



Potential Species of Copepods for Marine Finfish Hatchery

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Copepods are the most important group of zooplankton which forms the natural food for many fishes and invertebrates. One of the important problems in the marine fish hatchery is the lack of complete balanced larval feed. Copepods, even the newly hatched nauplii are nutritious, rich in PUFA, DHA and EPA, in most desirable ratios (Watanabe *et al.*, 1978; 1983; Sargent 1986; Watanabe and Kiron, 1994; Sargent *et al.*, 1997; Stottrup, 2000, 2006), easily digestible (Pederson, 1984; Stottrup, 2000) and rich in antioxidants, astaxanthine, vitamin C, D & E (Van der Meeren, 2003; McKinnon *et al.*, 2003). Copepods if fed during the larval phase, reduces malpigmentation and deformity rates, increases the pigmentation and survival (Bell *et al.*, 1997, Bell, 1998, Stottrup, 2000; Hamre *et al.*, 2005). More than 12000 species copepods are there living in a variety of ecological niches. Most of the early fish larvae are evolutionarily adapted for feeding on copepods than on other animals.

Copepods are successfully cultured in fin fish hatcheries of many countries including India, especially for feeding atresial larvae of certain fishes like groupers. Mostly species belonging to the orders Calanoida, Cyclopoida and Harpacticoida are popular for hatchery production as live feed. Species belonging to the genera, *Acartia*, *Calanus*, *Temora*, *Paracalanus*, *Pseudodiaptomus*, *Pseudocalanus*, *Centropages*, *Eurytemora*, *Euterpina*, *Tigriopus*, *Tisbe*, *Oithona* and *Apocyclopus* are widely cultured for hatchery use (Stottrup and McEvoy, 2003; Stottrup, 2006). In a study conducted on the wild-caught fish larvae, it was revealed that calanoid copepod nauplii were an essential item in the early feed of many fish species. Calanoids of the genera *Acartia* and *Gladioferens* have been proved as important live feed for improving survival of some fish species. Harpacticoid copepods also are a good source of larval and juvenile fish feed in aquaculture. According to Turingan *et al.*, (2005) the prey should be of 80% of the mouth gape of the fish larvae. Many copepod nauplii are less than 100 μ in size. Alone or as a supplement, in many cases copepods showed to improved primary growth than rotifers and brine shrimps. The smaller size of copepods enables their feeding by mouth gap-limited fish larvae like that of groupers and snappers (Fukuhara, 1989; Doi *et al.*, 1994). Only a few copepods have been continuously and successfully reared in extensive systems (Stottrup *et al.*, 1986; Stottrup, 2000). Most of the copepod rearing trails are done in small scale lasting for a few weeks or months and used only in experimental basis. Modern technologies including mass production of microalgae, with an input of large quantities of sea water copepod culture can be successfully enhanced and meet the required level like that or rotifers for marine finfish hatchery (Van der Meeren and Naas, 1997; Stottrup, 2006).

Species popularly cultured

Of the planktonic copepods in estuarine and coastal habitat, Calanoids are the most abundant taxa of pelagic realm forming an extreme connecting link between phytoplanktons and the fish in this inshore ecosystem. Due to this significance, Calanoids got keen attention from researchers. Among Calanoids, the popular cultivate is the *Acartia* spp. than *Calanus* spp. and *Temora* spp. Most of the species present in Calanoida are of approximately 1.0 mm total length (Mauchline 1998). *Acartia clausi* and *Calanus finmarchicus* are the most widely studied Calanoids. (Mauchline 1998), followed by *Temora longicornis*, *Paracalanus parvis*, *Calanushelgo landicus*, *Pseudocalanus elongates*, *Acartia tonsa*, *Centropages hamatus*, *Centropages typicus* and *Temora stylifera*.

