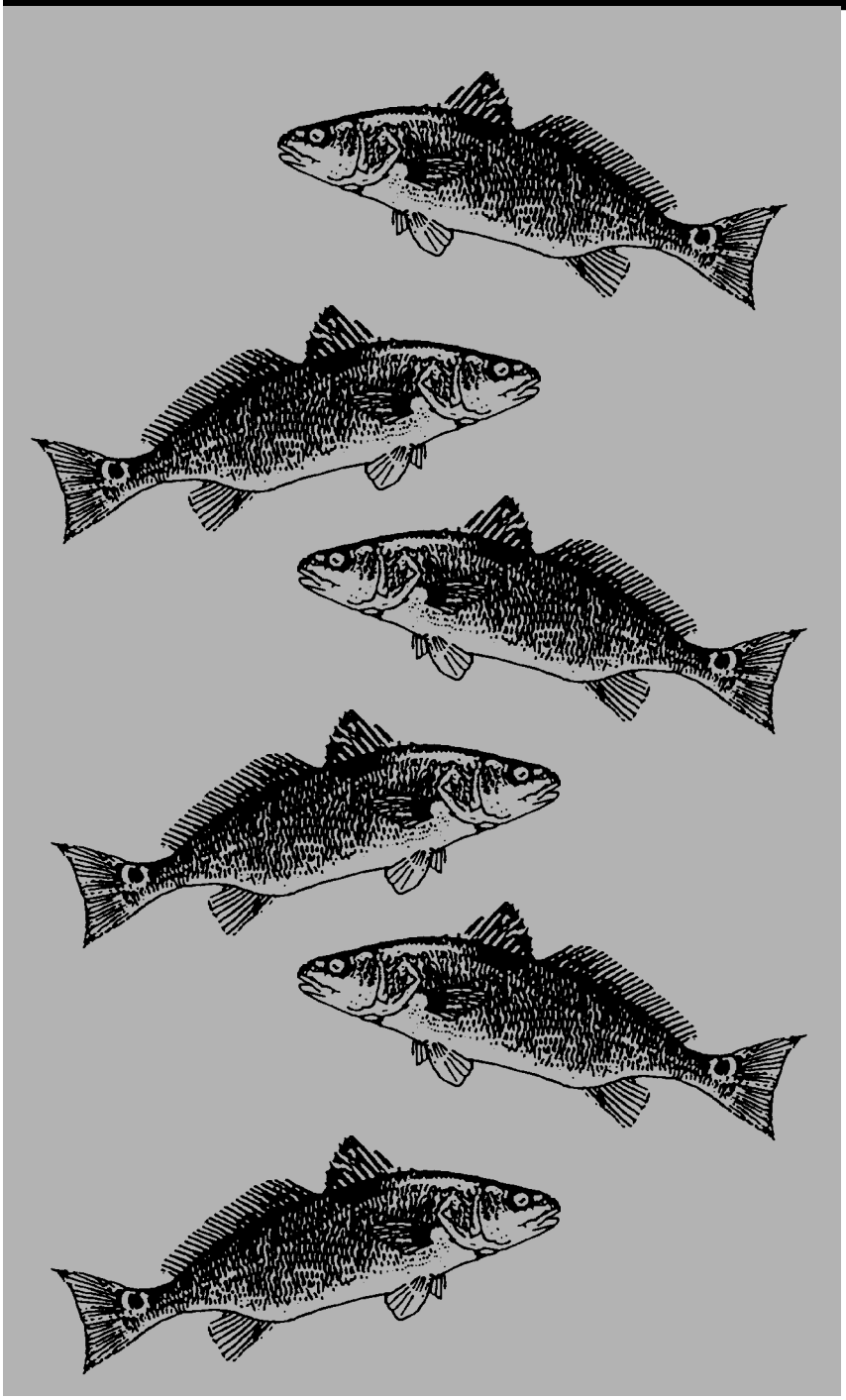
An Aquaculture-Oriented Bibliography of the Red Drum, *Sciaenops ocellatus*



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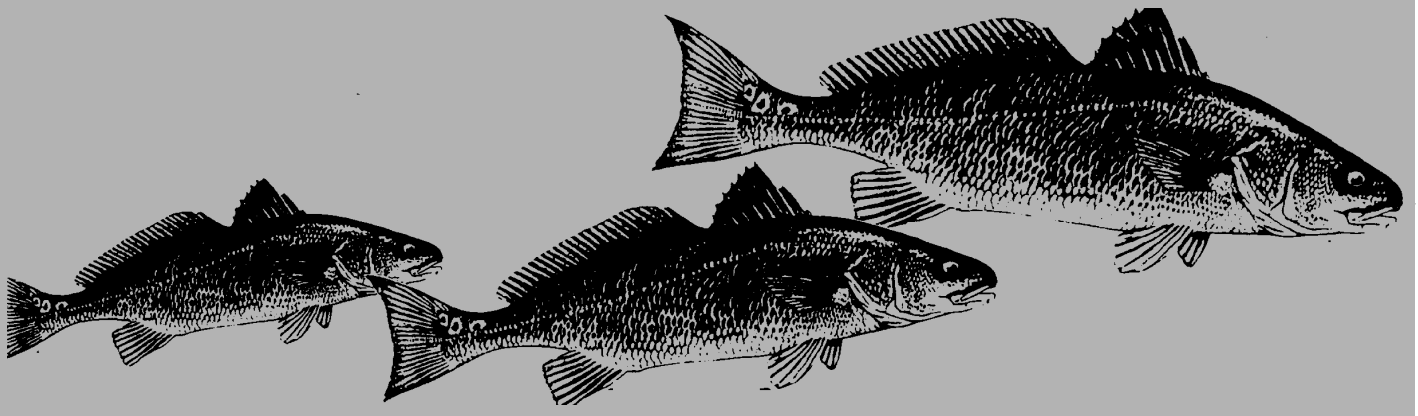

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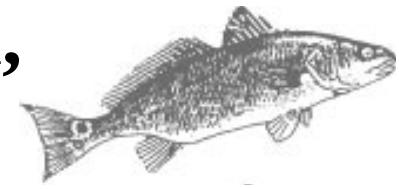


Introduction

This publication was designed to serve as a guide to aquaculture-related red drum (redfish) literature. The intended audience includes red drum producers as well as potential producers, investors and lenders. We also hope researchers and students will find this annotated guide helpful in finding and organizing information for future projects focused on improving the status of red drum aquaculture.

References are organized by subject. Publications that fit into more than one of the broad categories or that did not fall under any particular heading were placed under the General category. In some instances, older references were not included if more recent work was determined to be more applicable to current commercialization efforts. Additionally, several authorities published results from specific investigations in more than one journal or conference proceeding; in these cases only the most comprehensive publications were cited.

Readers interested in obtaining copies of cited works should use the resources of their local public or university libraries. The authors and Louisiana State University Agricultural Center assume no responsibility for the results of use or misuse of the information contained herein.

Biology

Davis, J.T. 1991. Red drum: biology and life history. Publication no. 320, Southern Regional Aquaculture Center, Stoneville, Mississippi.

-The author reviewed spawning, hatching, larval and juvenile development, and adult life history phases under natural conditions, with some references to coinciding components of the captive production cycle. Diseases and regulation of natural harvests were also discussed.

Holt, G.J. 1988. Laboratory studies of red drum and larvae: a review. Contributions in Marine Science, 30 (Supplement), 193.

- Larval and juvenile growth and development patterns of laboratory-reared red drum were reviewed briefly.

Liao, I.C. 1994. The biology of red drum, *Sciaenops ocellatus* - L. Relationships between total length, standard length, and body weight of 10-g to 2500-g fish. Journal of the Fisheries Society of Taiwan, 21(1), 79-89.

-First successful spawn of red drum in Taiwan was described. Length/weight relationships as fish grew were determined to be non linear. First observation of changes of caudal fin shape as fish grew.

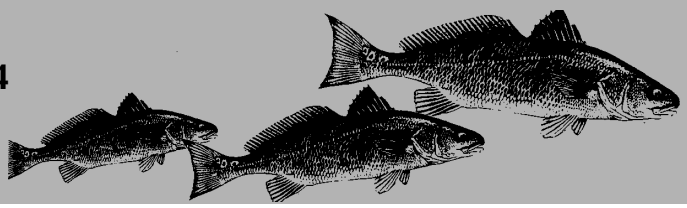
Cold Tolerance

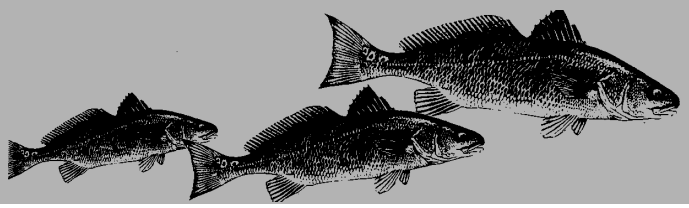
Craig, S.R., D.M. Gatlin III, and W.H. Neill. 1992. Effects of kinds and levels of dietary lipid on growth and cold tolerance of juvenile red drum (*Sciaenops ocellatus*). Aquaculture ‘92 - Orlando Book of Abstracts, World Aquaculture Society, Baton Rouge, 71-72.

- Diets containing 7% lipids from four different sources were evaluated at 7 and 35 ppt. A control diet with 14% menhaden oil resulted in the highest growth rate and cold tolerance. No significant differences in cold tolerance were attributable to source of lipid for the 7% diets, but a strong trend of increasing cold tolerance with higher desaturation levels was noted. Weight gain was higher in the 7 ppt treatments.

Hopkins, J.S., T.I.J. Smith, A.D. Stokes, and P.A. Sandifer. 1988. Winter survival of fingerling red drum *Sciaenops ocellatus* in South Carolina culture ponds. Contributions in Marine Science, 30 (Supplement), 5-10.

- Fingerlings (2-3 months old) were maintained at 3 densities in ponds from December through April. Survival was inversely proportional to stocking





density and ranged from 42% to 80%. Although a ration was offered, feeding activity appeared to be limited to natural sources, relating to the observed density effects.

Parmeter, M.M. 1995. The effect of calcium sulfate on red drum *Sciaenops ocellatus* fingerling survival during rapid decreases in water temperature: a descriptive study. Master's Thesis, Mississippi State University.

- Red drum fingerling survival during rapid reduction in water temperature was tested as a function of calcium concentration. Calcium concentrations of 264 mg/L (as CaCO3) produced 50% survival during temperature decreases from 24 to 7 C, whereas 102 and 203 mg/L produced significantly lower survival.

Procarione, L.S. 1989. Survival of laboratory-held Texas and South Carolina red drum fingerlings exposed to extreme Texas winter temperatures. Report no. 6, Management Data Series, Texas Parks and Wildlife Department, Coastal Fisheries Branch, Austin.

-Cultured red drum fingerlings were tested for cold tolerance to 2.8 degrees C. Survival was similiar between Texas (52.0 +2.4%) and South Carolina (76.0 +32.8%) fish. The authors implied South Carolina red drum did not offer the advantage of increased cold tolerance over Texas red drum.

Procarione, L.S., and T.L. King. 1993. Upper and lower temperature tolerance limits for juvenile red drums from Texas and South Carolina. Journal of Aquatic Animal Health, 5(3), 208-212.

- No difference was found in temperature tolerance between stocks of red drum fingerlings.

Ward, R., I.R. Blandon, T.L. King, and T.L. Beitinger. 1993. Comparisons of critical thermal maxima and minima of juvenile red drum *Sciaenops ocellatus* from Texas and North Carolina. Northeast Gulf Science, 13(1), 23-28.

-North Carolina red drum fingerlings showed lower thermal tolerances than Texas fish but results were not interpreted to be biologically significant.

Whitehurst, A., and H.R. Robinette. 1994. Tolerance of juvenile red drum *Sciaenops ocellatus* to rapidly decreasing water temperatures. Journal of the World Aquaculture Society, 25(2), 225-229.

-No red drum fingerling mortality was observed at 9 ppt salinity as water temperature was decreased to 10 degrees C. The authors recommended maintenance of similar salinities to maximize survival during and after cold front passage.

