Culture of the Copepod *Acartia tonsa* Utilizing Various Artificial Feeds

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ABSTRACT

In the interest of increasing zooplankton yields from culture tanks several supplemental feeds were evaluated. Triplicated trials utilizing small 1,000 L tanks with no water exchange were sampled weekly during four weeks for copepod abundance. Abundance of *Acartia tonsa* nauplii decreased for the unfed control and tanks fed algae, bacteria, and Isomil®. Nauplii numbers increased in tanks fed artificial plankton, rice bran and Rotirich®

KEY WORDS: Copepod, nutrition, *Acartia tonsa*

INTRODUCTION

The most widely accepted food offered to the larvae of fish has been plankton taken from the wild which consists mostly of copepods (May 1970, Turner 1984).

Success in rearing fish larvae has been limited using other foods, such as barnacle nauplii, mysids, oyster and mussel larvae, ciliates, and nematodes. It was the discovery by Rollefsen (1939) that plaice could be reared on *Artemia* sp. nauplii that first allowed the mass rearing of a number of marine fish. The use of the rotifer has likewise allowed the rearing of an additional group of fish species for which the larvae could not eat an *Artemia sp.* nauplii at first feeding. It has recently been recognized that a third group of fish larvae which will not feed on *Artemia* sp. or rotifers can be reared on the nauplii of copepods. It has also recently been suggested that even for those fish which can eat *Artemia* sp. or rotifers, the growth and survival is better if they are fed copepods (Neller 1985, Whitt et al. 1984, Pedersen 1984, Ogle and Lotz 2000a). The major drawback to the use of copepods is still the difficulty in providing sufficient quantities.

Traditionally fish larvae have been stocked into ponds that had been fertilized to increase zooplankton abundance (Horvath et al. 1984). The ponds may be fertilized with organic fertilizers, such as manure, cotton seed meal, fish meal or various inorganic fertilizers (Nees 1949, Swingle 1947, Hepher 1962, Yamada 1986, Boyd 1990). Ponds may also be enhanced by inoculating with a specific

zooplankton (Chamberlain et al. 1987, Horvath et al. 1984). Copepods have also been successfully cultured in large outdoor tanks which were fertilized with organic (Ono and Okamura 1988) or inorganic (Raymont and Miller 1962) fertilizers. Regardless, such blooms follow a natural succession of phytoplankton to zooplankton and then collapse. They are difficult to control and predict.

In attempting to find a species of copepod for mass culture Ikeda (1973) concluded that a small neritic brackish water species should be used. *Acartia* spp. are the dominant zooplankton in most neritic water of the United States (Roman 1977) and come to dominate in large fertilized tanks (Raymont and Miller 1962). It is also the dominate species within Davis Bayou adjacent to this laboratory. *Acartia* sp. is possibly able to dominate these estuarine areas due to its wide salinity tolerance (Stein 1981, Raymont and Miller 1962).

Acartia tonsa has been described as an omnivorous particle grazer and opportunistic feeder (Poulet 1962) and as an opportunistic omnivorous suspension feeder (Lonsdale et al. 1979). Energetic studies on feeding in a number of copepods has suggested that in the wild they can not derive enough energy from grazing exclusively on phytoplankton (Heinle and Flemer 1975). It has been demonstrated that copepod adults (Pafenhofer and Strickland 1970) and nauplii (Poulet 1977) can utilize detritus and indeed there is five times more detrital than phytoplankton biomass in the ocean. Dissolved organics have also been suggested as a source of food for copepods especially for pre-feeding and developmental stages (Poulet 1983). Direct uptake of organics is, however still controversial, and the amount of organic carbon is 10 times less than that of detritus. Poulet (1983) suggested that free bacteria are not used as a food by copepods, and there is 200 times less bacterial biomass in the ocean than detrital biomass.

Interestingly, in laboratory studies feeding detritus has not generally been successful (Roman 1977), whereas, the use of phytoplankton is standard (Omori 1973, Turner 1984). Culture systems designed to produce *Acartia* sp. have also relied primarily on phytoplankton (Stottrup et al. 1986, Schipp et al. 1999). The only reported use of a mixed detrital system being used as a food to produce *Acartia tonsa* is that of Ogle (1979). That system has been expanded recently and used to supply food to larval red snapper (Ogle et al. 2000, Ogle and Lotz 2000a). The system has also been investigated by Lemus et al. (2000) and compared to systems receiving rice bran as an organic food source. Rice bran was used by Turk et al. (1982) as a sole food source to produce *Acartia tonsa*. Rice bran has also been used to enhance zooplankton in ponds (Bishara 1979) and to feed *Artemia* sp. (Sorgeloos et al. 1980).