Based on the studies conducted by the Japanese scientists on the improvement of copepod mass culture, 13 species were recommended for mass cultivation. These includes *Acartia clausi* (*A. hudsonica* or *A. omorii*, on the basis of current classification), *A. longiremis*, *Eurytemora pacifica*, *Euterpina acutifrons*, *Microsetella norvegica*, *Oithona brevicornis* (*O. davisae*, based on current classification), *O. nana*, *O. similis*, *Pseudodiaptomus inopinatus*, *P. marinus* and *Tigriopus japonicus* (Omori 1973; Nihon Suisanshigen Hogokyoukai 1979). Among these, *Tigriopus japonicus* is the only one which is produced on a large scale and used in marine fish farming (Kitajima, 1973; Fukusho et al., 1977, 1978; Nihon Suisanshigen Hogokyoukai, 1979). Based on their studies, rearing of the other species was attributed only to laboratory (Iwasaki and Kamiya, 1977; Iwasaki et al., 1977). Maintenance of cultivation has a lot of difficulties including frequent replacement of water, the high demand for cultured algae as well as the low and unstable population growth.

Harpacticoids of the crustacean class Maxillopoda are easier for culture. These are hardy and can be cultured in high densities than calanoids and cyclopoids. The main disadvantage of harpacticoid copepod is its benthic nature while most of the fish larvae are pelagic in nature. The harpacticoids can be fed using a wide variety of food items including formulated diets. For many marine fish species, they serve as an important food source (Coull, 1990). For some fish species certain harpacticoids serve as prey for their entire life. Species of flatfishes, gobies, salmonids and sciaenids are sometimes considered to be harpacticoid feeders, atleast for a portion of their lives (Coull, 1990; McCall and Fleeger, 1995; Fleeger, 2005). Over 3000 species of Harpacticoids were reported so far (Huys and Boxshall, 1991). For the purpose of ecological, physiological and toxicological research, harpacticoid copepods were first isolated from the sediments and cultured Chandler (1986). Later on it was proved that, mass culture of harpacticoids can be easily achieved using wide variety of food items (Battaglia, 1970; Strawbridge et al., 1992; Ingole 1994; Chandler et al., 1997; Lotufo and Fleeger, 1997).

According to Conceicao et al., (2009), the wild zooplankton mostly consisting of copepods are the common food resource for fish larvae in nature. Occurrence of parasitic infections on most of the fish species is the major problem in using wild collected plankton for hatchery. The copepod parasites such as *Lepeophtheirus*, *Caligus* and *Pseudocaligus* can cause high mortality in fishes if the copepods from the wild collected plankton samples were used for feeding (Chinabut, 1996). Due to risk of parasitic transmission harvesting copepods from natural environments is not desirable. In order to avoid this problem Stottrup (2003) was the first to demonstrate the breeding of copepods in a holding tank (as an intermediate host). From tanks, the nauplii can be collected and used as feed for larvae. More than 60 copepod species have been raised in laboratory. For promoting the culture and improving cost-effectiveness of marine copepods in aquaculture industry, the development of appropriate culture techniques is essential. Copepods can be cultured extensively, intensively and semi-intensively. Copepods can be extensively developed in tanks, outdoor ponds, lagoons or enclosed fjords (Conceicao et al.,



2009). By using appropriate mesh sizes these cultured copepods can be made available to fish larvae. Planktonic copepods including *Acartia*, *Centropages* and *Temora* can be cultured in such systems. In extensive systems, culture is done normally on the basis of microalgal booms induced by agricultural fertilizers (Conceicao et al., 2009). Inconsistency in the production and domination of undesirable species are the common problem in this method. Rearing copepods in appropriate temperature, sufficient live feed (algae) with frequent exchange of seawater with the use of advanced mesh of varying measurements, continuous and a reliable supply of large scale copepods can be achieved for the use of hatchery without much difficulties.