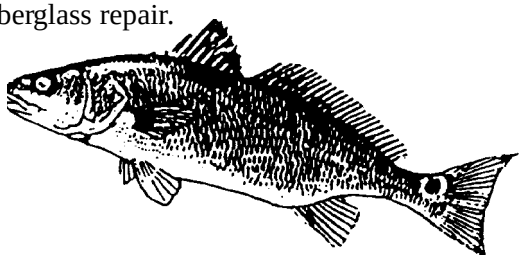
Conference Proceedings and Compilations

Arnold, C.R., G.J. Holt, and P. Thomas, editors. Red Drum Aquaculture, Proceedings of a Symposium on the Culture of Red Drum and Other Warm Water Fishes, University of Texas at Austin Marine Science Institute, Contributions in Marine Science, 30 (Supplement), 1988, 197 p.

- A review of recent technical and scientific advances at the time of publication. Major categories include culture and nutrition, reproduction and genetics, natural history and larval biology, and stress physiology, disease and environmental requirements.

Chamberlain, G.W., R.J. Miget, and M.G. Haby, editors. Red Drum Aquaculture, Texas A and M University Sea Grant College Program, TAMU-SG-90-603, 1990, 236 p.

-This publication was a complete manual for the culture of red drum at the time it was compiled. Sections include spawning technology, fingerling technology, biological, engineering and regulatory aspects, growout technology and information on past research, sources of information, water analyses and fiberglass repair.



Diseases/Fish Health

Bowden, R.A., D.J. Oestmann, D.H. Lewis, and M.S. Frey. 1995. Lymphocystis in red drum. Journal of Aquatic Animal Health, 7(3), 231-235.

- A review of an outbreak of lymphocystis at a commercial facility and laboratory: investigations of pathology, etiology and transmission.

Camus, A.C. and M.K. Lopez. 1996. Gastric cryptosporidiosis in juvenile red drum. Journal of Aquatic Animal Health, 8(2), 167-172.

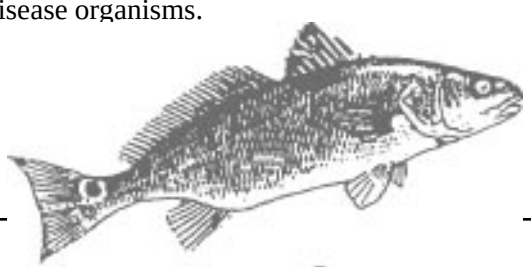
- Cryptosporidiosis was confirmed in a population of pond-reared red drum fingerlings. Pathology was discussed.

Hawke, J. P. 1991. An overview of the diseases of cultured hybrid striped bass and red drum. Louisiana Aquaculture Conference 1991, Louisiana Cooperative Extension Service and Louisiana Agricultural Experiment Station, LSU Agricultural Center, Baton Rouge, 52-54.

- Etiologies of submitted red drum from 1988 through 1990. Commonly observed parasites included *Amyloodinium, Trichodina,* and *Ambiphrya.* Common bacterial problems included *Vibrio, Aeromonas, Cytophaga columnaris* and *Eubaterium tarantellus.* Occurrence of *Acinetobacter* was associated with vitamin deficiency. *Saprolegnia* was observed in fish overwintered in fresh water.

Johnson, S. K. 1990. Recognition and control of diseases common to grow-out aquaculture of red drum. In: Red Drum Aquaculture, Chamberlain, G.W., Miget R.J., and Haby M.G., eds. Texas A and M University Sea Grant College Program, College Station, Texas, 113-130.

-A comprehensive guide to red drum diseases. Identification, control and treatment options are presented. Included are drawings and photographs of common disease organisms.



Landsberg, J. H., G. K. Vermeers, S. A. Richards, and N. Perry. 1991. Control of the parasitic copepod *Caligus elongatus* on pond-reared red drum. Journal of Aquatic Animal Health, 3(3), 206-209.

-Successful treatment of this parasite was reported on pond-reared (20 ppt salinity) red drum with a 20-minute freshwater dip.

Lewis, D. H., W. Wenxias, A. Ayers, and C. R. Arnold. 1988. Preliminary studies on the use of chloroquine as a systemic chemotherapeutic agent for amyloodinosis in red drum *Sciaenops ocellatus*. Contributions in Marine Science, 30 (Supplement), 183-189.

-Promising results indicated chloroquine was an effective oral therapeutant for this difficult-to-control parasite.

Oestmann, D.J., and D.H. Lewis. 1996. Effects of 3, N-methylglucamine lasalocid on *Amyloodinium ocellatum.* Diseases of Aquatic Organisms, 24(3), 179-184.

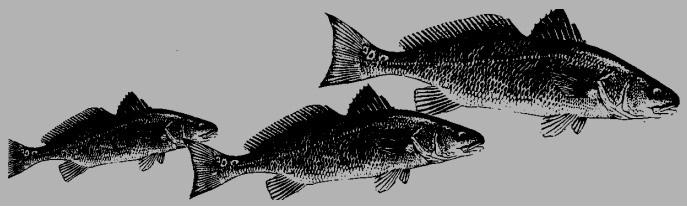
- Lasalocid, currently approved for use on food animals, reduced trophont infection on 0.5-1.0 gram red drum gill filaments by 80% at a concentration of 0.1 ppm. At 1.0 ppm, infection was completely prevented.

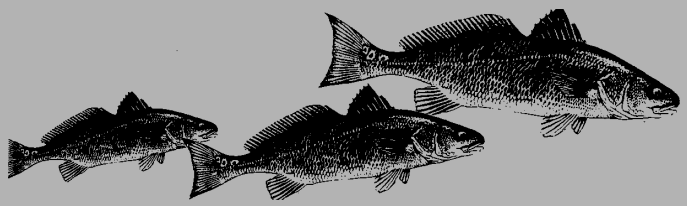
Peppard, E.M., W.R. Wolters, J.W. Avault, Jr., and W.G. Perry, Jr. 1991. Toxicity of chelated copper to juvenile red drum *Sciaenops ocellatus.* Journal of the World Aquaculture Society, 22(2), 101-108.

- Safe copper compound dosage for red drum fingerlings for short-duration treatment of external parasites was determined to be 0.2 - 0.25 mg/l. Mortality was positively correlated with temperature and negatively correlated with salinity**.**

Plumb, J.A. 1991. Major diseases of striped bass and redfish. Veterinary and Human Toxicology, 33 (Supplement 1), 34-39.

-Aquacultured red drum and hybrid striped bass exhibited similar diseases.Vibriosis (*Vibrio sp*.) and motile *Aeromonas septicemia* (*Aeromonas hydrophila*) were the most frequently encountered bacterial





diseases. Fungi (usually *Saprolegnia*) and *Amyloodinium ocellatum* were the most serious problems, but other protozoans (*Trichodina, Ichthyophthirius, Cryptocaron*, etc.) were also reported. Treatment of any of these diseases was shown to be a problem because of the absence of approved drugs or chemicals for use on striped bass or redfish.

Economics

Baldridge, T., L. Dellenbarger, and D. Huffman. 1991. Economics of commercial redfish production in Louisiana. D.A.E. Research Report No. 688. Louisiana Agricultural Experiment Station, Louisiana State University Agricultural Center, Baton Rouge, 32 p.

- A synthesized analysis based on preliminary cost estimates and a growth simulation model using anticipated survival and feed conversion values.

Griffin, W.L., and S.G. Thacker. 1994. Combined indoor/outdoor red drum aquaculture: a stochastic sensitivity analysis. Journal of Applied Aquaculture, 4(3), 1-21.

- Probability of economic survival (defined as avoidance of bankruptcy) was generally high (>50%) over a range of model variables such as growth rate, survival, market price, feed price and frequency of random (catastrophic) losses. Economic success (defined as a net present value greater than zero) was more variable in the stochastic output.

Haby, M.G., and M.L. Cuenco. 1990. Red Drum marketing opportunities. In: Red Drum Aquaculture, Chamberlain, G.W., Miget R.J., and Haby M.G., eds. Texas A and M Sea Grant College Publication, College Station, Texas, 209-213.

- An analysis of market characteristics in Texas at the time of publication. Size preferences, prices, yields, scope of market, infrastructure and potential marketing strategies were reviewed.

Lutz, C.G. 1994. An overview of Louisiana red drum production: investment, site selection and legal considerations for Louisiana and elsewhere. Louisiana Aquaculture Conference 1994, Louisiana Cooperative Extension Service and Louisiana Agricultural Experiment Station, LSU Agricultural Center, Baton Rouge, 48-51.

-Brief but comprehensive overview of potential and constraints in Louisiana for pond-based red drum aquaculture at the time of publication.

Lutz, C.G. 1996. Commercial prospects for red drum culture: implications from field trials. Louisiana State University Agricultural Center - Louisiana Cooperative Extension Service Publication no. 2619.

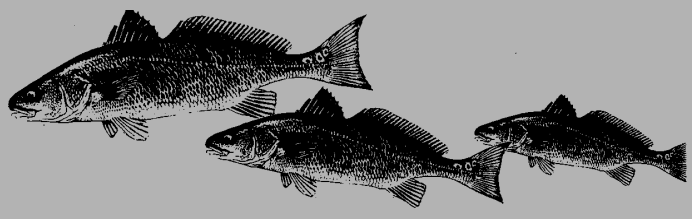
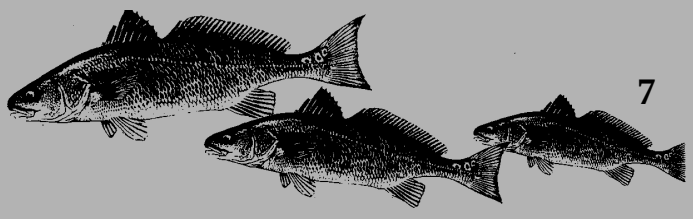
-Synthesis of university and commercial scale red drum pond grow-out trials. Results suggested break-even prices of $2.40/lb and $2.59/lb for early- and late-season stocking, respectively, with yields of 3,863 and 3,274 lb/acre realized before a second overwintering period. Low survival and high feed conversion ratios were cited as major constraints.

McBryde, G. 1994. Financial characteristics of a red drum aquaculture firm with winter nursery production. Aquaculture, 122(2-3), 107-118.

-Financial feasibility of vertically integrated red drum aquaculture was presented. Although potential for high profit existed, investors were discouraged because of mortality risk and dependence on each harvest to service debt.

Rhodes, R.J., and D. Hollin. 1990. Financial analysis of commercial red drum aquaculture enterprise. In: Red Drum Aquaculture, Chamberlain, G.W., Miget R.J., and Haby M.G., eds. Texas A and M University Sea Grant College Program, College Station, Texas, 189-208.

-Authors presented estimated capital requirements and operating cost estimates for a hypothetical red drum hatchery and semi-intensive grow-out facility at the time of publication. Sensitivity analysis for 10-year internal rate of return was included for variations in survival, product price and feed cost.

Thacker, S.G., W. Griffin, A. Rahman, and J. Lambregts. 1991. Modeling the financial risk of intensive redfish *Sciaenops ocellatus* aquaculture in Texas. Journal of the World Aquaculture Society, 22(3), 42A-43A.

-A 10-year financial analysis of an indoor, intensive production facility including hatchery, nursery and growout. Although profit potential was high, random catastrophic losses beyond managerial control were also predicted.

Thacker, S.G., and W.L. Griffin. 1994. Indoor intensive red drum aquaculture: A stochastic sensitivity analysis. Journal of the World Aquaculture Society, 25(1), 86-100.

-A 0.0-100% chance of financial success was predicted for indoor, intensive red drum farming under a number of scenarios. The most important predictor of failure for this type of endeavor was determined to be poor management. Other success factors included required rate of return and aversion to risk exposure.

Van Chau, A.N. 1982. Potential for aquaculture in southeast Texas: red drum farming. John E. Gray Institute, Lamar University. 43 p.

-A summary of a large volume of red drum literature as it related to the potential for red drum farming along the coast of Texas. Capital and operating costs at the time of publication were presented for a 50 water-acre farm with hatchery.

Fingerling Production

Colura, R.L. 1987. Saltwater pond fertilization. In: Manual of Red Drum Aquaculture, Chamberlain, G.W., Miget R.J., and Haby M.G., eds. Texas Agricultural Extension Service and Sea Grant College Program, College Station, Texas, p. III51-III53.

- Recommended schedules for fry pond fertilization.

Colura, R.L., B.W. Bumguardner, A. Henderson-Arzapalo, and J.D. Gray. 1990. Culture of red drum fingerlings. Report no. 22, Management Data Series, Texas Parks and Wildlife Department, Coastal Fisheries Branch, Austin.