The "brown water system" of Ogle (1979), while successfully used at the Gulf Coast Research Laboratory to produce several thousand juvenile red snapper (Ogle and Lotz 2000a.), requires a ratio of 100:1 for food to larval culture volumes. One advantage of the system is that it can be easily managed for collapses in production. Such declines in copepod production are usually the result of increases in competitors, such as mussels, oysters, barnacles or tunicates, or predators, such as jellyfish. The 100 m^2 tanks can easily be drained and cleaned in a matter of hours

and will be back to full copepod production in a matter of days. One disadvantage of the system is that such management is required. A long term goal, therefore, is to intensify production of a specific copepod in an indoor system. The first step in achieving that goal is to identify an alternate food to the "brown water". Therefore, a variety of foods were evaluated for their suitability as food for the copepod *Acartia tonsa*.

MATERIALS AND METHODS

Copepods were cultured in black polyethylene tanks holding 1,000 L of water. Water from an existing 100 m^2 outdoor tank, filtered to 300 microns was used to fill the tanks. The water from the outdoor tank was clear and contained a resident population of *Acartia tonsa*. The tanks were located under an open sided greenhouse having a 85% shade cover. Three replicates of each of four diets were evaluated for a total of 12 tanks during each of three trials. Three separate trials were conducted over the period January-April 2000. Four diets (algae, bacteria, Isomil, and shrimp water) and the unfed control were only used once. The other three diets, Rotirich® , rice bran , and artificial plankton were evaluated twice.

Tanks were fed every third day with commercially available diets consisting of the following: an algae paste of *Tetraselmes* sp., a bacteria The shrimp tank uses a bacterial floc as an internal filter (Ogle and Lotz 2000b). The control tanks received no additional food.

Every tank was sampled initially and once weekly for three successive weeks. A length of 2" pvc pipe was plunged vertically to the bottom of the tank to insure a uniform sample. Five replicate 200 ml vertical samples were taken from each tank for a total sample volume of 1 L. The contents of the entire sample was enumerated for nauplii and adults under a dissecting microscope. Copepodite and juveniles were included in the counts as adults. Results were reported as number of copepods/L

RESULTS

The salinity of the water throughout all trials was 25‰. Where as the temperature varied from 6°C to 16°C. Initial stocking densities varied between the three trials decreasing with season. Average stocking density for the first trial was 15.5 adults/L and 110 nauplii/L, for the second trial the average stocking density was 12.6 adults and 24 nauplii/L. and for the third trial the average stocking density was 10.0 adults and 10 nauplli/L. Since the stocking densities varied by tank and season the results are presented as the percent change from the initial estimate and averaged for the three replicates (Table 1).

The number of nauplii in the unfed control decreased with a first week increase in the number of adults followed by a decline. This suggests that some nauplii were able to molt before the overall numbers started to decline. The bacteria and Isomil® fed tanks both showed the same trends as the unfed control. Both adults and nauplii declined in the algae fed tanks. The number of adults and nauplii both increased

when fed shrimp water, artificial plankton, Rotirich® and rice bran. The number of nauplii continued to increase in the tanks fed shrimp water while a decline during the fourth week was noted for tanks fed artificial plankton, rotirich and rice bran. The greatest increase in adults were noted for the artificial plankton (2,306%) during the fourth week and rotirich (2,194%) during the third week. These percent increases represent 240 and 121.6 adults/L, respectively. Overall, the greatest increase in number of nauplii was noted for the Rotirich® during the third week (937%). This percent represents 120.3 nauplii/L which was the second highest density. The greatest average density of nauplii achieved was 171/L also for Rotirich® in the third week. However, due to the high initial stocking density in this trial (118 nauplii/L) this represents only a 44.9% increase.