Nowadays Culture methods for marine copepods are well advanced (Ogle, 1979. Ohno and Okamura 1988, Payne and Rippingale, 2001a,b,c; Santhosh and Anil, 2013). The body of a copepod is elongate, cylindrical, and clearly segmented. Copepods reproduce sexually only. Sexes are separate and can be easily distinguished in most of the cases. Mostly these have six naupliar and copepodite stages each. Two basic types are there, one carry eggsacs and the other scatter their eggs. Mostly these take 10-15 days to become adults and live for 25 to 55 days. (Jakob et al., 2012; Santhosh and Anil, 2013). In general copepod species that free-spawn their eggs have higher fecundity than species in which females carry their eggs in clusters (Mauchline, 1998). The species that protect their eggs by carrying them in clusters are reported to have lower mortality rates (Kiorboe and Sabatini, 1994). Small pelagic copepod species with short life cycles and fast growth can be cultured with high-yield using semi intensive technologies. In tropical and subtropical countries, with technically qualified labor and facilities, copepods could give good economic results in terms of highly stress-resistant larvae, good survival, growth and biomass productions when compared with enriched *Artemia* or rotifers (Hernandez Molejon and Alvarez-Lajonchere, 2003). Overcrowding (Miralto et al., 1996) and cannibalism (Ohno et al., 1990) also have got some influence on fecundity and population growth.

The basic morphology is similar to most of the crustacean type with large cephalosome and a small urosome, large first antennae and small second antennae with typical crustacean mouth parts. There are 4 pairs of two-branched swimming legs and the fifth pair mostly unbranched; each pair fused at the base by a plate which powers the legs to move organized and this is a highly successful evolutionary design. (Dussart and Defaye 2001). The calanoids are mainly herbivorous and the harpacticoids are mainly omnivorous. Most of the cyclopoids are predators. The smaller species tend to be plankton feeders, whereas the larger species tend to be aggressive predators, consuming protozoans, rotifers, and small aquatic animals (Fryer 1957; Hutchinson 1967).

Calanoids

The calanoid copepods are predominantly pelagic, occurring at all depths, with some near-bottom and benthic species. They are mainly feeding on small phytoplankton cells by filtration, rarely predators feeding on a variety of animal prey including copepod eggs. These can be easily distinguished by their long antennules, mostly as long as the body itself or sometimes, even longer, with up to 27 segments and biramous antennae mostly used as accessory locomotor appendages. Usually the antennule of male will be modified (Huys & Boxshall 1991; Dussart & Defaye 2001) and the position of the prosome–urosome articulation is between the fifth and sixth postcephalosome somite (Mauchline 1998; Dussart & Defaye 2001).

Among the calanoid copepods, the genera *Acartia*, *Pseudodiaptomus*, *Sinocalanus*, *Eurytemora*, *Centropages*, *Gladioferens*, *Parvocalanus*, *Bestiolina*, *Temora* and *Labidocera* were popularly proposed for hatchery production. Nauplii of some *Acartia* spp. are as small as 100 µm in length and 50-60 µm in width, making them suitable for first feeding of fish larvae. *Labidocera* sp. found to grow successively larger and produced more eggs in an

established laboratory culture. Several Paracalanoid species are larger, thus are more suitable, for feeding to larger fish larvae. Paracalanid copepods are very common in coastal areas, while *Acartia* spp. found almost everywhere (Cheng-sheng Lee, et al., 2005).

Among the families of larval fish that feeds on copepod prey, a vast majority shown clear preference for calanoid copepods and more specifically for small calanoid species (Sampey et al., 2007) are hence considered to be the most promising order of copepod for production and used as live prey items for marine hatcheries (Doiet al., 1997; Stottrup, 2000). Specifically, pelagic calanoid species from coastal waters with high tolerance to wide ranges of environmental conditions are preferred live prey candidates (Stottrup, 2003; Conceicao et al., 2010). Popular calanoid species reported as ideal live feed are *Acartia grani* (Spain), *A. sinjiensis* (Australia), *A. southwelli* (Taiwan, India), *A. spiniuda* (India), *A. tonsa* (Denmark, Uruguay), *A. parvula* (Germany), *A. centrura* (India), *A. erythrae* (India), *Centropages typicus* (Italy), *Eurytemora affinis* (France, Canada, Mediterranean sea), *Gladioferens imparipes* (Australia), *Pseudodiaptomus annandalei* (Taiwan), *P. serricaudatus* (India), *Temoralongicornis* (North Sea, UK), *T. stylifera* (Italy) and *T. turbinata* (India).