- Following brief introduction, materials, results and reference sections, the authors presented in-depth discussion of production procedures in appendix form, from broodfish procurement through advanced fingerling culture. Regulations at the time of publication and metric conversions were also presented.

Colura, R.L., B.T. Hysmith, and R.E. Stevens. 1976. Fingerling production of striped bass *Morone saxatilis*, spotted seatrout, *Cynoscion nebulosis*, and red drum *Sciaenops ocellatus*, in saltwater ponds. Proceedings of the World Mariculture Society, 7, 79-92.

- A summary of some very early trials, which showed good promise for red drum pond culture in salt water.

Craig, S. 1989. The effects of enriching live foods with highly unsaturated fatty acids on the growth and fatty acid composition of larval red drum *Sciaenops ocellatus* Linnaeus, Master's Thesis, Corpus Christi State University, Corpus Christi, Texas.

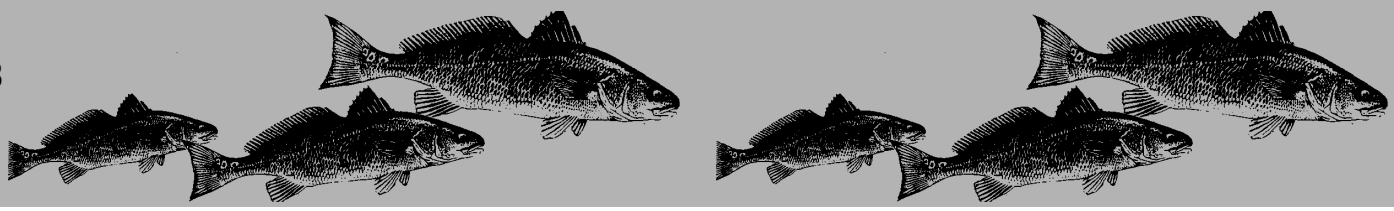
- Although enrichment increased EPA and DHA levels, control rotifers produced higher growth rates. Rotifers with no HUFA supplementation resulted in significantly lower growth.

Davis, J.T. 1991. Red drum: production of fingerlings and stockers. Publication no. 324, Southern Regional Aquaculture Center, Stoneville, Mississippi.

- Recommended methods for pond preparation, stocking with larvae, feeding, harvesting and growout were reviewed.

Douillet, P.A., and G.J. Holt. 1994. Surface disinfection of red drum *Sciaenops ocellatus* Linnaeus eggs leading to bacteria-free larvae. Journal of Experimental Marine Biology and Ecology, 179(2), 253-266.

- A number of disinfectants were evaluated for different stages of egg development. A "no observable effect concentration" of 3% hydrogen peroxide for 5 minutes allowed production of bacteria-free larvae.



Fernandez, R. 1990. Redfish fingerling harvest. In: Red Drum Aquaculture, Chamberlain, G.W., Miget R.J., and Haby M.G., eds. Texas A and M Sea Grant College Program, College Station, Texas, 91.

- Complete practical methodology for fingerling harvest, removal and sampling.

Henderson-Arzapalo, A. 1990. Red drum egg and larval incubation. In: Red Drum Aquaculture, Chamberlain, G.W., Miget R.J., and Haby M.G., eds. Texas A and M Sea Grant College Program, College Station, Texas, 51-52.

- Environmental requirements, enumeration sampling, and incubation mechanics and management.

Henny, D.C., G.J. Holt, and C.M. Riley. 1995. Recirculating-water system for the culture of marine tropical fish larvae. The Progressive Fish-Culturist, 57, 219-225.

- A larval culture system incorporating a high-density rearing area within a recirculating loop and an external filter unit was described. Authors related success with red drum and other species.

Holt, G.J. 1990. Growth and development of red drum eggs and larvae. In: Red Drum Aquaculture, Chamberlain, G.W., Miget R.J., and Haby M.G., eds. Texas A and M Sea Grant College Program, College Station, Texas, 46-50.

- Growth and development were described, and environmental (temperature, salinity, nitrogenous compounds) and dietary effects on these processes were discussed.

Holt, G.J. 1992. Experimental studies of feeding in larval red drum. Journal of the World Aquaculture Society, 23(4),265-270.

- A review of available information regarding factors limiting mass production of red drum fingerlings under controlled conditions.

Holt, G.J. 1993. Feeding larval red drum on microparticulate diets in a closed recirculating water system. Journal of the World Aquaculture Society, 24(2), 225-230.

- Successful weaning of red drum larvae to microdiets was described. Growth and metamorphosis rates were comparable to those attained with live diets, and survival rates were high.

Holt, G.J., C.R. Arnold, and C.M. Riley. 1990. Intensive culture of larval and post-larval red drum. In: Red Drum Aquaculture, Chamberlain, G.W., Miget R.J., and Haby M.G., eds. Texas A and M Sea Grant College Program, College Station, Texas, p. 53-56.

- Techniques and methodology for egg handling, larval culture, feeding and enumeration for small-scale, tank-based larviculture.

Holt, J., R. Godbout, and C.R. Arnold. 1981. Effects of temperature and salinity on egg hatching and larval survival of red drum, *Sciaenops ocellata*. Fishery Bulletin, 79(3), 569-573.

- Optimum temperature and salinity for incubation and rearing were estimated to be 25 degrees C and 30 ppt. The importance of temperature in maximizing growth increased with age.

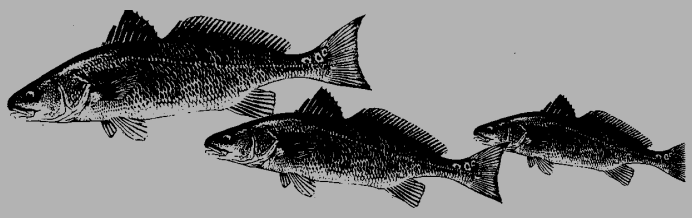
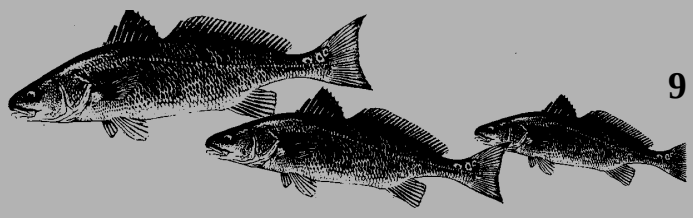
Johansen, P.L. 1986. Microplankton in red drum mariculture ponds. Report no.105, Management Data Series, Texas Parks and Wildlife Department, Coastal Fisheries Branch, Austin.

-Seasonal variation of numbers of plankters was reported but with little change in species present in red drum fingerling culture ponds in Texas.

Lee, W.Y., G.J. Holt, and C.R. Arnold. 1984. Growth of red drum larvae in the laboratory *Sciaenops ocellatus* Transactions of the American Fisheries Society, 113(2), 243-246.

-Larval red drum grew faster at 28 degrees C than 24 degrees C. Differences in survival were not reported.

Matlock, G.C., R.L. Colura, C. Porter, and T.L. Heffernan. 1985. Effect of two fertilizers on red drum survival in ponds. Report no.76, Management Data Series, Texas Parks and Wildlife Department, Coastal Fisheries Branch, Austin.

-Cottonseed meal and alfalfa meal (568 kg/ha) were compared as fertilizers for red drum fingerling production ponds. Although differences in survival were inconclusive statistically, authors made strong case for use of alfalfa meal based on higher dissolved oxygen levels in ponds and lower cost.

McCarty, C.E., and B.R. Gregg. 1992. Early prediction of pond harvest success rate. Aquaculture, 102(1-2), 89-94.

-Plankton tows were used to develop an equation to predict number of fingerlings present at harvest. Most mortality was reported to occur within the first 48 hours. Authors recommend restocking ponds that experience initial mortality to maximize profits.

Oestmann, D.J., D.H. Lewis, and B.A. Zettler. 1995. Clearance of *Amyloodinium ocellatum* dinospores by *Artemia salina*. Journal of Aquatic Animal Health, 7(3), 257-261.

- A density of 8 brine shrimp nauplii/ml eliminated dinospores initially present at 10,000/ml in 8 hours. When dinospores were stocked at 100,000/L, 1,000 nauplii/L reduced trophont load on juvenile fish by 65%.

Roberts, D.E.J., L.A.I. Morey, G.E. Henderson, and K.R. Halscott. 1978. The effects of delayed feeding, stocking density, and food density on survival, growth, and production of larval red drum *Sciaenops ocellata*. Journal of the World Mariculture Society, 9, 333-356.

- The optimal time of initial feeding was determined to be 3 days after hatching. A density of 10 larvae/liter and 5 rotifers/ml resulted in the highest survival and biomass, although growth was maximized at 2 larvae/liter.

Soletchnik, P. E., E. Thouard, E. Goyard, and D. Baisnee. 1991. Intensive aquaculture techniques for raising larval redfish (*Sciaenops ocellatus*) in Martinique: Preliminary results. Proceedings of the Gulf and Caribbean Fisheries Institute, 40, 367-381.

- Methods and techniques used during rearing trials were critically reviewed.

Soletchnik, P. E., E. Thouard, E. Goyard, C. Yvon, and P. Baker. 1988. First larval rearing trials of red drum *Sciaenops ocellatus* in Martinique (French West Indies). Contributions in Marine Science, 30 (Supplement), 125-130.

- A summary of problems encountered in larval trials highlighting cannibalism, poor swim bladder inflation and infestation by *Amyloodinium ocellatus.*

Stahl, C. J., S. S. Barnes, and W. H. Neill. 1995. Optimization of dissolved solids for the intensive culture of juvenile red drum *Sciaenops ocellatus* Journal of the World Aquaculture Society, 26(3), 323-326.

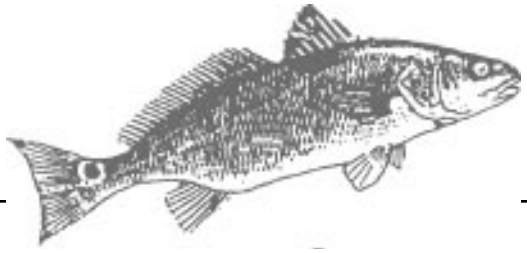
- A solution of 5g/L sodium chloride provided the highest survival rate when compared to a 6 g/L seawater control, 5 g/L calcium chloride or magnesium sulfate, and 1 g/L each of seawater control, sodium chloride, calcium chloride or magnesium sulfate.

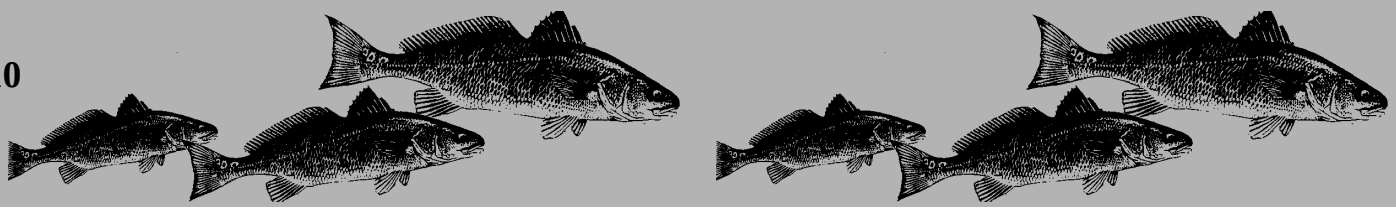
Stahl, C. J. 1994. Optimization of ionic conditions for the intensive culture of red drum, *Sciaenops ocellatus*. Aquaculture '94 - New Orleans Book of Abstracts, World Aquaculture Society, Baton Rouge.

- Results indicated that growth and survival of red drum cultured in 1 g/liter natural seawater may be comparable to those in seawater augmented with sodium chloride, calcium chloride or magnesium sulfate.

Sturmer, L. N. 1990. Zooplankton composition and dynamics in fingerling red drum rearing ponds. In: Red Drum Aquaculture, Chamberlain, G.W., Miget R.J., and Haby M.G., eds. Texas A and M Sea Grant College Program, College Station, Texas, 80-90.

- Characteristics of typical zooplankton groups found in rearing ponds and typical succession patterns are described. Recommended management techniques are also reviewed.





Freshwater Production

Gatlin, D.M, III, D.S. MacKenzie, S.R. Craig, and W.H. Neill. 1992. Effects of dietary sodium chloride on red drum juveniles in waters of various salinities. The Progressive Fish-Culturist, 54(4), 220-227.