Table 1. Average percent change from initial numbers of *Acartia tonsa*

	Adults and Juveniles				Naupli			
Diet	Initial #	Week 2	3	4	Initial #	Week 2	3	4
Algae	16.0	-50.0	-62.5	-75.0	137.0	-39.4	-81.7	-87.6
Bacteria	15.0	113.0	113.0	100.0	88.0	0	-23.8	-45.4
Isomil	16.6	32.5	153.0	420.0	27.0	-3.8	-24.8	12.2
Shrimp Water	10.3	87.4	259.0	1006.8	15.6	83.3	250.0	339.7
Control	11.3	247.8	197.3	156.6	95.0	-18.9	-44.2	-49.4
Artificial Plankton	10	416.0	1663.0	**2306.0**	24.3	268.7	111.1	-91.7
Artificial Plankton	18.6	172.0	247.0	-16.1	14	71.4	437.8	68.5
Roti Rich	17	276.0	1105.9	1188.2	118	40.6	44.9	31.3
Roti Rich	5.3	1283.0	**2194.3**	471.7	11.6	193.1	**937.0**	299.1
Rice Bran	12.3	422.8	796.7	652.8	24.3	263.3	355.1	20.5
Rice Bran	6	826.7	850.0	1226.7	12.3	89.4	**536.5**	495.9

DISCUSSION

The results of this study would seem to confirm that *Acartia tonsa* is indeed an omnivorous particle feeder (Poulet 1962) able to feed and reproduce on several of the diets offered. The lack of survival for the copepods offered the algae diet is unexplained. The algae was preserved and not living. However, even if the algal cells were considered as a detrital particle, some success would be expected. In addition such a product has been successfully used for oyster and shrimp larvae. It would be interesting in the future to compare the preserved algae with live algae. Live algae were not available at the time of these comparisons. The poor performance of bacteria was not surprising as bacteria are not considered a major food of copepods (Poulet 1983). The Rotirich® fed tanks with the greatest percent increase in nauplii, greatest total number of nauplii/L and second highest percent increase in adults appears to have promise as an artificial feed. Rotirich® outperformed rice bran in nauplii production and artificial plankton in percent increase of adults.

The success in this study of maintaining and in some cases increasing the number of copepods held in static cultures when fed an artificial diet offer the possibility of captive culture of *Acartia* sp. The selection of an appropriate diet will facilitate the selection, isolation, and cultivation of *Acartia* sp. indoors under controlled conditions. The final goal would be to enhance production to provide sufficient numbers of copepod nauplii for feeding to larval fish.

LITERATURE CITED

Avault, J.W.. 1996. *Fundamentals of Aquaculture*. AVA Publishing Company. Baton Rouge, Lousiana USA. 889 pp.

Bishara, N.F. 1979. Fertilizing fish ponds. III. Growth of *Mugil capito* in Egypt by pond fertilization and feeding. *Aquaculture* **16**:47-55.

Boyd, C.E., 1990. *Water Quality in Ponds for Aquaculture*. Auburn Univ., Alabama Agriculture Experiment Station. Auburn, Alabama USA. 482 pp.

Chamberlain, G. R. Miget, M. Haby. 1987. *Manual on red drum Aquaculture*. Red Drum Aquaculture Conference, June 22-24, 1987. Corpus Christi, Texas USA.

Heinle, D.R. and D.A. Flemmer. 1975. Carbon requirements of a population of the estuarine copepod *Eurytemora affinis*. *Marine Biology* **31**:235-247.

Hepher, B. 1962. Ten years research in fish ponds fertilization in Israel. *Bamidgeh* **14(2)**:29-38

Horvath, L, G. Tamas and I. Tolg. 1984. *Special Methods in Pond Fish Husbandry*. Halver Corporation, Seattle, Washington USA. 148pp.

Ikeda, T. 1973. On the criteria to select copepod species from mass culture. *Bulletin of the Plankton Society of Japan* **20(1)**:41-48

Lemus, J.T. J. Ogle and J. Lotz. 2000. Mass production of two species of calanoid copepods. Page 199 In: Aquaculture America 2000. February 2-5 New Orleans LA. U.S Chapter World Aquaculture Society (Abst).

Lonsdale, D., D. Heinle and C. Siegfried. 1979. Carnivorous feeding behavior of the adult calanoid copepod *Acartia tonsa*. *Dana. Journal of Experimental Marine Biology and Ecology* **36**:235-248.

May, R.C. 1970. Feeding larval marine fishes in the Laboratory: A Review. Calif. Marine Resource commission. CalCOFI Rept. **14**:76-83

Nees, J.C. 1949. Development and status of pond fertilization in Central Europe. *Transactions of the American Fisheries Society* **76**:335-358.

Nellen, W. 1985. Live animal food for larval rearing in aquaculture. Non-artemia organisms. In: Bilio, H. Rosenthal and C.J. Sinderman (eds.) *Realism in Aquaculture*. Proceedings of the World Aquaculture Society, Venice 1981.