Harpacticoids

The harpacticoids, comprises over 50% of copepod species, are primarily marine, free living, benthic organisms rarely represented in pelagic water samples. These are common in sediments occupying spaces between sand particles (interstitial), burrowing into sediment (burrowers), or living on sediment or plant surfaces (epibenthic). They are distinguished by their short and streamlined body, antennules with fewer than 10 segments and biramous antennae. The position of the prosome–urosome articulation is between the fourth and fifth postcephalosome segment (Dussart & Defaye 2001). Usually there is only one egg pouch and males are smaller with a specialized antennule.

Harpacticoid copepods are popular in culture for their higher population density but their benthic nature makes them less available to the fish larvae. However, the nauplii of some harpacticoids exhibit positive photo taxis so that they can be harvested easily and fed separately to fish larvae (Stottrup and Norsker, 1997). Harpacticoids copepod species can be reared to high production rates, are generally not cannibalistic and can be raised on formulated feeds. Two species or more species also can be cultured at high densities. Often harpacticoid come as a contaminant species along with ciliates in the culture of calanoid copepods. The nauplii of *Nitokralacustris* are benthic but the copepodid stages (90 µm in length and 30-40 µm in width) are mostly in column water and are suitable for feeding fish larvae. Nauplii of harpacticoid copepod species are difficult to separate from the culture and harvesting from the sediments is also not easy (Cheng-sheng Lee et al., 2005).

Harpacticoid copepods can be cultured easily in high densities than calanoids. Many species are epibenthic in nature with reduced size and can be utilized for feeding fish larvae. Their nutritional value is similar to that of calanoids. Some models are there with semi-automated system for feeding and harvesting of nauplii will minimize the labour using harpacticoid culture (Stottrup, 2006). Usual epibenthic nature of harpacticoids makes them less suitable for the fish larval feed except for some pelagic harpacticoids like *Euterpina acutifrons* which is used in the rearing of pelagic larvae of *Coryphaena hippurus* (Kraul et al., 1992). Popular harpacticoid species in the aquaculture system are *Ameira parvula* (Germany), *Amonordianormani*, *Amphiascoides atopus* (USA), *Euterpina acutifrons* (Mediterranean sea, India), *Trachidius discipes* (Germany), *Tigriopus japonicus* (India) and *Macrosetella agracilis* (India).



Cyclopoids

The cyclopoids include pelagic, epibenthic, benthic and parasitic species and are more abundant in freshwater environments (Huys & Boxshall 1991). The antennules in cyclopoids are shorter than in calanoids, rarely reaching beyond the cephalothorax and usually have six to 17 segments. Unlike calanoids and harpacticoids, cyclopoids have uniramous antennae which is modified for catching food (Huys & Boxshall 1991; Dussart & Defaye 2001). Like that of harpacticoids, the position of the prosome–urosome articulation is between the fourth and fifth postcephalosome segment (Dussart & Defaye 2001).