- Dietary NaCl at 2% supplementation resulted in signficantly greater weight gain and feed efficiency in fresh water. In brackish water (5ppt), no significant differences were demonstrated. In salt water (35 ppt), supplementation at 2% and 10% had no significant impact on growth, but reduced feed efficiency significantly at the 10% level.

Huner, J.V. 1994. Red drum in recreational ponds. Farm Pond Harvest, 28(1):10-11, 19.

- The historical fishery, life cycle, culture methods and requirements, and use of red drum in recreational ponds were reviewed. Constraints to recreational aquaculture of red drum were highlighted.

Miranda, L.E., and A.J. Sonski. 1985. Survival of red drum fingerlings in fresh water: dissolved solids and thermal minima. Proceedings Annual Conference Southeastern Fish and Wildlife Agencies, 39, 228-237.

-Authors indicated stocking of red drum fingerlings in fresh water should be successful at temperatures above 9 degrees C and chloride concentrations exceeding 130 mg/L.

Pursley, M.G., and W.R. Wolters. 1994. Effect of total water hardness and chloride on survival, growth, and feed conversion of juvenile red drum *Sciaenops ocellatus*. Journal of the World Aquaculture Society, 25(3), 448-453.

- Two 2 X 2 factorial designs evaluated the following hardness levels by chloride levels: 100 and 200 mg/L by 125 and 250 mg/L, and 100 and 400 mg/L by 150 and 500 mg/L. In the first trial, growth was significantly greater at 100 mg/L total hardness, while survival exhibited no significant treatment effects. In trial two, higher chlorides and hardness levels resulted in improved growth, survival and feed conversion.

Thomas, R.G., and W.R. Wolters. 1992. Factors affecting the survival of fingerling red drum in freshwater ponds. The Progressive Fish-Culturist, 54(4), 215-219.

-Use of sodium chloride as a salinity enhancer resulted in improved survival compared to calcium chloride. Increasing the salinity acclimation period from 2 to 6 hours resulted in no improvement in survival, nor did predator control treatments. Survival rates in fresh water of up to 90% were considered possible at chloride levels of 400 mg/L (using sodium chloride).

Wolters, W.R., K. Mulowayi, R.J. Laprarie, M.G. Pursley, and R.P. Romaire. 1994. Effect of salinity and stocking density on production and survival of red drum *Sciaenops ocellatus* in earthen ponds. World Aquaculture '94 - New Orleans Book of Abstracts, World Aquaculture Society, Baton Rouge.

- Brackish water ponds significantly improved yield, survival and feed conversion over freshwater ponds. Density effects were not reported.

General

Benetti, D.D., A. Venizelos, and C. Acosta. 1994. Finfish aquaculture in Equador. World Aquaculture, 25(2), 18-25.

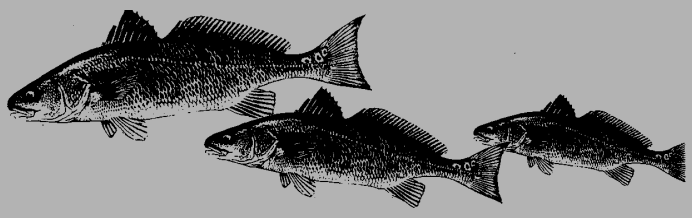
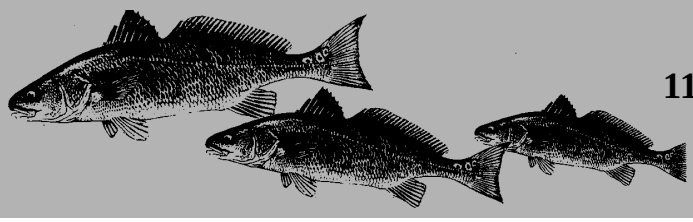
- Red drum were described as adaptable to conditions in Ecuadorian ponds previously used for shrimp culture.Very high larval survival was offset by low fingerling survival caused by cannibalism and external protozoan parasites.

Chamberlain, G.W. 1986. Red drum aquaculture status. Coastal Aquaculture, 3(3), 1-20.

- A thorough overview of the status of production technology, market demand, industry capitalization and other issues at the time of publication.

Davis, J.T. 1991. Red drum: site selection and pond construction. Publication no. 321, Southern Regional Aquaculture Center, Stoneville, Miss.

- A review of water requirements, soil and topographic considerations, and accessibility issues. Recommendations on pond design and construction.

Forsberg, J.A., and W.H. Neill. 1994. Suitability of saline groundwater for red drum aquaculture in West Texas. World Aquaculture '94 - New Orleans Book of Abstracts, World Aquaculture Society, Baton Rouge, 286.

- A series of bioassays using dilutions of saline groundwaters suggested red drum fingerlings would be expected to exhibit similar growth and survival in these waters as those cultured in 15 ppt artificial seawater.

Henderson-Arzapalo, A. 1992. Red drum aquaculture. Review of Aquatic Sciences, 6(5/6), 479-491.

- An overview of the history and development of techniques for mass production of red drum, with emphasis on the research shift from stocking and restoration to commercial, market production.

Higginbotham, B. 1990. Fee fishing potential for red drum. In: Red Drum Aquaculture, Chamberlain, G.W., Miget R.J., and Haby M.G., eds. Texas A and M Sea Grant College Program, College Station, Texas, 166-169.

- Environmental requirements for red drum, such as water quality (hardness, chlorides) and quantity, temperature, oxygen concentration and other factors were presented in the context of a fee-fishing operation. Management considerations for fee fishing enterprises, such as pond design, management, marketing, facility characteristics and other factors were reviewed.

Hopkins, S.J., A.D. Stokes, P.A. Sandifer, R.A. Smiley, and T.R. McTeer. 1986. Spawning and grow-out trials with red drum in South Carolina. Proceedings of the Fortieth Annual Conference of Southeastern Association Fish and Wildlife Agencies, 40, 179-186.

- Fingerling production from wild-caught broodstock was described. Production of food-size fish from fingerlings over a 22-month period was also reported, with atypically high survival rates**.**

Jahncke, M., M.B. Hale, J.A. Gooch, and J.S. Hopkins. 1988. Comparison of pond-raised and wild red drum *Sciaenops ocellatus* with respect to proximate composition, fatty acid profiles, and sensory evaluations. Journal of Food Science, 53(Jan./Feb.), 286-287.

-Similiar flavor and texture profiles were reported for both pond-raised and wild-caught fish. Pond fish were higher in linoleic acid and lower in docosahexaenoic acid, however, than their wild counterparts, presumably because of dietary differences.

Ladner, C.M., and J.B. Loftus. 1985. Redfish - Highlights regarding the potential for their culture in Mississippi. Mississippi Department of Wildlife Conservation, Bureau of Marine Resources.

-Authors reviewed potential for red drum farming in southern one-third of Mississippi .

Landry, W.J. 1991. Summary of redfish and striped bass production in Louisiana. Louisiana Aquaculture Conference 1991, Louisiana Cooperative Extension Service and Louisiana Agricultural Experiment Station, LSU Agricultural Center, Baton Rouge, 49.

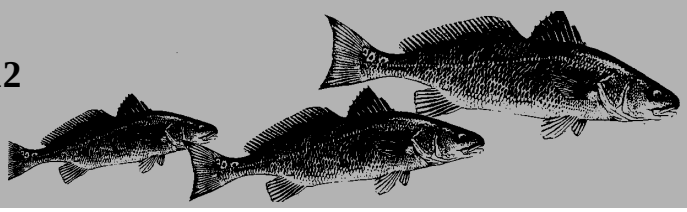
-Producer summary of red drum farms in Louisiana in 1991. Complete red drum mortality in ponds was reported as a result of 100 continous hours of freezing temperatures in December 1989.

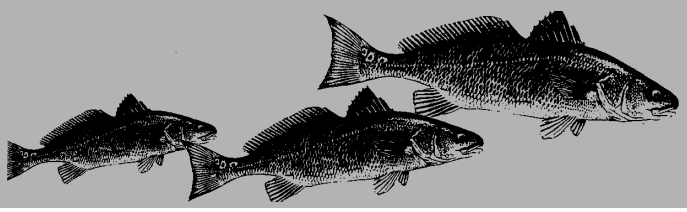
Lutz, C.G., W. Lorio and J. Avery. 1994. Site selection for Louisiana finfish production: Technical considerations for water quality, quantity and disposal. Louisiana State University Agricultural Center - Louisiana Cooperative Extension Service Publication no. 2543.

- Available sources of ground and surface water throughout the state were compared with recommended chemical profiles for popular cultured finfish, with an emphasis on red drum and hybrid striped bass. Discharge considerations were also discussed.

Lutz, C.G., W. Lorio and J. Avery. 1994. Site selection for Louisiana finfish production: Legal considerations for Louisiana and elsewhere. Louisiana State University Agricultural Center - Louisiana Cooperative Extension Service Publication no. 2544.

- Permitting and site selection were discussed with regard to federal and state environmental regulations affecting construction, access, effluents, water use and similar topics.





Miget, R.J. 1990. Site selection for redfish culture. In: Red Drum Aquaculture, Chamberlain, G.W., Miget R.J., and Haby M.G., eds. Texas A and M Sea Grant College Program, College Station, Texas, 131-137.

-An overview of site selection criteria such as temperature, water quality, elevation, water table, soil characteristics, wetlands delineation, permitting, etc.

Villarreal, B.W., P.M. Rosenblum, and L.T. Fires. 1994. Fatty acid profiles in red drum muscle: Comparison between wild and cultured fish. Transactions of the American Fisheries Society, 123(2), 194-203.

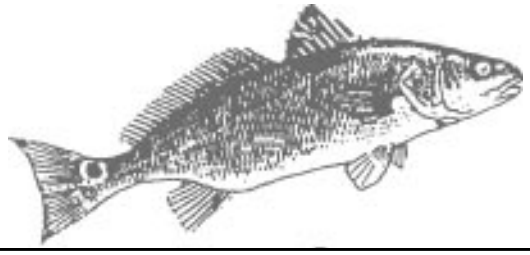
- Three fatty acids were identified as diagnostic for consistent discrimination of cultured fish: linoleic acid (18:2n-6) was consistently lower in wild fish, while arachidonic (20:4n-6) and adrenic (22:4n-6) acids were consistently higher in wild fish.

Wolters, W.R. 1988. Review of red drum pond culture. Louisiana Aquaculture Conference 1988, Louisiana Cooperative Extension Service and Louisiana Agricultural Experiment Station, LSU Agricultural Center, Baton Rouge, 130-132.

- Four pioneering studies were reviewed, with emphasis on implications for Louisiana industry, as well as potential for and constraints to profitability.

Younger, W.R., J. Moseley, and J.A. Shiner. 1987. Practical permitting suggestions. In: Manual on Red Drum Aquaculture Chamberlain, G.W., Miget R.J., and Haby M.G., eds. Texas Agricultural Extension Service and Sea Grant College Program, College Station, Texas, IV67-IV83.

- A review of the legal basis of permits, methodology in obtaining and completing applications, philosophy of the permitting process, types of permit categories, and agency contact information for coastal states from Texas to North Carolina.



Grow-out

Arnold, C.R., and B. Reid. 1990. High density recirculating grow-out systems. In: Red Drum Aquaculture, Chamberlain, G.W., Miget R.J., and Haby M.G., eds. Texas A and M Sea Grant College Program, College Station, Texas, 182-184.

- A protoype system was described. Principles and major considerations of water re-use were addressed, and miminal information was provided on performance of red drum in the system. Fingerlings (1 gram) grown for 116 days exhibited 44% survival and final weights ranging from 20 grams to 190 grams.

Crocker, P.A., C.R. Arnold, J.A. DeBoer, and G.J. Holt. 1981. Preliminary evaluation of survival and growth of juvenile red drum *Sciaenops ocellatus* in fresh and salt water. Journal of the World Mariculture Society, 12, 122-134.