Ohno, A. and Y. Okamura. 1988. Progagation of the calanoid copepod, *Acartia tsuensis*, in outdoor tanks. *Aquaculture* **70**:39-51

Ogle, J.T. 1979. Adaptation of a brown water culture technique to the mass culture of the copepod *Acartia tonsa*. *Gulf Research Reports* **6**(3):291-292.

Ogle, J.T., and J.M. Lotz. 2000a . Culture of red snapper. *Global Aquaculture* **3**(5):23-27

Ogle, J.T. and J.M. Lotz. 2000b. Closed systems for maturation and grow-out of shrimp. *Global Aquaculture*.

Ogle, J.T., J. M. Lotz, L.C. Nicholson, and D. Barnes. 2000. Larval culture of red snapper *Lutjanus campechanus* using copepod nauplii for first feeding. Page 249 in: *Aquaculture America 2000: Book of Abstracts*. February 2-5 New Orleans, LA. World Aquaculture Society. Baton Rouge, Louisiana USA.

Omori, M. 1973. Cultivation of marine copepods. *Bulletin of the Plankton Society of Japan* **20**(1): 3-11.

Pafenhofer, G.A. and J.D.H. Strickland. 1970. A note on the feeding of Calanus Helgolandicus on detritus. *Marine Biology* **5**:97-99

Pedersen, B.H. 1984. The intestinal evacuation rates of larval herring (*Clupea harengus* L.) Predating on wild plankton. *Dana* **3**:21-240.

Poulet, S.A. 1977. Grazing of marine copepods developmental stages on naturally occurring particles. *Journal of the Fisheries Research Board of Canada* **34**(12):2381-2387

Poulet, S.A. 1983. Factors controlling utilization of non-algal diets by particle-grazing copepods: a review. *Oceanologica Acta* **69**(3):221-234.

Raymont, J.E.G. and R.S. Miller. 1962. Production of marine zooplankton with fertilization in an enclosed body of sea water. *Hydrobiologia* **47**(2):169-209.

Roman, M.R. 1977. Feeding of the copepod *Acartia tonsa* on the diatom Nitzschia closterium and brown algae (*Fucus vesiculosus*) detritus. *Marine Biology* **42**:149-155.

Rollefsen, G. 1939. Artifical rearing of the fry of sea water fish. Preliminary communication. *Rapp. Et Proc.-Verb. Cons. Int. Explor. Mer*. **30**:204-221.

Schipp, G.R., J.M.P. Bosmans and A.J. Marshall. 1999. A method for hatchery culture of tropical calanoid copepods, *Acartia spp. Aquaculture* **174**:81-88.

Sorgeloos, P. et al. 1980. Culture of *Artemia* on rice bran: the conversion of a waste-product into highly nutritive animal protein. *Aquaculture* **21**:393-396

Stein,J.P. 1981. *Spatial and Temporal Distribution of Zooplankton in a Low-Salinity Mississippi Bayou System.* Ph.D. Dissertation. University of Mississippi.

Stottrup, J.G., K. Richardson, E. Kirkegaard and N.J. Pihl. 1986. The cultivation of *Acartia tonsa* for use as a live food source for marine fish larvae. *Aquaculture* **52**:87-96.

Swingle, H.S. 1947. Experiments on pond fertilization. *Bulletin of the Auburn University Agriculture Experiment Station* **6**:171-183.

Turk, P.E., M.E. Krejci and W.T. Yang. 1982. A laboratory method for the culture of *Acartia tonsa* using rice bran. *Journal of Aquariculture and Aquatic Sciences* **III** (2): 25-27

Turner, J.T. 1984. The feeding ecology of some zooplankters that are important prey items of larval fish. NOAA Technical Report NMFS-7:

Witt, U., G. Quantz, O. Kuhlmann and G. Kattner. 1984. Survival and growth of turbot larvae, *Scophthalmus maximus* L. reared on different food organisms with special regard to long chain polyunsaturated fatty acids. *Aquaculture Engineering* **3**(3):177-190

Yamada, R. 1986. Pond production systems: fertilization practices in warmwater fish ponds. Pages 97-110 in: Lannan, J.E., R.O. Smitherman, and G. Tchobanoglous (eds.) *Principles and Practices of Pond Aquaculture.* Oregon State University Press. Corvallis, Oregon USA.