Among the cyclopoid copepods, the genera *Oithona* and *Dioithona* are popular in culture. Nauplii of these are mostly less than 100 µm in length and are negatively phototactic, and can be collected in plankton nets. Nauplii of the cyclopoid copepod *Apocyclopsroyi* develop from eggs in 4-5 days and are used for first feeding practices in Taiwan (Cheng-sheng Lee et al., 2005). The swarm forming cyclopoid copepod *Dioithona oculata* culture experiments suggest that this species has good potential for the high density culture (Hernandez Molejon and Alvarez-Lajonchere, 2003). Cyclopoids can be easily cultured and can obtain higher densities than calanoids. They can be fed with a variety of foods but popularly cultured using phytoplankton in intensive systems (Stottrup, 2006). Hernandez Molejon and Alvarez-Lajonchere (2003) reported culture experiments with *Oithona oculata* and with a final population of 13 copepods /ml in 15-day cultures without aeration. Larvae of symbiotic poecilostomatoid copepods, which are swimming but non feeding, reported to be co cultured with mussels (the host of their adult stages) for feeding fish larvae in Taiwan (Cheng-sheng Lee et al., 2005). Ho (2005) reported that a symbiotic (with bivalve mollusk) copepod namely *Pseudomyicola spinosus* belonging to the family Myicolidae, can be used as live feed in marine finfish rearing. The first seven stages in the life cycle of the species are planktonic and can be used as the live feed.

Fisheries agency of Japan has recommended 13 species of copepod for the mass culture as a part of a project entitled “searching for suitable species and mass culture of zooplankton as food for the early stage of fish seed in marine fish farming” for Japan. The species includes *Acartia hudsonica*, *A. longiremis*, *Eurytemora pacifica*, *Euterpina acutifrons*, *Microsetella norvegica*, *Oithona davisae*, *O. nana*, *O. similis*, *Pseudodiaptomus inopinus*, *P. marinus* and *Tigriopus japonicus* (Omori 1973; Nihon Suisanhyogen Hogokyoukai 1979) and concluded that among these, *T. japonicus* was the most ideal species to be cultured on a large scale and which can be economically used as larval feed in marine fish farming (Kitajima 1973; Fukusho et al., 1977; Nihon Suisanhyogen Hogokyoukai, 1979). Popular cyclopoid species in the live feed purpose are *Apocyclops royi* (Taiwan), *A. panamensis* (UK), *Mesocyclops longisetus* (Florida), *Microcyclops albidus* (Florida), *Oithona davisae* (Spain) and *O. rigida* (India).

REFERENCES

- Battaglia, B. 1970. Cultivation of marine copepods for genetic and evolutionary research. *Helgoländer Wissenschaftliche Meeresuntersuchungen*, 20: 385-392.
- Bell, J. G. 1998. Current aspects of lipid nutrition in fish farming. In: *Biology of farmed fishes* (K. Black and A.D. Pickering, Eds.), Sheffield, UK, Sheffield Academic Press, p. 114-145.
- Bell J. G., Stottrup, J. G. and Shields, R.J. 1997. Utilisation of copepod diets for larviculture of halibut, cod and grouper. *Aquaculture Asia*. 1998, 42-49.
- Chandler, G.T. 1986. High density culture of meiobenthic harpacticoid copepods within a muddy sediment substrate. *Canadian Journal of Fisheries and Aquatic Science*, 43: 53-59.
- Chandler, G.T., Coull, B.C., Schizas, N.V. and Donelan, T.L. 1997. A culture-based assessment of the effects of Chlorpyrifos on multiple meiobenthic copepods using microcosms of intact estuarine sediments. *Environmental Toxicology and Chemistry*, 16: 2339-2346.