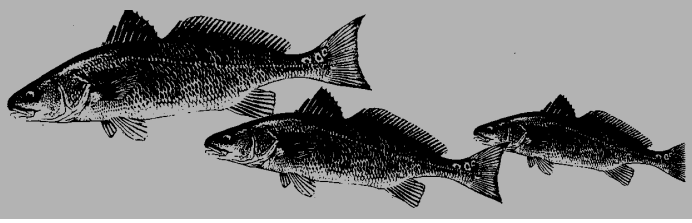
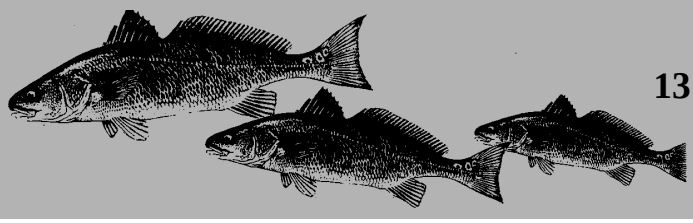
- Larvae, post-larvae and juveniles exhibited survival rates of 5%, 70% and 95%, respectively, when subjected to dechlorinated fresh water for 96 hours. Although survival did not differ significantly, growth and appetite of juveniles in saltwater flow-through raceways were significantly greater than those of similar-aged fish in freshwater flow-through raceways.

Davis, J.T. 1990. Inland culture of red drum. In: Red Drum Aquaculture, Chamberlain, G.W., Miget R.J., and Haby M.G., eds. Texas A and M Sea Grant College Program, College Station, Texas, 185-188.

- Considerations for culturing red drum at inland sites were reviewed. Major constraints were availability and disposal of water supplies with sufficient ionic content, and insufficient options to avoid massive crop losses from exposure to low temperatures. Fingerling production trials and general production techniques were also covered.

Davis, J. T. 1991. Red drum: production of food fish. Publication no. 322, Southern Regional Aquaculture Center, Stoneville, Mississippi.

- A review of recommended practices, facilities, equipment and management for pond grow-out to marketable size.

Dorsett, P., E. Seidman, S. Boren, M. Schwarz, and W.H. Neill. 1996. Thermal refuge technology to protect red drum (*Sciaenops ocellatus*) from cold-kill in aquaculture ponds. Aquaculture America 1996 - Arlington Book of Abstracts, World Aquaculture Society U.S. Chapter, Baton Rouge, 36.

- Three designs for thermal refuges were described and compared. All consisted of a plastic cover with hanging curtains located in one corner of a culture pond. Additional information relating to salinity manipulation was presented.

Garces-Boticaio, H.A. 1991. Observed and modeled growth of red drum in aquacultural ponds in the Republic of Panama, Ph.D. Dissertation, Texas A&M University.

-Salinity ranged from 7 to 41 ppt, although temperature varied little (24-28 C). Stocking rates varied from extensive to semi-intensive (2,100 - 48,000 fish/ha) but produced similiar results. Average growth was reported at 2 g/day with 65% overall survival. The main focus of this research was to develop a growth model that would explain experimental results.

Garces-Boticaio, H.A. 1992. Proximate composition of muscle of cage-raised red drum, *Sciaenops ocellatus* (Pisces: Sciaenidae), in Panama. Revista Biologica Tropical, 40(1), 147-148.

- Red drum raised in cages and fed 36% protein floating pellets exhibited suitable growth rates and chemical profiles similar to those of red drum cultured in earthen ponds or living in a marine environment.

Garces-Boticaio, H.A. 1993. Application of bioenergetics modeling to fish growth in ponds. Revista Biologica Tropical, 41(suppl. 1), 27-30.

- A bioenergetic growth model suggested changes of 1 ppm dissolved oxygen could result in large (+ 60%) differences in average weight over time. Similarly, a change of 10% total dietary energy in the model resulted in a 75% loss or gain in average weight over time.

Hein, S.H., and J.A. Shepard. 1980. Growth of juvenile red drum, *Sciaenops ocellata* in a quarter-acre pond. Technical Bulletin 31, Marine Research Laboratory - Grand Terre Island, Louisiana Department of Wildlife and Fisheries, Baton Rouge, 85.

- From mid-October to early January, juveniles stocked at approximately 10,000/ha exhibited growth rates of 0.92 mm and 0.05 g per day. Water temperature averaged 19 degrees C. The trial was abruptly ended by a die-off caused by low temperatures.

Hopkins, J.S. 1990. Semi-intensive grow-out in saltwater. In: Red Drum Aquaculture, Chamberlain, G.W., Miget R.J., and Haby M.G., eds. Texas A and M Sea Grant College Program, College Station, Texas, 170-177.

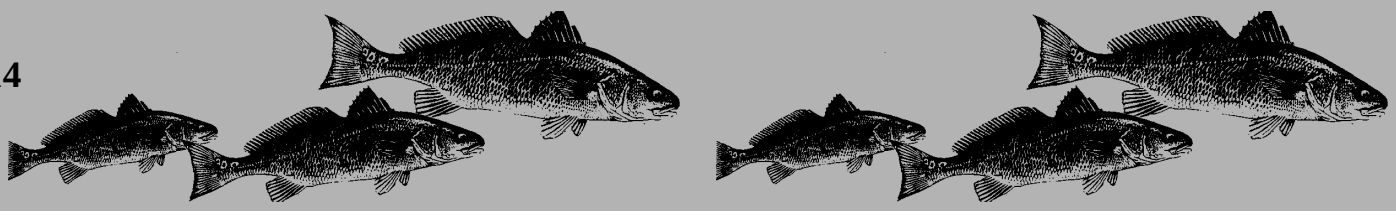
- A three-phase production methodology was proposed based on preliminary research results. Facility and equipment recommendations to accommodate this approach were presented.

Hopkins, J.S., T.I.J. Smith, A.D. Stokes, and P.A. Sandifer. 1987. Recent progress in the development of culture techniques for redfish *Sciaenops ocellatus*. Journal of the World Aquaculture Society, 18(1), 36A.

- A brief review of production trial results reported elsewhere. Fingerlings produced from normal season spawning of broodstock that had been brought indoors from conditioning ponds were not weaned to prepared rations before the overwintering period and accordingly exhibited poor survival, inversely related to density. Yearling fish from spring spawns exhibited excellent overwintering survival.

Hysmith, B. ., G.C. Matlock, and R.L. Colura. 1983. Effects of stocking rate and food type on growth and survival of fingerling red drum. Special Publication no. 3. World Aquaculture Society, Baton Rouge.

- Feeding improved growth and survival of overwintered fingerlings, but the influence of stocking rate on performance was negligible.



Liao, I.C., M.-S. Su, S.-I. Chang, and W.-C.Wang. 1997. A study of the feasibility of red drum, *Sciaenops ocellatus*, aquaculture in Taiwan. World Aquaculture '97 - Seattle Book of Abstracts, World Aquaculture Society, Baton Rouge, 285.

- Spontaneous spawning of 53-month-old red drum initially shipped to Taiwan from Texas as fertilized eggs occurred in 1991. Temperatures of 25-30 degrees C resulted in good growth, and viability at 15 degrees C suggested this species can survive normal cold season temperatures in Taiwanese ponds.

Luebke, R.W., and K. Strawn. 1973. The growth, survival, and feeding behavior of redfish *Sciaenops ocellata* in ponds receiving heated discharge water from a power plant. Proceedings of the World Mariculture Society, 4, 143-154.

-Results of an early study involving 100 wild red drum caught by hook and line. Survival (83%) and growth (3 g/day) were high despite temperatures in the cooling ponds as high as 35 degrees C. Wild-caught fish were trained to eat trout chow two weeks after capture.

Procarione, L.S., and G.C. Matlock. 1990. Long-term growth of hatchery stocks of Texas and South Carolina red drum 1986-1989. Report no.19, Management Data Series, Texas Parks and Wildlife Department, Coastal Fisheries Branch, Austin.

- Neither hatchery stock exhibited a clear advantage in growth, production or survival. No consistent differences were seen during pond or tank phases of the study.

Procarione, L.S., and B.W. Bumguardner. 1989. Long-term growth of South Carolina and Texas red drum 1986-1988. Report no.5, Management Data Series. Texas Parks and Wildlife Department Fisheries Division Coastal Fisheries Branch.

- No significant differences were observed in growth or survival, although South Carolina fish tended to exhibit slightly more elongate body conformation.

Procarione, L.S., A. Henderson-Arzapalo, and A. Maciorowski. 1989. Comparison of pond-culture characteristics between Atlantic and Gulf Coast red drum fingerlings. The Progressive Fish-Culturist, 51(4), 201-206.

- Although the two populations exhibited similar patterns of production and survival, Atlantic strain fish appeared to be more variable in length and weight gain over time.

Sandifer, P.A., J.S. Hopkins, A.D. Stokes, and R.D. Smiley. 1993. Experimental pond grow-out of red drum, *Sciaenops ocellatus*, in South Carolina. Aquaculture, 118(3-4), 217-228.

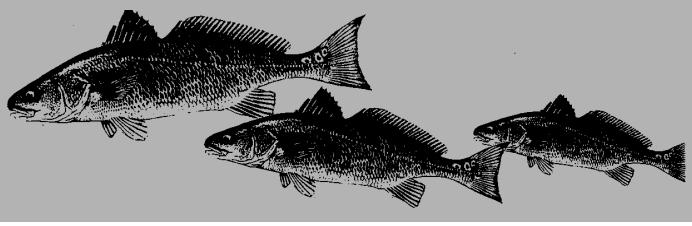
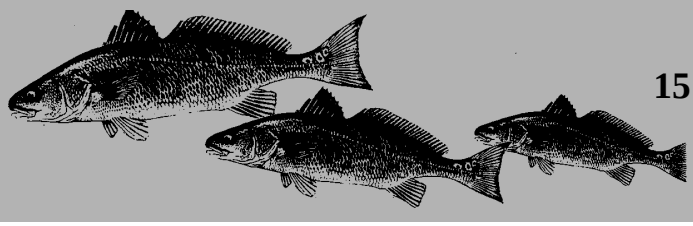
- Although water was exchanged daily at 16% to 27% of pond volume and near continuous aeration was applied during the second grow-out season, parasitic infection and oxygen depletions resulted in large losses in some ponds. In other ponds, however, yields were high (8,997 - 24,082 kg/ha), growth was acceptable (1.0 - 1.3 kg avg. weight at harvest) and survival was high (88.7% to 94.9%). Food conversion ranged from 2.15 to 2.60.

Stahl, C.J., D.M. Gatlin, and W.H. Neill. 1997. The effect of dissolved oxygen on the growth performance of juvenile red drum, *Sciaenops ocellatus*. World Aquaculture '97 - Seattle Book of Abstracts, World Aquaculture Society, Baton Rouge, 438.

- Over a six-week period, dissolved oxygen levels in 5 treatments averaged 9.8, 6.2, 5.2, 4.5 and 2.8 mg/L at 26.7 degrees C. Dissolved oxygen levels of 5.2 mg/L and higher resulted in significantly better growth rates than observed in the 2.8 mg/L treatment, as well as higher survival.

Stokes, A.D. 1990. Semi-intensive pond management methods. In: Red Drum Aquaculture, Chamberlain, G. W., Miget R. J., and Haby M. G., eds. Texas A and M Sea Grant College Program, College Station, Texas, 178-181.

- Pond and water quality management, sampling, grading, feeding and disease control practices associated with a proposed system using phase II and phase III grow-out periods of 12 months each.

Tomasso, J.R., and C.J. Kempton. 1997. Effects of temperature on production characteristics and blood chemistries of red drum fingerlings, *Sciaenops ocellatus* World Aquaculture '97 - Seattle Book of Abstracts, World Aquaculture Society, Baton Rouge, 249.

- At a salinity of 9-11 g/L, weight gain, growth in total length and feed conversion of red drum fingerlings (16.2 to 49.5 g initial mean weight) were all maximized at 29.1-31.1 degrees C.

Trimble, W.C. 1979. Yield trials for red drum in brackish-water ponds, 1976-1979. Proceedings Annual Conference Southeast Association of Fish and Wildlife Agencies., 33, 432-441.

- Early grow-out trials resulted in yields of 787-2,292 kg/ha, feed conversions of 2.8 to 4.6, survival rates of 75% to 89% and <1% to 33% marketable fish at harvest.

Wilson, C.W. 1990. Extensive aquaculture of red drum in the southern United States. In: Red Drum Aquaculture, Chamberlain, G.W., Miget R.J., and Haby M.G., eds. Texas A and M Sea Grant College Program, College Station, Texas, 154-164.

- Considerations and management recommendations for low-input production of red drum in coastal impoundments were reviewed. Particular emphasis was placed on legal and regulatory issues, site selection requirements and approaches to production and harvest.