- Cheng-sheng Lee, Patricia J. O'Bryen and Nancy H. Marcus (Eds), 2005. *Copepods in aquaculture*. Black well publishing professional 1ST ed. Papers presented at a work shop held in Honolulu, Hawaii, May 5-8, 2003, 2121 state avenue, Ames, Iowa 50014 (USA).
- Chinabut, S. 1996. *Sea lice*. AAHRI Newsletter Article 5:p.2.
- Conceicao, L.E.C., Yufera, M., Makridis, P., Morais, S. and Dinis, M.T. 2009. Live feeds for early stages of fish rearing. *Aquaculture Research*, 41(5): 1-28.
- Coull, B.C. 1990. Are members of the meiofauna food for higher tropic levels? *Transactions of the American Microscopical Society* 109: 233-246.
- Doi, M., Ohno, A. and Taki, Y. 1994. Development of mixed feed state larvae of red snapper, *Lutjanus argentimaculatus*, *Suisanzoshoku* 42: 471-476.
- Dussart, B.H. and Defaye, D. 2001. *Introduction to the Copepoda. 2nd ed., Guides to the Identification of the Micro invertebrates of the Continental Waters of the World 16*. Leiden: Backhuys Publishers.
- Fleeger, J. W. 2005. The potential to mass-culture harpacticoid copepods for use as food for larval fish. In: Lee C.S., O'Bryen P. J. and Marcus, N.H. (Eds.) *Copepods in aquaculture*. Blackwell, p. 11-24.
- Fryer, G. 1957. The food of some freshwater cyclopoid copepods and its ecological significance. *Journal of Animal Ecology*, 26:263-286.
- Fukuhara, O. 1989. A review of the culture of grouper in Japan. *Bulletin of Nansei Regional Fisheries Research Laboratory*, 20:47-57.
- Fukusho, K. 1980. Mass production of a copepod, *Tigriopus japonicus* in combination culture with a rotifer *Brachionus plicatilis* fed yeast as a food source. *Bull Japanese Society Fishery Science* 46: 625-629.
- Fukusho, K., Hara, O., Iwamoto, H. and Kitajima, C. 1977. Mass production of the copepod *Tigriopus japonicus*, in combination with rotifer, *Brachionus plicatilis*, feeding baking yeast and using large scale outdoor tanks. *Report of Nagasaki Prefectural Fisheries experimental station* 3: 33-40.
- Fukusho, K., Iwamoto, H., Seikai, T. and Kitajima, C. 1978. Effects of initial supply of *Chlorella* sp. On the copepod *Tigriopus japonicus* population in combination with rotifer *Brachionus plicatilis*, feeding bakers' yeast. *Report of Nagasaki Prefectural Fisheries experimental station*, 4: 47-56.
- Hamre, K., Moren, M., Solbakkan, J., Opstad and I., Pittman, K. 2005. The impact of nutrition on metamorphosis in Atlantic halibut (*Hippoglossus hippoglossus* L.). *Aquaculture*, 250: 555-565.
- Hernandez Molejon, O. G. and L. Alvarez-Lajonchere, 2003. Culture experiments with *Oithona aciculata* Farran, 1913 (Copepoda: Cyclopoida), and its advantages as food for marine fish larvae. *Aquaculture*, 219: 471-483.
- Ho, J. S. 2005. Symbiotic copepods as live feed in marine finfish rearing. *Copepods in aquaculture, Papers presented at a work shop held in Honolulu*. Cheng-sheng Lee, Patricia J. O'Bryen and Nancy H. Marcus (eds). Black well publishing professional 1ST Ed. 2121 state avenue, Ames, Iowa 50014 (USA).
- Hutchinson, G. E. 1967. *A Treatise on Limnology, Vol. 2: Introduction to Lake Biology and the Limnoplankton*. New York: John Wiley & Sons.
- Huys, R. and Boxshall, G.A. 1991. *Copepod Evolution*. London, U.K.: The Ray Society. 468pp.
- Ingole, B.S. 1994. Influence of salinity on the reproductive potential of a laboratory cultured harpacticoid copepod, *Amphiascoides subdebilis* Willey, 1935. *Zoologica Anzeiger*, 232: 31-40.
- Iwasaki, H. and Kamiya, S. 1977. Cultivation of marine copepod, *Pseudodiaptomus marinus* Stato. *Bulletin of the Plankton Society of Japan* 24: 44-54.
- Iwasaki, H., Katoh, H. and Fujiyama, T. 1977. Cultivation of marine copepod *Acartia clausi* Geisbrecht. I. Factors affecting the generation time and egg production. *Bulletin of the Plankton Society of Japan*, 24: 55-61.
- Jakob A. Boehler and Kenneth A. Krieger. 2012. *Taxonomic Atlas of the Copepods (Class Crustacea: Subclass Copepoda: Orders Calanoida, Cyclopoida, and Harpacticoida) Recorded at the Old Woman Creek National Estuarine Research Reserve and State Nature Preserve, Ohio*, National Center for Water Quality Research Heidelberg University Tiffin, Ohio, USA 44883.
- Kiorboe, T. and Sabatini, M. 1994. Reproductive and life cycle strategies in egg carrying cyclopoid and free-spawning copepods. *Journal of Plankton Research* 16: 1353-1366.
- Kitajima, C. 1973. Experimental trails on mass culture of copepods. *Bulletin of the Plankton Society of Japan*, 20: 54-60.
- Kraul, S., Ako, H., Nelson, A., Brittain, K. and Ogasawara, A., 1992. Evaluation of live feeds for larval and postlarval mahimahi, *Coryphaenahippurus*. *Journal of the World Aquaculture Society*. 23 (1), 299-306.