Wisner, B.B., M. Lee, S. Zeches, and T.R. Capo. 1992. Preliminary evaluation of red drum cage culture in South Florida freshwater rock pits. Aquaculture '92 - Orlando Book of Abstracts, World Aquaculture Society, Baton Rouge, 237.

- Red drum fingerlings (approximately 30 gram) were grown in cages for 37 days. Although growth was acceptable (1.38% body weight per day), survival was 87% at the end of the study period. No mention was made of feed conversion efficiency.

Wurts, W.A., and R.R. Stickney. 1993. Growth rates of juvenile red drum *Sciaenops ocellatus* reared on commercial salmon feed in fresh and salt water. Journal of the World Aquaculture Society, 24(3), 422-424.

- No significant differences were detected in the growth rate constant, k, for 1-17 gram red drum reared in aquaria with fresh water containing 0.9-1.9 g/L total dissolved solids or salt water containing 5 and 35 g/L total dissolved solids. In other fresh- and saltwater production systems, growth rates were comparatively constant for fish ranging from 1-258 grams.

Wurts, W.A., and R.R. Stickney. 1989. Responses of red drum *Sciaenops ocellatus* to calcium and magnesium concentrations in fresh and salt-water. Aquaculture, 76(1-2), 21-35.

- Although environmental magnesium exhibited no influence on survival, calcium levels had a significant effect in saltwater. Acid washing of biofilter media between trials was suspected to have resulted in reduction of essential trace elements and overall fish performance.

Hybridization

Henderson-Arzapalo, A., R.L. Colura, and A.F. Maciorowski. 1994. A comparison of black drum, red drum, and their hybrid in saltwater pond culture. Journal of the World Aquaculture Society, 25(2), 289-296.

- Hybrid drum exhibited superior growth and intermediate survival over 9 months when compared to parental species. Mean weights were 190 grams, 142 grams, and 144 grams, respectively, for hybrids, red drum and black drum. Survival ranged from 63% for red drum to 94% for black drum, and hybrids exhibited 72% survival.

Henderson-Arzapalo, A., and R.L. Colura. 1984. Black drum x red drum hybridization and growth. Journal of the World Mariculture Society, 15, 412-420.

- Growth and development of hybrids were described from fertilization through day 197 post-hatching. Hybrids performed acceptably when compared to red drum.

Prentice, J.A. 1985. Freshwater tolerance of red drum x black drum hybrids. F-31-R-11, Final Report - Federal Aid Project, Texas Parks and Wildlife Department.

- Hybrid vigor was not noted with respect to freshwater tolerance.

Travis, C.D. 1985. Freshwater tolerance of red drum x black drum hybrids. F-31-R-11, Final Report. Texas Parks and Wildlife Department.

- Hybrid performance was intermediate to that of parental species.

Nutrition

Boren, R.S., and D.M. Gatlin, III. 1995. Dietary threonine requirement of juvenile red drum *Sciaenops ocellatus.* Journal of the World Aquaculture Society, 26(3), 279-283.

- Protein efficiency ratios, protein conversion efficiencies and free threonine levels in plasma suggested a minimum threonine requirement of approximately 0.8% of dry diet for juvenile red drum.

Brinkmeyer, R.L., and G.J. Holt. 1995. Response of red drum larvae to graded-levels of menhaden oil in semipurified microparticulate diets. The Progressive Fish-Culturist, 57(1), 30-36.

- Among test diets, a total lipid level of 18.3% (from menhaden oil and red drum muscle lipid) resulted in the best growth rate, compared to levels of 13%, 22.7% and 27.1%. A commercial microparticulate diet, Kyowa-A, however, resulted in significantly greater larval growth.

Brown, P.B., D.A. Davis, and E.H. Robinson. 1988. An estimate of the dietary lysine requirement of juvenile red drum *Sciaenops ocellatus*. Journal of the World Aquaculture Society, 19(3), 109-112.

- A 5.7% dietary lysine level was recommended for red drum diet formulations.

Craig, S.R., C.R. Arnold, and G.J. Holt. 1994. The effects of enriching live foods with highly unsaturated fatty acids on the growth and fatty acid composition of larval red drum *Sciaenops ocellatus.* Journal of the World Aquaculture Society, 25(3), 424-431.

- Although 10-day-old red drum larvae had similar fatty acid profiles regardless of experimental diet, supplemental DHA (docosahexaenoic acid) was recommended to attain a level of 0.3-0.4 mg/l00 mg tissue in rotifers used for feeding.

Craig, S.R., and D.M. Gatlin, III. 1992. Dietary lysine requirement of juvenile red drum *Sciaenops ocellatus.* Journal of the World Aquaculture Society, 23(2), 133-137.

- A lysine level of 4.43% dietary protein was determined as optimal. A zein-based diet exhibited insufficient palatability to allow its use in feeding trials.

Craig, S.R., and D.M. Gatlin, III. 1994. Choline and lecithin in the diet of juvenile red drum *Sciaenops ocellatus.* World Aquaculture ’94 - New Orleans Book of Abstracts, World Aquaculture Society, Baton Rouge, 145.

- Dietary supplementation of lecithin at either 1% or 4% improved growth of jvenile red drum, but choline supplementation failed to produce similar results.

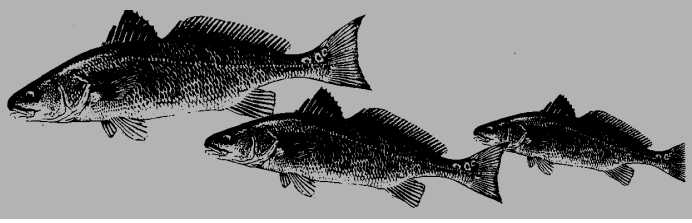
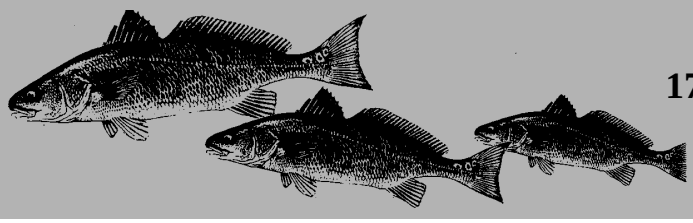
Craig, S.R., and D.M. Gatlin, III. 1995. Dietary choline requirement of red drum (*Sciaenops ocellatus*). Aquaculture ’95 - San Diego Book of Abstracts, World Aquaculture Society, Baton Rouge, 91.

- A minimum dietary choline recommendation of approximately 750 mg/kg of diet was proposed based on feeding trials with juvenile red drum.

Craig, S.R., W.H. Neill, and D.M. Gatlin, III. 1995. Effects of dietary lipid and environmental salinity on growth, body composition, and cold tolerance of juvenile red drum *Sciaenops ocellatus*. Fish Physiology and Biochemistry, 14(1), 49-61.

- Brackish water (5ppt) improved weight gain over salt water (32ppt). Data analysis suggested inclusion of high levels of dietary lipid rich in n-3 HUFA’s may reduce lower lethal temperature for juvenile red drum.

Craig, S.R., B. Washburn, and D.M. Gatlin, III. 1997. Effects of lipid levels on weight gain, feed efficiency and liver composition of juvenile red drum, *Sciaenops*

ocellatus. World Aquaculture ’97 - Seattle Book of Abstracts, World Aquaculture Society, Baton Rouge, 92.

- Feeding trials utilizing levels of 0%, 7%, 14% or 21% dietary lipid suggested performance in terms of weight gain, feed efficiency, fat deposition and liver composition could be optimized with total lipid levels ranging from 7% to 14%.

Davis, D.A., and E.H. Robinson. 1987. Dietary phosphorus requirements of juvenile red drum *Sciaenops ocellatus*. Journal of the World Aquaculture Society, 18(3), 129-136.

- A level of 0.86% was established as necessary for maximum tissue mineralization. Although weight gain and feed conversion did not differ significantly among treatments, survival was generally lower for fish fed phosphorus-deficient diets.

Davis, D.A., D. Jirsa, and C.R. Arnold. 1995. Evaluation of soybean proteins as replacements for menhaden fish meal in practical diets for the red drum *Sciaenops ocellatus*. Journal of the World Aquaculture Society, 26(1), 48-58.

- Increasing fish meal content in test diets resulted in increases in weight gain, survival and feed efficiency ratios. Methione supplementation was required in a low fish meal diet, but increasing levels of fish meal increased fish performance even with methionine supplementation. Based on these results, a low fish meal diet incorporating palatability enhancers was developed, resulting in weight gain and feed efficiency ratios not significantly different from those attained with a high fish meal diet.

Davis, D.A., J.P. Lazo, and C.R. Arnold. 1996. Effects of the utilization of medium-chain triglycerides on growth and body composition of the red drum (*Sciaenops ocellatus*). Aquaculture America 1996 - Arlington Book of Abstracts, World Aquaculture Society U.S. Chapter, Baton Rouge, 101.

- MCTs were evaluated as a means of producing high-energy diets while reducing fat deposition in red drum. Higher levels of MCTs reduced growth and feed efficiency, but also reduced intraperitoneal fat deposition.

Ellis, S.C., and R.C. Reigh. 1991. Effects of dietary lipid and carbohydrate levels on growth and body composition of juvenile red drum, *Sciaenops ocellatus.* Aquaculture, 97(4), 383-394.

-Dietary energy levels and carbohydrate content were inversely related to weight gain, feed efficiency, apparent net protein retention and apparent net energy retention. Juvenile red drum appeared to have limited ability to use dietary carbohydrate as an energy source, with greater protein-sparing action observed from dietary lipids.

Gatlin, D.M., III, D.S. Mackenzie, S.R. Craig, and W.H. Neill. 1992. Effects of dietary sodium chloride on red drum juveniles in waters of various salinities. The Progressive Fish-Culturist, 54(4), 220-227.

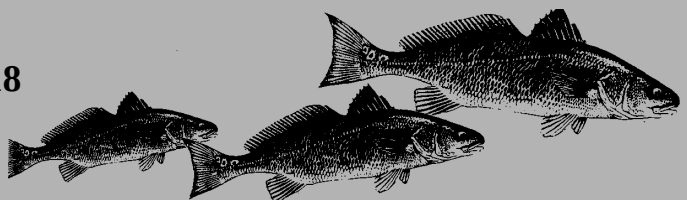
- Dietary NaCl at 2% supplementation resulted in signficantly greater weight gain and feed efficiency in fresh water. In brackish water (5ppt), no significant differences were demonstrated. In salt water (35 ppt), supplementation at 2% and 10% had no significant impact on growth, but reduced feed efficiency significantly at the 10% level.

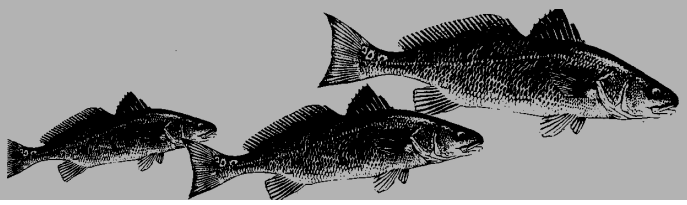
Gatlin, D.M., III, J.P. O’Connell, and J. Sarpa. 1991. Dietary zinc requirement of the red drum, *Sciaenops ocellatus*. Aquaculture, 92(2-3), 259-266.

- A minimum requirement of 20-25 mg Zn/kg dry diet was suggested by the authors.

Gaylord, T.G., and D.M. Gatlin III. 1996. Determination of digestibility coefficients of various feedstuffs for red drum (*Sciaenops ocellatus*). Aquaculture, 139(3-4), 303-314.

- Organic matter digestibility decreased with increasing nitrogen-free extract fraction. Crude protein digestibility was low for poultry by-product meal, but high (77%-97%) for other feed sources. Digestible energy coefficients were higher for animal products than for plant products, and an inability to effectively digest nitrogen-free extract portions of plant products was noted.





Holt, G.J., F. Sun, P. Lavens, P. Sorgeloos, E. Jasper, and F. Ollevier. 1991. Lipase activity and total lipid content during early development of red drum *Sciaenops ocellatus.* Larvi '91, Special Publication of the European Aquaculture Society, no. 15, 30-33.

- Since lipid is the principal energy reserve in red drum eggs and a major (30%-50% dry weight) component of natural foods of larval red drum, the authors identified developmental changes in lipase activity and lipid content and documented variations in these levels resulting from artificial diets and pulsed starvation.

Lochmann, R.T., and D.M. Gatlin III. 1993. Evaluation of different types and levels of triglycerides, singly and in combination with different levels of n-3 highly unsaturated fatty acid ethyl esters in diets of juvenile red drum, *Sciaenops ocellatus*. Aquaculture, 114(1-2), 113-130.

- Two trials were conducted to shed light on the lipid requirements of juvenile red drum. Increasing dietary lipid resulted in increased EFA requirements. Linseed and menhaden oils, providing 18:3n-3 and 3n-3 HUFA's, resulted in improved weight gain**.**

Lochmann, R.T., and D.M. Gatlin. 1993. Essential fatty-acid requirement of juvenile red drum *Sciaenops ocellatus*. Fish Physiology and Biochemistry, 12(3), 221-235.

-Laboratory feeding studies were performed to determine minimum essential fatty acid requirement of red drum. Authors determined the requirement to be 0.5-1% (n-3) HUFA, but the control diet, containing 7% menhaden oil. resulted in even better performance. Food conversion, growth and survival were all reduced in EFA-deficient diets.

McGoogan, B.B., and R.C. Reigh. 1994. Apparent digestibility coefficients for common feed ingredients in diets for red drum, *Sciaenops ocellatus*. World Aquaculture '94 - New Orleans Book of Abstracts, World Aquaculture Society, Baton Rouge, 276.

-Results indicated that animal protein sources were well used by red drum. Corn, wheat middlings and sorghum were also well digested, but rice bran and cottonseed meal were not. Authors concluded high levels of fiber were not desirable in red drum feeds.

McGoogan, B.B., and R.C. Reigh. 1996. Apparent digestibility of selected ingredients in red drum (*Sciaenops ocellatus*) diets. Aquaculture, 141(3-4), 233-244.

- Using reference diets and test diets based on the reference and additional test ingredients, apparent digestibility of dry matter, crude protein and energy were estimated for a number of common aquaculture feed components. Red drum appeared to use dietary protein efficiently regardless of the sources provided, while energy digestibility was somewhat low for animal and plant products. Crude fiber content reduced digestibility of dry matter and energy in general.

McGoogan, B.B., and D.M Gatlin, III. 1997. Determination of protein and energy requirements of red drum, *Sciaenops ocellatus*, for maintenance and maximum growth. World Aquaculture '97 - Seattle Book of Abstracts, World Aquaculture Society, Baton Rouge, 319.

- Two separate feeding trials indicated dietary recommendations of 1.6-2.7 g protein and 13.1-21.7 kcal per kg BW/day for maintenance, compared to 22-27 g protein and 176-217 kcal per kg BW/day for maximum growth.

Meilahn, C.W., D.A. Davies, and C.R. Arnold. 1996. Effects of commercial fish meal analogue and menhaden fish meal on growth of red drum fed isonitrogenous diets. The Progressive Fish-Culturist, 58(2), 111-116.

- When a commercially available fish-meal analogue was substituted for menhaden fish meal, little impact was noted at a 50% replacement level, but growth was reduced at a 75% replacement level.

Moon, H. Y., and D. M. Gatlin, III. 1990. Amino acid nutrition of the red drum (*Sciaenops ocellatus*): Determination of limiting amino acids and development of a suitable amino acid test diet. In: The Current Status of Fish Nutrition in Aquaculture. Proceedings of the Third International Symposium on Feeding and Nutrition in Fish, Takeda, M., and Watanabe, T., eds. Toba, Japan, 201-208.

-Limiting amino acids were determined by singular deletions in 35% crude protein diets based on peanut meal and shrimp meal and in test diets using crystal-

line amino acids with limited amounts of intact protein. Growth and feed efficiency were significantly reduced without supplemental histidine, leucine, methionine and phenylalanine.

Moon, H.Y., and D.M. Gatlin, III. 1991. Total sulfur amino acid requirement of juvenile red drum, *Sciaenops ocellatus*. Aquaculture, 95(1-2), 97-106.

-Total sulfur amino acid requirement of juvenile red drum was determined to be 1.06% of diet (3.03% of dietary protein). Cystine was determined to be a suitable replacement for 40% of dietary methionine requirements.

Moon, H.Y., D.M. Gatlin, III, and D.S. MacKenzie. 1992. Differential effects of dietary 3,5,3'-triiodothreonine (T3) and Thyroxine (T4) on juvenile red drum *Sciaenops ocellatus*. Aquaculture '92 - Orlando Book of Abstracts, World Aquaculture Society, Baton Rouge, 297.

-Dietary supplementation of T3 and T4 did not produce increased fish growth when added to a high-quality diet. T3 reduced fish growth and altered body composition when fed at high doses.

Moon, H.Y., W.H. Neill, and D.M. Gatlin. 1991. Evaluation of protein sources for red drum *Sciaenops ocellatus* diets. Journal of the World Aquaculture Society, 22(3), 42A-43A.

-Experimental diets (35% protein) made from various marine and freshwater fish muscle tissue produced faster growth than 35% protein commercial trout chow. Commercial formulations were theorized to have lower digestibility than the experimental diets produced from whole fish muscle.

Moon, H.Y.L., and D.M. Gatlin III. 1994. Effects of dietary animal proteins on growth and body composition of the red drum (*Sciaenops ocellatus*). Aquaculture, 120(3-4), 327-340.

- Juvenile red drum performance, expressed as weight gain, feed efficiency and protein efficiency ratio, was ranked from highest to lowest when fed test diets containing protein from the following sources: lyophilized red drum muscle, lyophilized whole body croaker (*Micropogon undulatus*), red drum waste, striated beef muscle and menhaden fish meal.

Reigh, R.C., and S.C. Ellis. 1992. Effects of dietary soybean and fish-protein ratios on growth and body composition of red drum *Sciaenops ocellatus* fed isonitrogenous diets. Aquaculture, 104(3-4), 279-292.

- Red drum fed diets containing only soy protein, with or without methionine supplementation, exhibited poor growth and survival.

Robinson, E.H. 1990. Nutrition and feeding of red drum. Red Drum Aquaculture, Chamberlain, G.W., Miget R.J., and Haby M.G., eds. Texas A and M Sea Grant College Publication, College Station, Texas, 109-112.

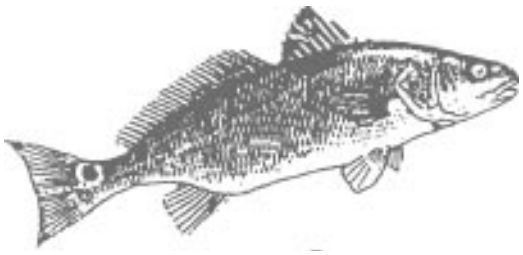
- Natural diets and previous nutrition research were briefly reviewed. Feed storage, selection and delivery were reviewed with an emphasis on red drum.

Williams, C.D., and E.H. Robinson. 1988. Response of red drum to various dietary levels of menhaden oil. Aquaculture, 70, 107-120.

- Dietary lipid levels of 7.4%-11.2% resulted in maximum weight gain, lowest feed conversion ratio and highest survival.

Wisner, B.B., T.R. Capo, and J. Cramer. 1991. Comparison of four commercial aquaculture diets for red drum. Journal of the World Aquaculture Society, 22(3), 66A.

- Although a soft-moist salmon diet produced the greatest gains and lowest FCR, a trout diet was determined to be the most economical for commercial red drum production. A shrimp diet resulted in acceptable growth but low survival and a catfish diet resulted in poor growth and FCR.



Physiology

Caldwell, C.A., and J.R. Tomasso. 1987. Stocking and handling-induced stress in red drum fingerlings. Proceedings Annual Conference of Southeastern Fish and Wildlife Agencies, 39, 238-247.

- The effects of net confinement and transport on plasma glucose levels, plasma chloride levels and hematocrit dynamics were evaluated. Although little mortality occurred during transport evaluations, 50% cumulative mortality occurred after 9 hours of net confinement.

Crocker, P.A., C.R. Arnold, J.A. DeBoer, and G.J. Holt. 1983. Blood osmolality shift in juvenile red drum, *Sciaenops ocellatus* L. exposed to fresh water. Journal of Fisheries Biology, 23(3), 315-319.

- Characteristic patterns of osmolality shift and survival rates following abrupt transfer from 28 ppt to <1 ppt were described.

Neill, W.H. 1994. Oxygen dynamics and fish growth in aquaculture. In: High Performance Fish: Proceedings of an International Fish Physiology Symposium, MacKinlay, D.D. ed., University of British Columbia, Vancouver, 336.

- In large (115,000-L) tank systems, metabolic rates of 30- to 200-gram red drum ranged from 0.54 to 0.69 mg oxygen/gram/hour.

Robertson, L., P. Thomas, C.R. Arnold, and J.M. Trant. 1987. Plasma cortisol and secondary stress responses of red drum *Sciaenops ocellatus* to handling, transport, rearing density and a disease outbreak. The Progressive Fish-Culturist, 49(1), 1-12.

- Transient and long-term changes in plasma cortisol, glucose levels and osmolality responses are described and compared to findings from previous studies. Increasing density did not affect plasma glucose and only temporarily altered cortisol titers.

Reproduction

Arnold, C.R. 1991. Precocious spawning of red drum. The Progressive Fish-Culturist, 53(1), 50-51.

- Red drum hatched and reared under laboratory conditions spawned at 19.5 months of age. Average weight at spawning was 2.9 kg.

Arnold, C.R., W.H. Bailey, T.D. Williams, A. Johnson, and J.L. Lasswell. 1976. Laboratory spawning and larval rearing of red drum and southern flounder. Proceedings Annual Conference of Southeastern Fish and Wildlife Agencies, 31, 437-440.

- A detailed account of techniques, equipment used and recommended management methodologies.

Colura, R.L. 1990. Hormone induced strip-spawning of red drum. In: Red Drum Aquaculture, Chamberlain, G.W., Miget R.J., and Haby M.G., eds. Texas A and M Sea Grant College Program, College Station, Texas, 33-34.

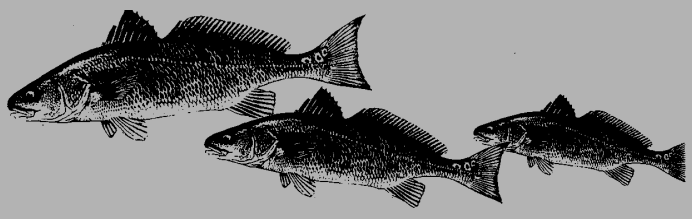
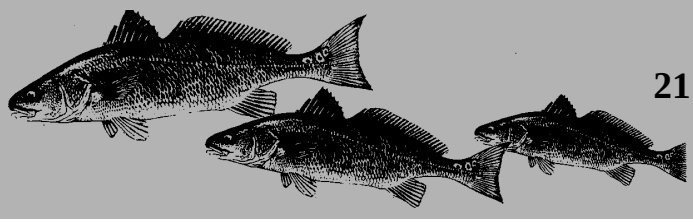
- Biological theory and methodology for obtaining fertilized red drum eggs.

Davis, J.T. 1991. Red drum: brood stock and hatchery production. Publication no. 323, Southern Regional Aquaculture Center, Stoneville, Mississippi.

- Suggested methods for collecting, holding and spawning adults and for maintaining and culturing fry and larvae. Required equipment and supplies also.

Falls, W.W., C.W. Dennis, P.A. Hindle, and J.C. Young. 1997. Refinements in methods of inducing spawning in cultured red drum, *Sciaenops ocellatus* (L.), in Florida. World Aquaculture ‘97 - Seattle Book of Abstracts, World Aquaculture Society, Baton Rouge, 147.

- A number of improvements over conventional practices were developed, including 1) initial maturation of wild-caught broodstock in outdoor ponds, 2) adjustment of light cycles to allow mid-day collection, evaluation and transfer of eggs immediately following spawning, 3) genetic fingerprinting of female broodstock using mitochondrial DNA extracted from oocytes during ovarian biopsies, and 4) use of actively

spawning "mentor" females to train new and non-spawning females to shed their eggs.

Jenkins, W.E., C.B. Bridgham, and T.I.J. Smith. 1997. Closely controlled spawning of captive red drum (*Sciaenops ocellatus*) broodstock. World Aquaculture '97 - Seattle Book of Abstracts, World Aquaculture Society, Baton Rouge, 227.