- Lee, C. S., O'Bryen, P. J., Marcus, N. H. 2005. *Copepods in aquaculture*. Blackwell, Oxford, 269 pp.
- Lotufo, G. R. and Fleeger, J. W. 1997. Effect of sediment-associated phenanthrene on survival, development and reproduction of two species of meiobenthic copepods. *Marine Ecology Progress Series* 151: 91-102.
- Mauchline, J. 1998. *The Biology of Calanoid Copepods*. San Diego, California, USA: Academic Press. 710 pp.
- Mckinnon, A. D., Duggan, S., Nichols, P. D., Rimmer, M. A., Semmens, G. and Robino, B. 2003. The potential of tropical paracalanid copepods as live feeds in aquaculture. *Aquaculture* 223: 89-106.
- Miralto, A., Ianora, A., Poule, S. A., Romano, G. and Laabir, M. 1996. Is fecundity modified by crowding in the copepod *Centropages typicus*, *Journal of Plankton Research* 18: 1033-1040.
- Nihon Suisanshigen Hogokyoukai, 1979. *Mass Culture of Zooplankton as Food for Fish Larvae*. Tokyo, Japan: Nihon suisanshigen Hogokyoukai. (in Japanese), 142 pp.
- Ogle, J. 1979. Adaptation of a brown water culture technique to the mass culture of the copepod *Acartiatonsa*. *Gulf Res. Rep.* 6:291-292.
- Ohno, A. and Okamura, Y. 1988. Propagation of the calanoid copepod, *Acartiatsuensis* in outdoor tanks. *Aquaculture* 70: 39-51.
- Ohno, A., Takahashi, T. and Taki, Y. 1990. Dynamics of exploited populations of the Calanoid copepod *Acartiatsuensis*. *Aquaculture*, 84: 27-39.
- Omori, M. 1973. Cultivation of marine copepods. *Bulletin of the Plankton Society of Japan*, 20:3-11.
- Payne, M. F. and Rippingale, R. J. 2001a. Intensive cultivation of the calanoid copepod *Gladioferens imparipes*, *Aquaculture*, 201: 329-342.
- Payne, M. F. and Rippingale, R. J. 2001b. Effects of salinity, cold storage and enrichment on the calanoid copepod *Gladioferens imparipes*. *Aquaculture*, 201: 251-262.
- Payne, M.F. and Rippingale, R. J. 2001c. Intensive cultivation of the calanoid copepod *Gladioferens imparipes*. *Aquaculture*, 201: 329-342.
- Pederson, B. H., 1984. The intestinal evacuation rate of larval herring (*Clupeaharengus* L.) preying on wild zooplankton. *Dana*, 3: 21-30.
- Santhosh, B. and Anil, M. K., 2013. Zooplankton for marine fish larval feed. In: Imelda Joseph and Joseph V. Edwin (Eds.) *Customized Training in Mariculture for Maldivian Officials*. Central Marine Fisheries Research Institute Publication, Kochi, 107-114.
- Sargent, J. R. and Henderson, R. J. 1986. Lipids. In *The Biological Chemistry of Marine Copepods*, Corner, E.D.S. and O'Hara, S.C.M. (Eds.), Oxford, England: Clarendon Press. p. 59-108.
- Sargent, J. R., McEvoy, L. A. and Bell, J. G., 1997. Requirements, presentation and sources of polyunsaturated fatty acids in marine fish larval feeds. *Aquaculture*. 155. 117-128.