- Following a normal, 6-month photothermal manipulation cycle and subsequent 3-month spawning period under constant conditions (25 degrees C, 13 hrs. light), a closely controlled thermal management schedule was established wherein temperature was reduced to 21 degrees C for 3 days then raised immediately to 25 degrees C for 4 days, allowing regular, predictable spawning for a period of 14 months on those days when spawning tanks were at the higher temperature level.

Lawson, T.B., C.M. Drapcho, S. McNamara, H.J. Braud, and W.R. Wolters. 1989. A heat exchange system for spawning red drum. Aquacultural Engineering, 8(3), 177-208.

-An earth coupled heat pump was used for successful temperature manipulation in a red drum spawning tank. Authors indicated potential for energy savings and improved temperature control when using heat pumps for thermal conditioning/maturation of red drum.

McCarty, C.E. 1990. Design and operation of a photoperiod/temperature spawning system for red drum. In: Red Drum Aquaculture, Chamberlain, G.W., Miget R.J., and Haby M.G., eds. Texas A and M University, 44-45.

-Authors describe the temperature/photoperiod spawning system used by the Texas Parks and Wildlife Department's redfish hatchery.

Pursley, M.G., and C.G. Lutz. 1994. Louisiana red drum production. Technical considerations: collecting and maintaining wild broodstock. Louisiana State University Agricultural Center - Louisiana Cooperative Extension Service, Publication no. 2542.

- Logistical and methodology considerations based on the authors' experience. Collection equipment, bait, technique, day-to-day maintenance, feeding, moving, medication, water management for inland facilities and practical considerations were all discussed in detail.

Reese, R.O., D.E. Roberts, Jr., and E. Truby. 1987. Red drum spawning: the 120 day cycle, vitellogenesis and maturation. Journal of the World Aquaculture Society, 18(1), 24A-25A.

- General stages of ovarian maturation and oocyte development were described briefly for the 120-day artificial cycle used to induce vitellogenesis and spawning.

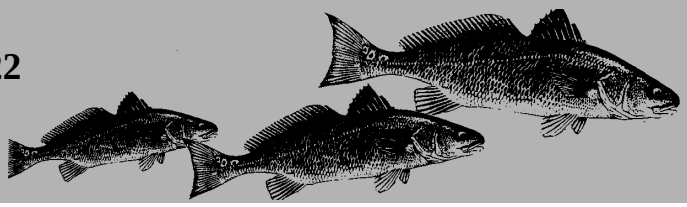
Roberts, D.E. 1990. Photoperiod/temperature control in the commercial production of red drum *Sciaenops ocellatus* eggs. Red Drum Aquaculture, Chamberlain, G.W., Miget R.J., and Haby M.G., eds. Texas A and M University Sea Grant College Program, College Station, Texas, 35-43.

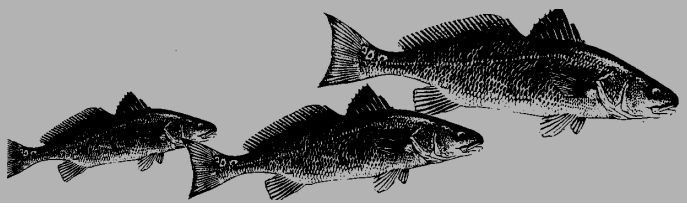
- A review of the principles of using exogenous stimuli to trigger maturation and spawning in captive fishes, practical approaches to construction and management of photoperiod/temperature spawning tank facilities, and methods and procedures used by three pioneering hatcheries producing fingerling red drum in mass quantities.

Thomas, P., C.R. Arnold, and G.J. Holt. 1995. Red drum and other sciaenids. In: Broodstock management and egg and larval quality, Bromage, N. R. and Roberts R. J., eds. Blackwell Science Ltd., Oxford, 118-137.

- A review of all aspects of broodstock management and fingerling production, from oocyte development through induction of spawning and larval culture.

Thomas, P., and N. Boyd. 1988. Induced spawning of spotted seatrout, red drum, and orange-mouth corvina (Family: Sciaenidae) with lutenizing hormone-releasing hormone analog injection. Contributions to Marine Science, 30 (Supplement), 43-48.





- LHRHa at 0.1 mg/kg body weight injected intramuscularly below the dorsal fin consistently resulted in ovulation in mature red drum.

Tillman, R.E. 1990. Broodstock collection. Red Drum Aquaculture, Chamberlain, G.W., Miget R.J., and Haby M.G., eds. Texas A and M Sea Grant College Program, College Station, Texas, 30-32.

- Tips for locating, collecting and transporting wild broodstock.

Transport

Jensen, G.L. 1990. Transportation of warmwater fish—loading rates and tips by species. Publication no. 394, Southern Regional Aquaculture Center, Stoneville, Mississippi.

- Recommendations presented for red drum included temperature and salinity guidelines and acclimation shedules based on salinity of receiving waters**.**

McCraren, J.P. 1990. Transportation and acclimation of red drum fingerlings. In: Red Drum Aquaculture, Chamberlain, G.W., Miget R.J., and Haby M.G., eds. Texas A and M Sea Grant College Program, College Station, Texas, 92-104.

-A well-written overview of live fish transportation. History, equipment, chemicals, loading rates, acclimation as well as loading/unloading techniques. Recommended practices for red drum are listed concisely, and an extensive bibliography is provided.

Robertson, L., P. Thomas, and C.R. Arnold. 1988. Plasma cortisol and secondary stress responses of cultured red drum *Sciaenops ocellatus* to several transportation procedures. Aquaculture, 68, 115-130.

- Based on glucose and plasma cortisol levels, capture and loading appeared to be the most stressful components of the transportation process for red drum. Anesthesia did not reduce capture and loading stress response indicators. Long-term sedation during transport increased plasma cortisol levels.

Tomasso, J.R., and G.J. Carmichael. 1988. Handling and transport-induced stress in red drum fingerlings *Sciaenops ocellatus.* Contributions in Marine Science, 30 (Supplement), 133-138.

- Although red drum fingerlings generally exhibited little mortality after up to 5 hours of hauling, 12%-51% cumulative mortality was typical over the following 10 days. Tolerance of net confinement was proposed as an indicator of the overall condition of fingerlings with respect to handling and hauling.

Weirich, C.R., and J.R. Tomasso. 1991. Confinement- and transport-induced stress on red drum juveniles: Effect of salinity. The Progressive Fish-Culturist, 53(3), 146-149.

- Salinities of 2 and 35 ppt were determined to be too extreme to allow for successful confinement and transport. Intermediate salinities (4-16 ppt) resulted in acceptable survival, especially at an isosmotic level with red drum plasma (11ppt).

Water Quality

Neil, W.H. 1990. Environmental requirements of red drum. In: Red Drum Aquaculture, Chamberlain, G.W., Miget R.J., and Haby M.G., eds. Texas A and M University Sea Grant College Program, College Station, Texas, 105-108.

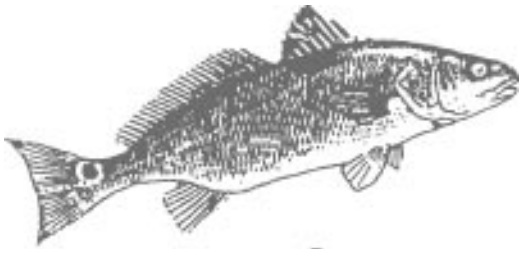
- A discussion of known water quality requirements for this fish at the time. Particular attention was given to temperature and levels of dissolved ions.

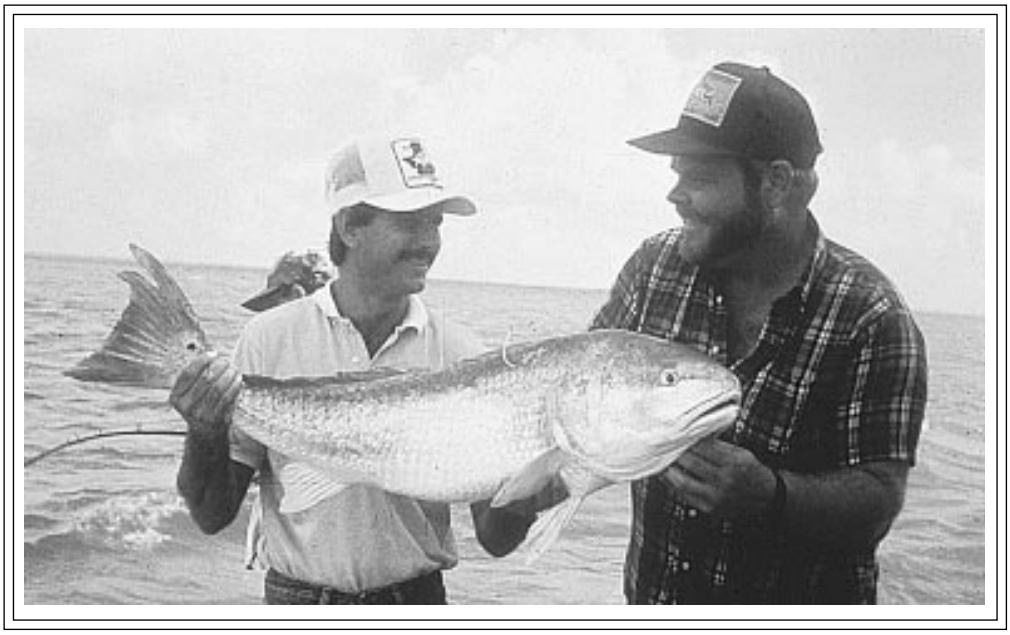
Wise, D.J., and J.R. Tomasso. 1989. Acute toxicity of nitrite to red drum *Sciaenops ocellatus*: Effect of salinity. Journal of the World Aquaculture Society, 20(4), 193-198.

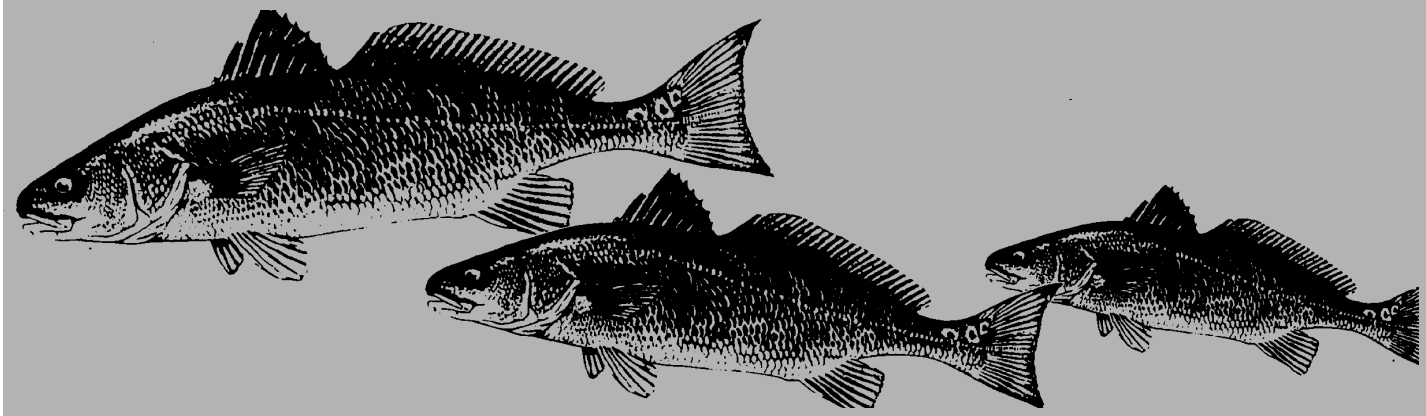
- The authors illustrated potential for nitrite toxicity in low-salinity waters. Chloride concentrations were not as effective in preventing methemoglobinemia as in other fish species. The 48 h median lethal concentration of nitrite was only 2.8 mg/L nitrite-N in 0.6 g/L salinity.

Wise, D.J., C.R. Weirich, and J.R. Tomasso. 1989. Toxicity of ammonia to red drum *Sciaenops ocellatus*fingerlings with information on uptake and depuration. Journal of the World Aquaculture Society, 20(4), 188-192.

- Ammonia moved from the environment into the plasma of red drum at a very rapid rate (within one hour), but left the plasma even more quickly (within 5 minutes) when fish were moved to ammonia-free water. Recommended chronic exposure levels were determined to be no more than 0.05 mg/L unionized ammonia-N.







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