- Stottrup, J.G. 2000. The elusive copepods: their production and suitability in marine aquaculture. *Aquaculture Research*, 31: 703-711.
- Stottrup, J. G. 2003. Production and nutritional value of copepods. In: *Live feeds in marine aquaculture*, Stottrup, J.G and McEvoy, L.A. (Eds.). Blackwell, Oxford, 318p.
- Stottrup, J. G. 2006. A Review on the status and progress in rearing copepods for marine Larviculture. Advantages and disadvantages among Calanoid, Harpacticoid and Cyclopoid copepods. In: L. Elizabeth Cruz Suarez, Denis Rique Marie, Mireya Tapia Salazar, Martha G. Nieto Lopez, David A Villarreal Cavazos, Ana C. Puello Cruz and Armando Garcia Ortega, (Eds.). *Advances en Nutricion Acuicola VIII. VIII Simposium Internacional de Nutricion Acuicola*. 15-17 Noviembre. Universidad Autonoma de Nuevo Leon, Monterrey, Nuevo Leon, Mexico. P62-83.
- Stottrup, J. G. and McEvoy, L. A. 2003. *Live Feeds in Marine Aquaculture*. Ames, Iowa, USA: Iowa State Press. 336 pp.
- Stottrup J. G. and N. H. Norsker, 1997. Production and use of copepods in marine fish larviculture. *Aquaculture*, 155: 231-247.
- Stottrup, J. G., Richardson, K., Kirkegaard and E., Pihl, N. J. 1986. The cultivation of *Acartiatonsa* Dana for use as a live food source for marine fish larvae. *Aquaculture*, 52: 87-96.
- Strawbridge, S., Coull, B.C. and Chandler, G.T. 1992. Reproductive output of a meiobenthic copepod exposed to sediment - associated Fenvalerate. *Archives Environmental Contamination Toxicology*, 23: 295-300.
- Turingan, R. G., Beck, J. L., Krebs, J. M. and Licamele, J. D. 2005. Development of feeding mechanics in marine fish larvae and the swimming behavior of zooplankton prey: Implications for rearing marine fishes In. *Copepods in aquaculture*. C. S. Lee, P. J. O'Bryen, and N. M. Marcus (Eds.), Blackwell Publishing Professional, Ames, Iowa, USA. 125-129.

- Van der Meeren, T. 1991. Selective feeding and prediction of food consumption in turbot larvae (*Scophthalmus maximus* L.) reared on the rotifer *Brachionus plicatilis* and natural zooplankton. *Aquaculture*, 93: 35-55.
- Van der Meeren, T. and Naas, K. E. 1997. Development of rearing techniques using large enclosed ecosystems in the mass production of marine fish fry. *Reviews in Fisheries Science*, 5: 367-390.
- Watanabe, T., Arakawa, T., Kitajima, C., Fukusho, K. and Fujita, S. 1978. Nutritional quality of living feed from the viewpoint of essential fatty acids for fish. *Bulletin Japanese Society for Scientific Fisheries*, 44: 1223-1227.
- Watanabe, T., Kitajima, C. and Fujita, S. 1983. Nutritional values of live organisms used in Japan for mass propagation of fish: a review. *Aquaculture*, 34: 115 – 143.
- Watanabe, T. and Kiron, V. 1994. Prospects in larval fish dietetics. *Aquaculture*, 124: 223-251.